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ΔΙΕΘΝΕΣ ΣΥΝΕΔΡΙΟ
BEE RES 2014 CONFERENCE

Buildings Energy Efficiency
& Renewable Energy Sources

ΕΝΕΡΓΕΙΑΚΗΣ ΑΠΟΔΟΣΗΣ ΚΤΙΡΙΩΝ
& ΑΝΑΝΕΩΣΙΜΩΝ ΠΗΓΩΝ ΕΝΕΡΓΕΙΑΣ 2014

ΤΕΙ Δυτικής Μακεδονίας, Κοζάνη
TEI of Western Macedonia, Kozani
01/06/2014 - 03/06/2014

Conference Proceedings

TEI OF WESTERN MACEDONIA

Municipality of Prespes

WELCOME

Languages

All Sessions and speeches are held at the Spyros Arsenis Hall (Big Amphitheater). Languages of the Conference: ***English*** *and* ***Greek*** *(Translation services are available)*

Sunday, 01 June 2014

21:00 Registration
19:00 - 21:00 Standing dinner

Monday, 02 June 2014

09:30 - 11:30 - Session1: **Buildings CO_2 Footprint Estimation**
(Chair: Prof Stelios Maropoulos)

1) "**Estimation of Embodied CO2 in Electro-Mechanical Installations for an Urban Hellenic Dwelling**", D.G. Koubogiannis[1], A. Lavoutas[1], A. Lekkas[1] and C.A. Balaras[2],
[1]-*Dept. of Energy Technology Engineering, Technological Educational Institute of Athens, Agiou Spyridonos Str, Aigaleo, GR 12210, Athens, Greece.*
[2]-*Institute for Environmental Research and Sustainable Development, National Observatory of Athens, I. Metaxa & Vas. Pavlou, P. Penteli, GR 15236 Athens, Greece.*

2) "**Preliminary Study on the Thermal Mass Characteristics of Stone Buildings in Crete, Greece**", M. Sanoudaki, N. Papamanolis.
School of Architectural Engineering, Technical University of Crete, Chania, Greece.

3) "**Results from Preliminary Energy Audit in the Faculty of Technical Sciences - Bitola**", Vladimir Mijakovski*, T. Geramitcioski, V. Mitrevski, G. Trombev, R. Ristevski,
Faculty of Technical Sciences - Bitola, University "St. Kliment Ohridski", Bitola, MK 7000, The former Yugoslav Republic of Macedonia.

4) "**Blower door test - Measurement protocol**",
V. Mitrevski, T. Geramitcioski, G. Trombev, V. Mijakovski, I. Andreevski,
Faculty of Technical Sciences - Bitola, University "St. Kliment Ohridski", Bitola, MK 7000, The former Yugoslav Republic of Macedonia.

5) "**Energy performance analysis of pre- and post- retrofit households in Greece**", T. Papadopoulos[1], D. Tampakis[1], G. Papagiannis[1], G. Christoforidis[2].
[1]-*School of Electrical & Computer Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece.*
[2]-*Dept of Electrical Engineering, Technological Educational Institute of West Macedonia, Kozani, Greece*

6) "**Energy Audits in Public Buildings**", Dimitrios Stimoniaris, Dimitrios Tsiamitros, V. Zacharaki, T. Kottas, S. Maropoulos[1], M. Stefanovski, Z. Stepanovski, I. Milosovska[2], N. Susevski, K. Micalevski[3], V. Karagiannis, K. Zarmakoupis[4].
[1] - *Dept of Electrical Engineering, Technological Educational Institute of West Macedonia, Kozani, Greece*
[2] – *ARCHAM Association, Bitola, The former Yugoslav Republic of Macedonia.*
[3] – *Resen Municipality, , The former Yugoslav Republic of Macedonia*
[4] – *Prespes Municipality, Greece.*

11:30 - 12:00 Coffee break
12:00 - 12:30 Welcome speeches
12:30 – 13:10 Modern Issues on Renewable Energy Sources

"Reliability and Security Issues Of Modern Electric Power Systems With High Penetration Of Renewable Energy Sources", **Prof Evaggelos Dialynas**, School of Electrical and Computer Engineering, National Technical University of Athens (GREECE)

"The EU 2030 framework for energy and climate policies", **Dr Athanasios Dagoumas,** Special Advisor to the Minister of the Hellenic Ministry of Environment, Energy and Climate Change (GREECE)

"Strategies for a flexible biogas production for the integration into smart grid concepts", **Dr-Ing Stefan Junne**, Chair of Bioprocess Engineering, TU-Berlin (GERMANY)

13:10 - 14:10 Standing Lunch
14:10 – 15:30 Speeches by the Invited Speakers

"The residence in Ancient Greece", **Dr-Archaelogist. Mrs Georgia Karamitrou-Mentessidi.**

"KNX: The worldwide STANDARD for home and building control", **Mr Vasileios Lourdas**, KNX Association-Brussels (BELGIUM)

"The district heating grid of the Wider Region of Amyntaio", **Mr Konstantinos Kyriakopoulos**, Municipal District Heating Company of the Wider Region of Amyntaio (GREECE)

15:30 - 17:00 - Session2: **Improvement of Buildings Energy Efficiency and Buildings Management Systems Application**
(Chair: Assist. Prof George Christoforidis)

1) "**Optimization-based active techniques for Energy Efficient Buildings Control: Part I: Optimization Algorithms**", Iakovos Michailidis[1,2], Simone Baldi[1], Elias B. Kosmatopoulos[1,2], and Yiannis S. Boutalis[2].
[1]-*Information Technologies Institute, Centre of Research & Technology - Hellas (I.T.I.-CE.R.T.H.) Thessaloniki, Greece*
[2]-*Department of Electrical and Computer Engineering, Democritus University of Thrace,Xanthi, Greece*

2) "**Optimization-based active techniques for Energy Efficient Buildings Control: Part II: Real-Life Experimental Results**", Iakovos Michailidis[1,2], Simone Baldi[1], Elias B. Kosmatopoulos[1,2], and Yiannis S. Boutalis[2].
[1]-Information Technologies Institute, Centre of Research & Technology - Hellas (I.T.I.-CE.R.T.H.) Thessaloniki, Greece
[2]-Department of Electrical and Computer Engineering, Democritus University of Thrace,Xanthi, Greece

3) "**Thermal Insulation Characteristics of the Building Shell according to the New Legislation for Decreasing Energy Consumption in Buildings in Greece**", M. Davaki, N. Papamanolis.
School of Architectural Engineering, Technical University of Crete, Chania, Greece.

4) "**Energy Management System and Substitution of Fuels and Energy Sources in Public Buildings**", I. Andreevski, G. Trombev, V. Mitrevski, V. Mijakovski, T. Geramitoski,
Faculty of Technical Sciences - Bitola, University "St. Kliment Ohridski", Bitola, MK 7000, The former Yugoslav Republic of Macedonia.

17:00 - 17:30 Coffee Break

17:30 - 19:00 Title**: Application of Renewable Energy Sources in Buildings**
Round Table
Hellenic Association of Electrical & Mechanical Engineers- West Macedonia Division & Technical Chamber of Greece-West Macedonia Division (TEE/TDM)

Tuesday, 03 June 2014

09:30 - 11:00 - Session3: **Renewable Energy Sources 1**
(Chair: Lecturer Adamos Stimoniaris)

1) "**DG and EV Penetrations for Future's Smart Network in Turkey**", Sitki GUNER [1], Aydogan Ozdemir [2].
[1]- Department of Electrical & Electronics Engineering, Istanbul Arel University, Istanbul, Turkey.
[2]-Department of Electrical Engineering, Istanbul Technical University, Istanbul, Turkey.

2) "**An Advanced and Efficient Sun Tracking System based on a Novel Algorithm for Maximum Electrical Power Generation on Solar Array**", S. Kouridakis.
Department of Electronic Engineering, School of Applied Sciences - ??? of Crete, Halepa Chania, Greece.

3) "**Implementation the tasks of the Renewable Energy Directive 2009/28/EC in EU Members and the former Yugoslav Republic of Macedonia as a country-candidate**", T. Geramitoski, G. Trombev, V. Mitrevski, V. Mijakovski, I. Andreevski.
Faculty of Technical Sciences - Bitola, University "St. Kliment Ohridski", Bitola, MK 7000, The former Yugoslav Republic of Macedonia.

4) "**Supply-side Ancillary Services at a Microgrid-based Smart Grid Topology**", D. Tsiamitros, D. Stimoniaris, N. Poulakis[1], and E. Dialynas[2],
[1]-Dept of Electrical Engineering, Technological Educational Institute of West Macedonia, Kozani, Greece
[2]-School of Electrical and Computer Engineering, National Technical University of Athens, Athens, Greece

11:00 - 11:30 Coffee break
11:30 – 14:00 Speeches by the Invited Speakers

"Role of Advanced Demand Response in Organizing Distributed Energy Resources as Virtual Power Plants", **Prof Aydogan Ozdemir**, Dept of Electrical Engineering, Istanbul Technical University (TURKEY).

"GReen procurement And Smart city suPport in the energy sector – the GRASP – MED project", **Prof Yorgos Stephanedes**, Dept of Civil Engineering, University of Patras (GREECE)

"Modelling the anaerobic methane production process: current developments and importance for an increased process flexibility", **Dr.-Ing. M. Nicolas Cruz Bournazou,** Chair of Bioprocess Engineering, TU-Berlin (GERMANY)

"The MARIE (Mediterr?nean Building Rethinking for Energy Efficiency Improvement) Strategic Project: Building a New Renovation Strategy around the Mediterranean area", **Mr Thanos Papotis**,, Production and Management Engineer, Euroconsultants SA (GREECE)

"*The Levelized Cost of Energy from PV's in Greece and Mediterranean: The PV-NET projec***t", Assist. Prof. George Christoforidis**, Dept of Electrical Engineering, TEI of West Macedonia (GREECE)

14:00 - 15:00 Standing lunch

15:00 - 16:30 Session4: **Renewable Energy Sources 2**
(Chair: Prof Paraskevi Mitliagka)

1) "**Comparative analysis of selection suitable feedstock for biodiesel production in the former Yugoslav Republic of Macedonia**", M.Sc.Katica Belcheska Arizankoska.
ARHAM-Bitola, former Yugoslav Republic of Macedonia

2) "**Harmonic Behavior of Residential Low Voltage Appliances for Load Signatures Formulation**", A. Bouchouras.
Dept of Electrical Engineering, Technological Educational Institute of West Macedonia, Kozani, Greece.

3) "**A.Q.M.E.I.S.: Air Quality Meteorological and Enviromental Information System in Western Macedonia, Hellas.**", I. Skodras[1], G. Fragulis [2] and A. Triantafyllou [1].
[1]- Lab. of Atmospheric Pollution & Environmental Physics, Dept. of Geotechnology and Environmental Engineering, Technological Educational Inst. of Western Macedonia, Kozani, Greece.
[2]- Dept of Electrical Engineering, Technological Educational Institute of West Macedonia, Kozani, Greece

4) "**Control algorithm and infrastructure for smart grid topologies**", D. Tsiamitros, D. Stimoniaris, T. Kottas, V. Zacharaki[1], and E. Dialynas[2],
[1]-*Dept of Electrical Engineering, Technological Educational Institute of West Macedonia, Kozani, Greece*
[2]-*School of Electrical and Computer Engineering, National Technical University of Athens, Athens, Greece*

16:30 - 17:00 Coffee break

17:00 - 18:30 Title:
Renewable Energy Sources based on Waste Management (Biomass-Biogas)
Round Table
Chair of Bioprocess Engineering - TU-Berlin & DIADYMA

20:00 Closing Dinner

Wednesday, 04 June 2014

Technical visit to Prespes
(In cooperation with GREEN-BOAT project – Solar boats)

or

Workshop
10:00 – 14:00 at the small Amphitheater:

1) **KNX tutorial**: Vasileios Lourdas – *KNX Association, Brussels*
2) **Operation and optimization of biogas plants: Basics of substrate preparation, operation and fertilizer generation,** Dr Stefan Junne, *Chair of Bioprocess Engineering, TU-Berlin.*
3) **Operation and optimization of biogas plants: Case study of a biogas plant in Greece,** Ms Anja Lemoine, *Chair of Bioprocess Engineering, TU-Berlin*.

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ΥΠΟΣΤΗΡΙΚΤΕΣ
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Το έργο συγχρηματοδοτείται από την Ευρωπαϊκή Ένωση και Εθνικούς Πόρους των Συμμετεχουσών Χωρών υπό το πρόγραμμα IPA Cross-Border Programme "Greece - The former Yogoslav Republic of Macedonia 2007-2013"

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Estimation of Embodied CO_2 in Electro-Mechanical Installations for an Urban Hellenic Dwelling

D.G. Koubogiannis[1*], A. Lavoutas[1], A. Lekkas[1] and C.A. Balaras[2]

Abstract **- Embodied energy and carbon (dioxide) emissions contained in the Electro-Mechanical (EM) installations of a typical urban Hellenic single-family dwelling are estimated. A breakdown methodology to derive their constitutive materials is described and implemented in a case study, extending previous similar work performed in a multi-family dwelling. The results are assessed in terms of repeatability and possible correlation between the two case studies, as well as in terms of the contribution of the EM installations to the building's environmental footprint.**

Index Terms **– Embodied energy, Embodied CO_2, building electrical and mechanical installations, Hellenic dwelling.**

I. Introduction

European buildings are responsible for about 40% of the total energy consumption and about a third of the total energy related CO_2 emissions. Given that current practice moves towards nearly zero energy buildings, it is important nowadays to assess the environmental impact and energy consumption of a building during its whole life cycle (by means of Life Cycle Assessment - LCA), instead of just its operational period of time. Embodied Energy (EE) and associated CO_2 emissions (ECO_2) of a building are important input parameters for an LCA. Furthermore, results concerning EE and ECO_2 should be taken into account in the context of the ongoing national efforts to implement various energy conservation measures in existing buildings. For example, replacing old space heating systems with more energy efficient units, one should also account for their EE and ECO_2 against the anticipated operational energy savings.

To estimate EE and ECO_2, it is first required to breakdown the various system components to their constitutive materials, to quantify their contribution in terms of mass percentage and identify the dominant ones. In previous work [1], the authors defined a methodology as a first attempt to reveal the materials and estimate their quantities used in the components of typical residential heating installations. Using a typical urban three-floor multi-family apartment building in Athens, for the first time, presented results concerning space heating and hot water installations, focusing on their EE.

In this paper, a similar analysis is implemented for a different typology of a residential building, located in another region of Athens, the EM installations of which have been designed by a different professional. The aims are to extend the previous work [1] by including electrical, lighting installations and air conditioning units, to compare the new results on the heating system material percentage between the two case studies and to focus on the ECO_2 footprint.

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II. Case study

To perform the material and ECO_2 analysis of a building, a typical urban two-story ($152m^2$) single-family dwelling (mezonette), located in Athens, was chosen as the current case study.

An operational building requires a wide range of EM installations that include numerous components, either being in the form of single materials or finished products or even whole equipment. The major installations include heating and cooling equipment, electrical and lighting installations, automation systems, materials for hydraulic and hot water pipe networks. In order to perform ECO_2 and EE analysis of the EM installations, it is necessary to breakdown these major components in single materials, record them, calculate their mass and identify the most important of them in terms of mass contribution.

The present study focuses on major components of EM installations in a typical urban Hellenic dwelling. The relevant technical reports and drawings concerning the EM installations of the building under consideration were made available by a professional technical office and used to extract all the necessary relevant information. For example, floor plans (Fig. 1) were used to determine the length of piping and then normalized for the size of the dwelling.

III. Methodology

The main EM installations of the building under consideration were organized in four distinct *groups of major components*, namely:

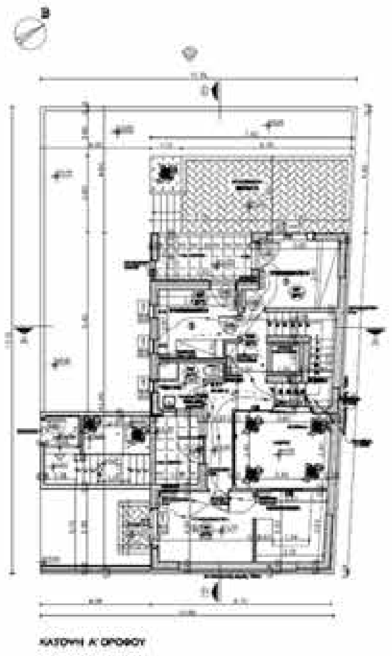

Fig. 1: Typical floor plan.

- *Space Heating* (SH), containing the boiler, oil burner, fuel tank, flue gas exhaust, pump, radiators, pipe network, expansion tank, valves, and other components like magnesium anode, thermostats, deaerators, etc.
- *Hot Water* (HW), containing solar collectors, hot water storage tank, support base, various fittings and accessories, hot water pipe network.
- *Air Conditioning* (AC), containing split unit heat pumps, i.e. internal units (vaporizer, fan, motor, support materials) and external units (condenser, compressor, fan, motor, four-way valve, connection and drainage materials).
- *Electrical* (EL), containing panels, cables, pipes and wall plugs (for SH, for HW and for the lighting network).

For each of the above *major components*, the following tasks [1] were carried out:

(T1) *Item analysis* (breakdown of a *group of major components* to its constitutive *basic items*): This was accomplished by identifying the major items of the group and splitting them continuously to *sub-items* till reaching the level of *basic items*, i.e. the lower level entities in the item tree that cannot be further split into sub-items, but rather to their constitutive *single materials*.

(T2) *Material analysis* (breakdown of the *basic items* to their constitutive *single materials*): identify and record the *single materials* that make up the *basic items* recorded in (T1).

(T3) *Mass analysis*: evaluate the mass contribution of each *single material* in the *basic item* it belongs.

(T4) *EE-ECO$_2$ analysis*: estimate the EE and ECO$_2$ contributions of each single material in the whole EM set.

The above procedure can be briefly described by the sequence: Electro-Mechanical installations (EM) → groups of major components (SH, HW, AC, EL) → major items (e.g. boiler, radiators, etc) → sub-items → (e.g. burner breakdown) → ... → basic items → constitutive single materials (steel, iron, copper, aluminum, glass, etc).

To accomplish tasks (T1), (T2) and (T3), detailed composition data were collected for representative commercial EM installations, disassembled to their *basic items* and finally analyzed to their constitutive materials. Accurate mass values were obtained for the *basic items* by electronically weighing them. When this was not practically possible, relevant data was obtained either by the manufacturer or by internet sources. In some limited cases, logical engineering assumptions and estimations were made. Figs 2 and 3 illustrate representative examples of the item analysis performed for the present case study. Further details can be found in [2].

Fig. 2: Major items and sub-items of the AC group on the left (a: indoor unit, b: outdoor unit, c: heat exchanger, d: axial fan) and of the HW group on the right (a: solar collectors, b: storage tank with thermal insulation, c: electric resistance tubing) [2].

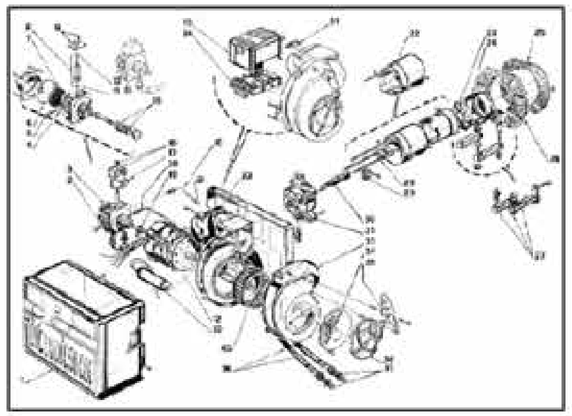

Fig. 3: Detailed breakdown of the burner in sub-items [2].

Concerning task (T4), EE and ECO$_2$ values for the *single materials* comprising the four distinct *groups of major components* were required. In [3], three databases containing EE (MJ/kg) and ECO$_2$ (kgCO$_2$/kg) coefficients for commonly used materials from different countries (U.K., N. Zealand and Australia) were compared. Although similarities exist in their trends, significant differences occur between them due to the different data involved in each country (row material sources, distances of material transport, manufacturing processes, etc) and due to the different analysis methods implemented. Taking into account that there is no official relevant database in Greece and in order to have some quantitative results for the EE and ECO$_2$ impact in the current case study, the coefficients of the U.K. database [4] were used, as in [1]. The obtained embodied values were then normalized by the total floor area of the building (152m^2). It should be clarified, that like in [1], the estimated embodied energy values do not account for the assembly of the EM equipment due to lack of relevant information from local manufacturers, neither for the transport and final installation.

IV. Results

The methodology presented in the previous section was implemented in the case study under consideration, to be denoted by DW2, while the dwelling studied in [1] will be referred to as DW1. The results concerning the SH group for both DW1 and DW2 are presented in Table 1 in the form of percentage mass contribution of each main item (including the relevant EL items). The dominant items in mass percentage in DW1 were radiators, pipes, boiler, flue gas exhaust, while in DW2 these are radiators, boiler, oil tank, flue gas exhaust. DW1 has no tank (fuel natural gas), but has a lot of piping due to its many apartments.

SH Items	DW2	DW1	DW2	DW1	DW2	DW1
Mass	*kg*	*kg*	*kg/m^2*	*kg/m^2*	*%*	*%*
Radiators	**219.0**	535.5	**1.44**	1.23	**30.6**	45.5
Boiler	**186.0**	218.0	**1.22**	0.50	**26.0**	18.5
Fuel tank	**126.0**	0.0	**0.83**	0.00	**17.6**	0.0
Flue gas exhaust	**66.6**	112.0	**0.44**	0.26	**9.3**	9.5
Electrical	**38.3**	18.5	**0.25**	0.04	**5.3**	1.6
Pipes	**29.2**	240.2	**0.19**	0.55	**4.1**	20.4
Valves, etc.	**27.8**	25.7	**0.18**	0.06	**3.9**	2.2
Burner	**12.0**	11.0	**0.08**	0.03	**1.7**	0.9
Expansion tanks	**8.8**	12.5	**0.06**	0.03	**1.2**	1.1
Pump	**2.9**	4.8	**0.02**	0.01	**0.4**	0.4
Sum	**716.7**	1178.2	**4.71**	2.70	**100.0**	100.0

Table 1: SH items along with their pure mass, area-normalized mass and % contribution for the present case study (DW2) and DW1 [1].

Table 2 presents similar results for the single materials contained in SH and HW groups together for DW2 (present study) and DW1 [1]. The dominant materials in mass percentage in DW1 were steel, copper, cast iron, while in DW2 these are steel, cast iron, iron (due to fuel tank), copper.

SH+HW Materials	DW2	DW1	DW2	DW1	DW2	DW1
Mass	*kg*	*kg*	*kg/m^2*	*kg/m^2*	*%*	*%*
Steel	**334.4**	700.3	**2.20**	1.61	**36.8**	41.7
Cast iron	**169.1**	199.4	**1.11**	0.46	**18.6**	11.9
Iron	**136.7**	12.5	**0.90**	0.03	**15.0**	0.7
Copper	**119.2**	495.6	**0.78**	1.14	**13.1**	29.5
Brass	**32.9**	33.7	**0.22**	0.08	**3.6**	2.0
Glass	**30.6**	72.0	**0.20**	0.17	**3.4**	4.3
Plastic	**26.5**	9.1	**0.17**	0.02	**2.9**	0.5
HDPE	**20.2**	11.7	**0.13**	0.03	**2.2**	0.7
Rockwool	**17.5**	56.8	**0.11**	0.13	**1.9**	3.4
Polypro-pylene	**7.9**	0.0	**0.05**	0.00	**0.9**	0.0
Aluminum	**6.6**	57.6	**0.04**	0.13	**0.7**	3.4
PVC	**2.2**	7.8	**0.01**	0.02	**0.2**	0.5
PEF	**1.7**	22.8	**0.01**	0.05	**0.2**	1.4
Synthetic rubber	**1.5**	0.0	**0.01**	0.00	**0.2**	0.0
Magnesium	**1.0**	0.0	**0.01**	0.00	**0.1**	0.0
Polyester	**0.6**	0.3	**0.00**	0.00	**0.1**	0.0
Sum	**908.5**	1679.6	**5.98**	3.86	**100.0**	100.0

Table 2: SH+HW materials along with their pure mass, area-normalized mass and % contribution for the present case study (DW2) and DW1 [1].

The results for the entire EM installations of DW2 are summarized in Table 3. The mass dominant materials are not necessarily ranked higher in terms of ECO$_2$ and EE, since some of them have greater CO$_2$ or energy impact despite their lower mass due to their high ECO$_2$ and EE values per mass unit. For example copper is ranked higher than iron in terms of ECO$_2$ or second (after steel) in terms of EE.

EM all materials	% mass	% ECO$_2$	% EE
Steel	**29.1**	35.67	28.47
Iron	**20.9**	15.31	12.80
Copper	**15.5**	**17.81**	**18.96**
Cast iron	**14.6**	10.67	8.92
Plastic	**5.1**	4.94	**10.04**
Brass	**3.4**	3.19	3.70
Aluminum	**2.7**	**8.59**	**10.32**
Glass	**2.6**	0.86	0.97
HDPE	**1.7**	1.20	**3.27**
Rockwool	**1.5**	0.61	0.62
Polypropylene	**1.0**	0.00	0.00
PEF	0.7	0.77	1.18
PVC	0.4	0.34	0.69
Rest materials	0.6	0.03	0.06
Total	100.0	100.00	100.00

Table 3: EM materials along with their % mass, ECO$_2$ and EE contribution for the present case study (DW2).

The total contribution of the EM installations to the building's environmental footprint in terms of ECO$_2$ and EE for DW2 were estimated 3026.3 kgCO$_2$ (or 19.9 kgCO$_2$/m^2)

and 86.6 kWh/m², respectively.

Table 4 presents ECO_2 and EE values corresponding to the SH and HW groups, as well as to the boiler and burner items. The ECO_2 and EE values corresponding to the SH group for DW2 are 1372 $kgCO_2$ (or 9 $kgCO_2/m^2$) and 39.5 kWh/m^2, respectively. The corresponding values for DW1 [1] were 3524 $kgCO_2$ (or 6 $kgCO_2/m^2$) and 33.2 kWh/m^2. According to [5], a benchmark value of operational thermal energy consumption for space heating in climatic zone B (Athens) is 115 kWh/m^2 for single dwellings and 91.4 kWh/m^2 for apartment buildings.

Item	ECO_2 ($kgCO_2$)		EE (kWh/m^2)	
	DW1	DW2	DW1	DW2
Burner	56	61	0.7	2.3
Boiler	438	373	3.9	9.5
Burner+Boiler	494	434	4.6	11.8
SH	3524	1372	33.2	39.5
HW	1580	933	17.6	23
SH+HW	5104	2305	50.8	62.5

Table 4: ECO_2 and EE for SH, HW and boiler burner for the present case study (DW2) and DW1 [1].

From a practical point of view, the results of a study like the present one could be considered for the replacement of oil fired boilers in old central heating installations with new units, which is a popular energy conservation measure. According to [5], such a replacement in the case of single-family dwellings would result to 17% annual operational thermal energy savings and a total of 335.6 $ktCO_2$ savings, for the entire Hellenic single-family building stock. This corresponds to annual operational savings of about 625.4 $kgCO_2$ per single-family dwelling. From the current analysis, the estimated ECO_2 of a boiler-burner unit is 434 $kgCO_2$ (Table 4). The total ECO_2 for the replacement of an old boiler-burner unit should account for the values of both the old and the new unit. Accordingly, for the simple replacement of a boiler-burner, $ECO_{2,repl}=2ECO_2=868$ $kgCO_2$. Thus, $ECO_{2,repl}$ would be compensated by the reduced operational emissions in about 17 months, as a result of the improved thermal energy performance of the new unit and its operational energy savings. On the other hand, the corresponding annual energy savings are estimated, according to [5], at about 19.6 kWh/m^2. The EE corresponding to the boiler-burner set of DW2 is $EE=11.8 kWh/m^2$ (Table 4). Again, the total EE for the replacement is doubled to account for the new unit, i.e. $EE_{repl}=23.6$ kWh/m^2. Thus, the operational energy savings would compensate the EE_{repl} in about 14 months, or about over two heating seasons.

V. Conclusions

In this paper, the work of [1] for a multi-family apartment building was extended and implemented to a single-family residential building. The new findings reveal that the prevailing materials in terms of mass are generally the same, since the EM installations used in the Hellenic residential buildings are similar. However, the normalized material quantities have different values among the two investigated typologies of a single- and multi-family building. The estimated ECO_2 values provide some initial guidance for the LCA evaluation of common energy conservation measures. Results indicate that the annual operational energy savings and CO_2 abatement as a result of common actions (e.g. replacing boilers with more energy efficient units) will account for the EE and ECO_2 in relatively short time frames. However, a proper analysis of the embodied versus operational savings, should account for the relevant differences in achieving the anticipated savings.

Future work includes an extension of the current analysis for a number of different Hellenic building typologies, to conclude on the repeatability and correlation of the results. Similar efforts are also underway towards the collection of relevant information and perform an analysis for the building envelope construction materials that dominate a building's total EE and ECO_2. The long term goal is to derive suitable benchmarks in order to compare the results, since no Hellenic database for EE or ECO_2 exists.

Acknowledgements

The authors would like to acknowledge Mr. C. Herouvim, Mechanical Engineer, for kindly providing the technical data for the building installations used as a case study in this work.

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Preliminary Study on the Thermal Mass Characteristics of Stone Buildings in Crete, Greece

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Abstract— **The external wall of a construction is part of the building envelope, the physical boundary between the internal space and the exterior environment of the building. Consequently, it constitutes one of the principal parameters of the energy performance of a building. One important category of buildings with particular architecture, materials, and construction techniques is the buildings of vernacular architecture. This paper investigates the thermophysical characteristics of a stone wall of a typical vernacular dwelling in Crete, a big island in the Mediterranean. Specifically, this study calculates the value of thermal transmittance co-efficient and the thermal inertia factors for distinct thicknesses of lime stone walls and analyses the results. The conclusions of the study are useful for the research of energy performance of relevant buildings.**

Index Terms—**building, stone building, thermal mass, vernacular architecture, U-value.**

I. Introduction

In each building, the building envelope affects and determines the energy efficiency and the environmental performance of the construction. Specifically, the thermophysical characteristics of the building envelope determine heat exchange between internal space and the external environment and, through them, the condition of thermal comfort in the inside of the building. Main parameters and principal thermophysical properties of building envelope are the thermal transmittance and thermal mass (heat storage capacity). The thermal transmittance measures the effectiveness of a material as an insulator in buildings and the thermal mass describes a material's capacity to absorb, store and release heat. Thermal transmittance co-efficient (U-value) is defined as the heat flow through one square meter of a structure when the temperature on either side of the structure differs by one degree Celsius. The thermal mass is calculated as the product of the mass m of the body and the specific heat capacity c for the material and describes how the mass of the building provides thermal inertia against temperature fluctuations. The values of the thermal transmittance co-efficient and the thermal mass of the envelope constitute essential parameters in each study of the energy performance of buildings, as the local climatic conditions of the place of the case study constitute essential data.

In the last few years, there has been a significant increase of interest in environmental, bioclimatic design in Greece. One important reason for this is the new law (KENAK) which is in force since October 2010 at the country, pursuant of the relevant European Directive (Energy Performance of Buildings Directive 2010/31/EU). This new legislation regards to new and existing buildings and defines minimum energy performance standards for them. The maximum acceptable U-values are set up for the opaque and transparent elements of building envelope and for the total of building envelope.

The interest in the energy performance of buildings also extends to the field of vernacular architecture. Vernacular architecture is characterized by the use of empirical knowledge. The different local materials and climate contribute to the distinct building typology, form and construction techniques [1]-[3]. This implies difficulties in determining the thermophysical properties of the envelopes of the buildings and complicates the study of energy performance.

In the present work, the thermophysical properties of a representative typical stone wall of a Cretan vernacular dwelling with variations of deferent values of thickness are being examined. The study results serve to determine the energy performance of respective buildings. Also, evince the weaknesses of energy performance and, if applicable, indicate the direction of search options in order to address them.

II. Definition of Thermal Mass Characteristics

Time lag and decrement factor are the main thermal inertia parameters for the study of thermal performance of building envelope. Time lag (or time shift), φ, is the period of time between the maximum amplitude of a cause and the maximum amplitude of its effect. More specifically, time lag is defined as the time it takes for the heat wave to propagate through a wall from the outer surface to the inner surface. Decrement factor, f, is defined as the decreasing ratio of its temperature amplitude during the transient process of a wave penetrating through a solid element.

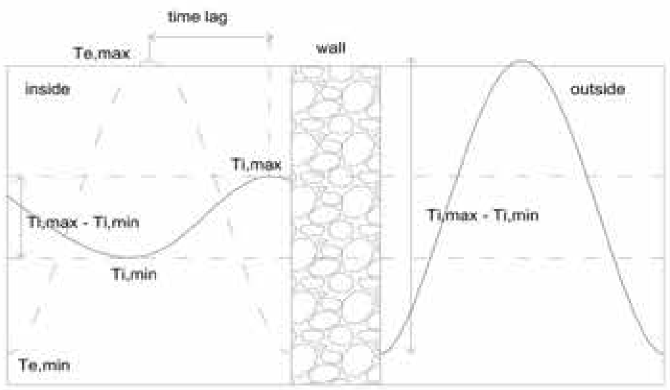

Figure 1. Sinusoidal graphic of time lag and decrement factor *f*

Time lag and decrement factor are defined by the following equations [4].

$$\phi = t_{Ti,min} - t_{Te,min} \quad (1)$$

$$\phi = t_{Ti,max} - t_{Te,max} \quad (2)$$

$$f = \frac{Ti,max - Ti,min}{Te,max - Te,min} \quad (3)$$

Where:

$t_{Ti,min}$ and $t_{Te,min}$ declare the time in which interior surface temperature and exterior surface temperature of the wall reach the minimum point and $t_{Ti,max}$ and $t_{Te,max}$ declare the time in which these reach the maximum point.

$T_{i,max}$ is the maximum interior surface temperature and $T_{i,min}$ is the minimum one.

$T_{e,max}$ represents the maximum exterior surface temperature and $T_{e,min}$ the minimum one.

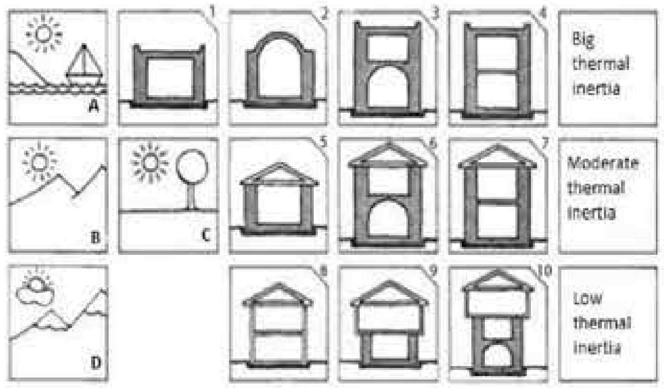

Figure 2. Building construction and climatic zones [5]

III. Climatic Zone

Crete, as the biggest island of Greece is characterized by Mediterranean climate. Greece has three climatic zones and Crete belongs to the coastal zone [5]. In vernacular architecture, the location of the dwelling defines the construction of the building envelope (Fig.2). At the more cold zones the dwellings have low thermal inertia in contrast to the more warm areas where the dwellings have higher thermal inertia. The research relating to thermal mass is valuable particularly in cases where there are wide diurnal fluctuations and also the average exterior temperatures are near the comfort zone, such as the hot and dry climate of Crete.

IV. Method

In this study, the thermophysical characteristics of the wall are calculated based on the calculation methods of the International Standard EN ISO 6946:2007 [6] and EN ISO 13786:2007 [7].

ISO 6946:2007 provides the method of calculation of the thermal resistance and thermal transmittance of building components.

$$U = \frac{1}{Rse + \Sigma R + Rsi} \quad (4)$$

Where:

U [$W/m^2{\cdot}K$] thermal transmittance co-efficient

R_{si} [$m^2{\cdot}K/W$] internal surface resistance. Its value, according to EN ISO 6946, is set constant, equal to 0.13 $m^2{\cdot}K/W$.

R_{se} [$m^2{\cdot}K/W$] external surface resistance. Its value, according to EN ISO 6946, is set constant, equal to 0.04 $m^2{\cdot}K/W$.

ISO 13786:2007 specifies the characteristics related to the dynamic thermal behavior of a complete building component such as time lag and decrement factor and provides methods for their calculation.

The properties considered are thermal admittances and thermal dynamic transfer properties, relating cyclic heat flow rate to cyclic temperature variations. Thermal admittance relates heat flow rate to temperature variations on the same side of the component. Thermal dynamic transfer properties relate physical quantities on one side of the component to those on the other side [7].

According to the procedure,

1) The materials comprising the layers of the building component and the thickness of these layers are identified and their thermal characteristics are determined. The stone wall under investigation is constituted from limestone and lime plaster thickness 20 mm. This information is presented at the following table.

TABLE I. Thermal Properties of Layers of Stone Wall

Thermal properties of layers of stone wall	*Lime plaster*	*Limestone*
λ [W/m·K]	0.87	1.7
ρ [kg/m³]	1800	2200
c [J/Kg·K]	1000	1000

Where:

λ [$W/m{\cdot}K$] thermal conductivity

ρ [kg/m^3] density

c [$J/Kg{\cdot}K$] specific heat capacity

d [*m*] thickness of a layer

R [$m^2{\cdot}K/W$] thermal resistance

2) The period of the variations at the surfaces is specified.

a) Initially, the period of the thermal variations which has been selected is one day (86,400 s), corresponding to daily meteorological variations and temperature setback.

b) In addition to the diurnal heating and cooling cycle, thermal mass also influence longer time periods. Therefore the period of one week (604,800 s) has been selected, corresponding to longer term averaging of the building.

TABLE II. Thermal Tranmittance Coefficient of Stone Wall

Thickness, d [mm]	*Thermal transmittance co-efficient (U-value)*	
	U-value of the wall with plaster	*U-value of the wall without plaster*
300	2.71	2.89
400	2.34	2.47
500	2.06	2.15
600	1.83	1.91
700	1.66	1.72
800	1.51	1.56
900	1.39	1.43
1000	1.28	1.32

TABLE III. Thermal properties stone wall, one day period

Thickness, d [mm]	*Thermal properties*		
	Decrement factor, f	*Time lag [h]*	*Thermal admittance [W/m²·K]*
300	0.30	8.24	5.29
400	0.18	10.84	5.27
500	0.10	13.46	5.26
600	0.06	16.08	5.26
700	0.03	18.70	5.26
800	0.02	21.32	5.26
900	0.01	23.94	5.26
1000	0.01	2.57	5.26

TABLE IV. Thermal properties stone wall, one week period

Thickness, d [mm]	*Thermal properties*		
	Decrement factor, f	*Time lag [h]*	*Thermal admittance [W/m²·K]*
300	0.93	13.75	3.2
400	0.86	20.43	3.25
500	0.77	27.48	3.37
600	0.67	34.63	3.48
700	0.57	41.74	3.55
800	0.48	48.78	3.58
900	0.41	55.76	3.58
1000	0.34	62.71	3.58

As we can see in Table II, the U-value decreases as the thickness of the wall increases. Even if the thickness is 1000 mm the U-value is more than the maximum limit of 0.60 $W/m^2{\cdot}K$, according to the law for Energy Performance of Buildings for the A climatic zone where Crete belongs. U-value thermal transmittance under steady state boundary conditions is the measure of the heat transmission through a construction element for a given difference between internal and external temperature, which is assumed to be constant. This value defines the insulating properties of the shell of the construction. But if the outdoor temperature has a wider diurnal fluctuation than the indoor temperature, the actual heat loss of a high mass wall could be less than the U-value calculation. The heat flow through the wall does not have steady state conditions and only one direction as the outdoor and the indoor temperature is constantly change. The direction of heat flow will be change depends if the outside temperature will be higher or lower than the inside temperature. Also, there is a small difference between the value of U-value of the wall with plaster and without plaster. The U-value of the wall with the plaster is lower, therefore better than the wall without plaster.

Nevertheless, the decrement factor is relatively low according to the Table III. The wall with thickness 500 mm has a decrement factor value 0.10. If this wall experiences a 10° C diurnal variation in the external temperature, it will experience a diurnal variation in the internal temperature of only 1° C. Consequently, a low value of decrement factor offers a more stable indoor temperature and low amount of temperature fluctuations. The overall peak interior temperature must be delayed until the exterior is at the lowest value. As the thickness is increased, the lime lag is also increased up to 1000 mm thickness where the time lag values 2.57 h, since time lag has overlapped the 24 h of one day. The optimum value of time lag is 12 h. The results show that the typical stone wall with thickness 500 mm has 13.46 h time lag, approximately the optimum value.

As we can see in Table III and Table IV, the results show that the values of dynamic thermal characteristics depend on the periods of the variations. Thermal admittance values decline as the period increases, while decrement factor and time lag values increase. The maximum effective thickness depends on the period of the variations. If the period of the variations is one day the maximum effective thickness is 100 mm and if it is one week the maximum effective thickness is 250 mm. Longer periods than one day allow thermal mass to be tapped at depths in excess of the 100 mm associated with a 24-hour cycle.

V. CONCLUSIONS

In this study, we calculated the thermophysical properties (U-values and thermal inertia factors) of stone walls of different thickness, from 300 to 1000 mm for one day and one week period of the variations based on the calculation methods of the International Standard EN ISO 6946:2007 [6] and EN ISO 13786:2007 [7]. The analysis shows that limestone wall has a high thermal transmittance co-efficient. Nevertheless vernacular dwellings have relatively stable indoor thermal conditions, with a low decrement factor and a high time lag, due to the considerable high thermal mass of the structure. The conclusions demonstrate the specific features of the energy performance of the building with stone wall at temperate climate. Specifically, the numeric results that were calculated can be used at the studies of energy efficiency of the vernacular buildings at Crete and additional at other regions with similar climatic conditions.

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Results from Preliminary Energy Audit in the Faculty of Technical Sciences - Bitola

Vladimir Mijakovski*, T. Geramitcioski, V. Mitrevski, G. Trombev, R. Ristevski

Abstract **- Measures for increasing of energy efficiency in buildings are closely related to Energy Audit. Faculty of Technical Sciences – Bitola (FTSB) is the biggest faculty within the state University "St. Kliment Ohridski" in Bitola. Preliminary energy audit for the building of FTSB was performed as a part of the training for energy auditors. The calculations were performed by using of ENSI© EAB software.**

Index Terms **– Energy Audit, Faculty, energy class, ENSI software.**

I. INTRODUCTION

Following recent adoption of EU regulative in the area of energy auditing in the country, [1,2], the first step was to train energy auditors for a purpose of obtaining licenses for energy auditing. In the course of this training, the building of the Faculty of Technical Sciences in Bitola, as one of the institutions licensed for training of Energy Auditors, was used as an example for energy auditing with determination of its energy class using ENSI© EAB software.

The building of the FTSB is located in the south-eastern part of the city of Bitola. The object does not have attached building to it, located in averagely urbanized part of the city, next to the city park, bus station and railway station. It was built in 1961 with reconstruction and extensions in 1977 and 1989. Main entrance of the building is on the south-western side (Fig. 1).

Fig. 1: Location of Faculty of Technical Sciences' building

Faculty of Technical Sciences - Bitola, University "St. Kliment Ohridski", Bitola, MK 7000, former Yugoslav Republic of Macedonia (*corresponding author's e-mail: vladimir.mijakovski@tfb.uklo.edu.mk).

II. DESCRIPTION OF THE BUILDING AND OTHER DATA REQUIRED FOR ENERGY AUDIT

The building is mainly divided in 2 parts: classrooms and administrative part. Classrooms building has two parts: main and annex building. Main classrooms building has northeast – southwest orientation and consists of basement and three floors with wooden roof construction and asbestos-cement (salonit) roofing, while the annex building has basement and two floors with reinforced concrete flat roof. Administrative building consists of high-basement and one floor with metal sheet roof.

Total net area of the building is approx. 5950 m^2, while total net volume is approx. 21000 m^3.

Last reconstruction of the building consisted of partial replacement of external windows and carpentry and took place in the year 2010.

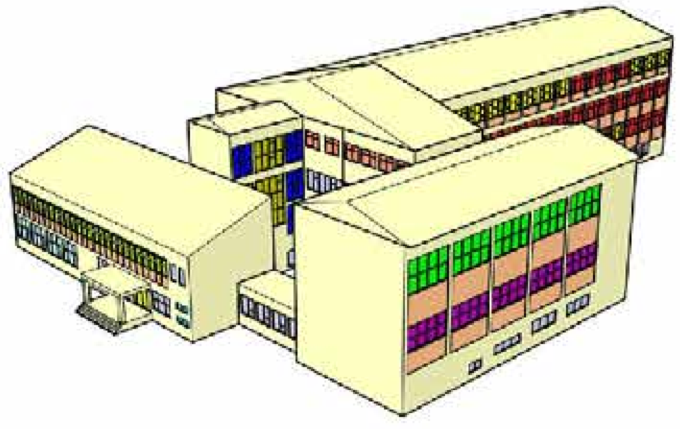


Fig. 2: Appearance of the building from the south-west

Part of the other relevant data for the energy audit, required by the legislative, are given in the following table:

Table 1: Part of the data relevant for Energy Audit of FTS' building

Characteristics of the building construction	Material (concrete, brick, hollow brick)	Total thickness [cm]	Thickness of the thermal insulation layer [cm]	Area of the construction [m^2]	Heat transfer coefficient U [W/m^2K]	Note
External wall NORTH	Concrete	46		126,7	1,99	
	Brick	31		411,2	1,59	
	Hollow brick	31		300,4	1,38	

External wall SOUTH	Concrete	48		127,1	1,99	
	Brick	31		370,7	1,59	
	Hollow brick	31		325,1	1,38	

	Execution of glazing for the windows, for example: triple insulated glass with inert gas and low emission coating	Carpentry – frame for the glazing, for example: wooden, aluminium, plastic etc	Heat protection	Heat transfer coefficient through the window U [W/m²K]
North façade [m²]				
170,9	Double glazing	Wooden		2,9
378	Double thermopan glass	Plastic (PVC)		2,44
South façade [m²]				
166,6	Double glazing	Wooden		2,9
392	Double thermopan glass	Plastic (PVC)		2,44

Prior to entering of data in ENSI© EAB software, a detailed calculation of areas of all surfaces (external building envelope) as well as heat transfer coefficient for all materials was performed. In the following figures, example of calculated areas for building's south façade and cross-section of one type of external wall and roof are shown.

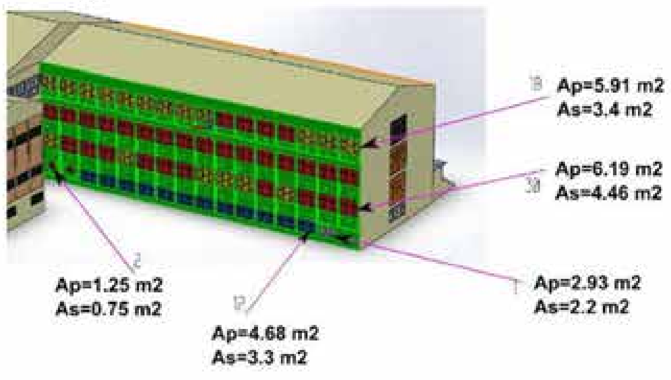


Fig. 3: FTSB south façade – Total area without windows 398,8 m²; red colored windows are with double glazing and plastic carpentry; A_p – area of window; A_s –glass area of the window

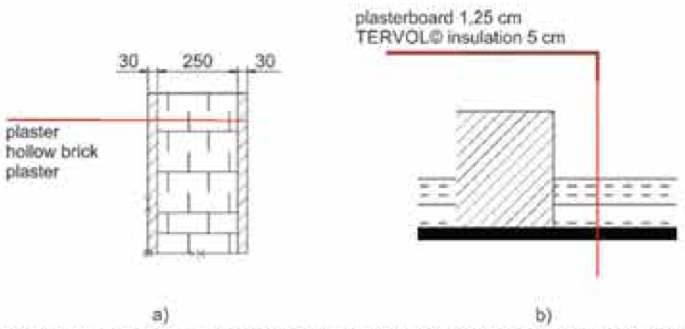


Fig. 4: Cross section of construction - a) external wall with hollow brick; b) roof with plasterboard

At the end, we grouped external walls and windows in three groups according to building construction and heat transfer coefficients.

For the heating of building, hot water radiator heating system with forced circulation (with pump) is used. Heating installation is of a two-pipe system with lower horizontal branching. Two pumps are used for circulation of heating media (water). Boiler house consists of two hot water boiler connected in parallel, each having approx. 800 kW of installed heat power. Light oil is used as fuel. As part of the energy audit, a measurement of flue gases emission from one of the boilers was also taken.

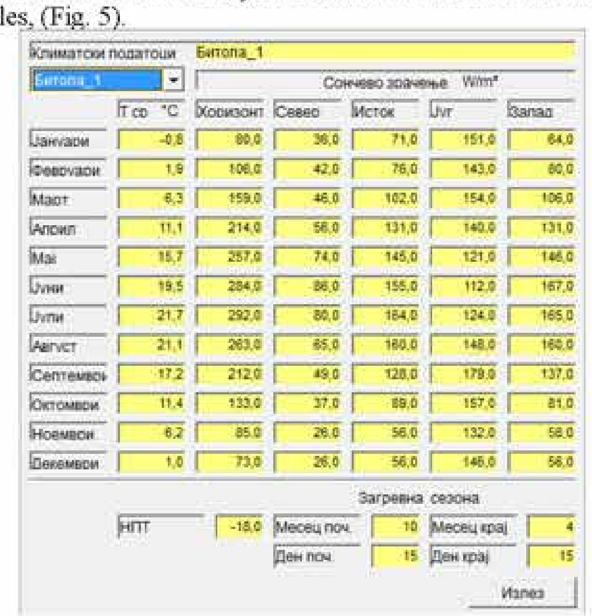
Electrical equipment in use consists of more than 200 Personal Computers (PC's), 10 electric boilers, around 40 printers, 3 copier machines, 20 air conditioning units (split system) etc. There is also a substantial number of electric heaters (around 40) that are used prior to/after heating season (before 15.10 or after 15.04). There are also around 900 fluorescent lightning tubes with electronic ballast installed for lamination.

For the purpose of energy audit preparation, detailed invoices – bills for electric energy and water consumption were collected from the accounting department.

III. Inserting of Data in ENSI© EAB Software and Obtaining of Results

The ENSI© EAB Software, [3, 4], is tailored for quick energy calculations of the energy performance of existing and new buildings.

The calculations can either be based on the standard climatic data, standard values and holiday tables that are included in the software, or by creating user defined standard values and holiday tables. In our case, we used the standard climatic values for the city of Bitola with user defined holiday tables, (Fig. 5).



Климатски податоци: Битола_1

Битола_1 — Сончево зрачење W/m²

	Т ср °C	Хоризонт	Север	Исток	Југ	Запад
Јануари	-0,8	80,0	36,0	71,0	151,0	64,0
Февруари	1,9	106,0	42,0	76,0	143,0	80,0
Март	6,3	159,0	46,0	102,0	154,0	106,0
Април	11,1	214,0	58,0	131,0	140,0	131,0
Мај	15,7	257,0	74,0	145,0	121,0	146,0
Јуни	19,5	284,0	86,0	155,0	112,0	167,0
Јули	21,7	292,0	80,0	164,0	124,0	165,0
Август	21,1	263,0	65,0	160,0	148,0	160,0
Септември	17,2	212,0	49,0	128,0	179,0	137,0
Октомври	11,4	133,0	37,0	89,0	157,0	81,0
Ноември	6,2	85,0	26,0	56,0	132,0	58,0
Декември	1,0	73,0	26,0	56,0	146,0	56,0

Загревна сезона

НПТ -18,0 | Месец поч. 10 | Месец крај 4

Ден поч. 15 | Ден крај 15

Излез

Fig. 5: Climatic data for Bitola

After naming the project in the software, the first step is to enter the actual condition of building envelope (areas and U-values). The software allows to enter walls and windows in eight directions (N, NE, E, SE, S, SW, W, NW). "Walls" allow input of non-transparent constructions and "Windows" for transparent parts, (Fig. 6).

Fig. 6: "Actual" and "After measures" condition of walls and windows on building's south façade

After entering of actual U-values, we also enter the U-values for the "Measures" – that is maximum permitted U-values for non-transparent surfaces according to the Rulebook for energy characteristics of buildings, [2]. When the entering of values for building envelope (walls, windows, floor and roof) is finished we proceed to enter the total conditioned (heated) area of the building and heat gains from occupants.

Next step is to enter/modify actual parameters for "Heating". This is done by changing of different efficiency coefficient referring to emission of heating objects, distribution efficiency, automatic control and production efficiency. It is also possible to enter parameters for "Measures" referring to condition after, for example, replacement of hot water boiler running on light oil fuel with corresponding boiler that uses wood pellets as fuel.

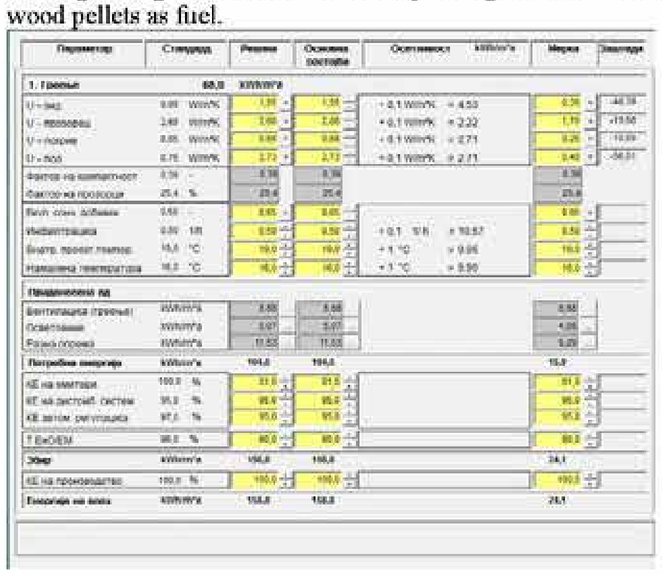


Fig. 7: ENSI© EAB "Heating" screen

The next few steps include entering of values for "Ventilation" (in our case there is no mechanical ventilation of the building), followed by "Domestic Hot Water", "Fans, Pumps and Lighting", "Various exploitable and unexploitable" and "Cooling and Outdoor".

When all the data are filled in, the software gives the results of calculations on five screens. The "Energy Budget" includes the energy use for the standard building and calculated energy use for "Actual", "Baseline" and "After Measures". The "After Measures" values summarize all the savings from the "Measure" columns for each budget item.

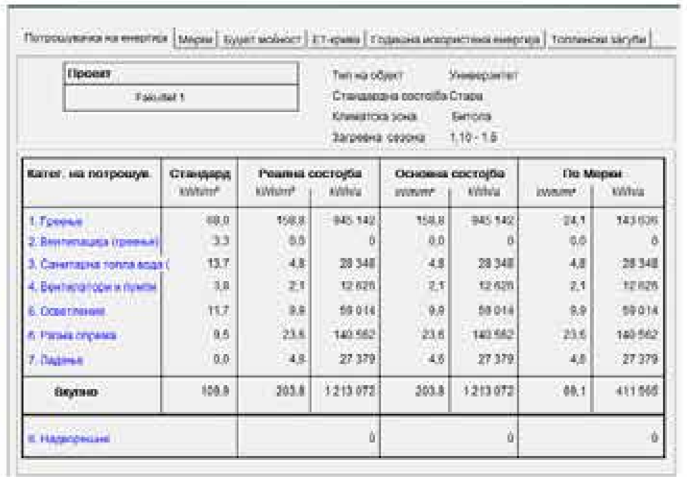


Fig. 8: "Energy budget" results screen

By clicking "Power budget", the corresponding budget for maximum simultaneous power demand for each budget item will appear.

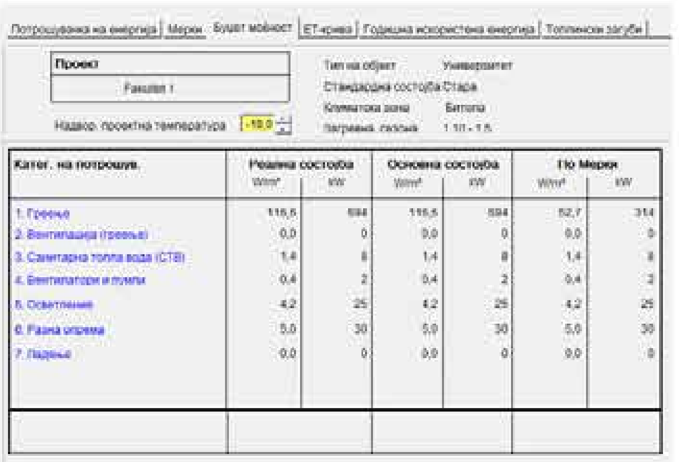


Fig. 9: "Power budget" results screen

Both specific and total power demands are presented in the columns "Actual", "Baseline" and "After Measures". The kW's is the specific value multiplied by the conditioned area of the building, defined in the "Building envelope" window.

IV. Conclusions

Following recent adoption of EU regulative in the field of Energy Auditing of buildings, the Faculty of Technical Sciences in Bitola is one of country's five licenced training centers for energy auditors, [5]. In the scope of training, practical part, the building of FTSB was taken as an example and general energy audit was performed on it. Calculations were performed using ENSI© EAB software for quick energy performance calculations.

The results from the calculations categorized the building of the Faculty of Technical Sciences – Bitola as class "E" building. Calculated value of energy consumption is 158,8 kWh/(m^{2}a).

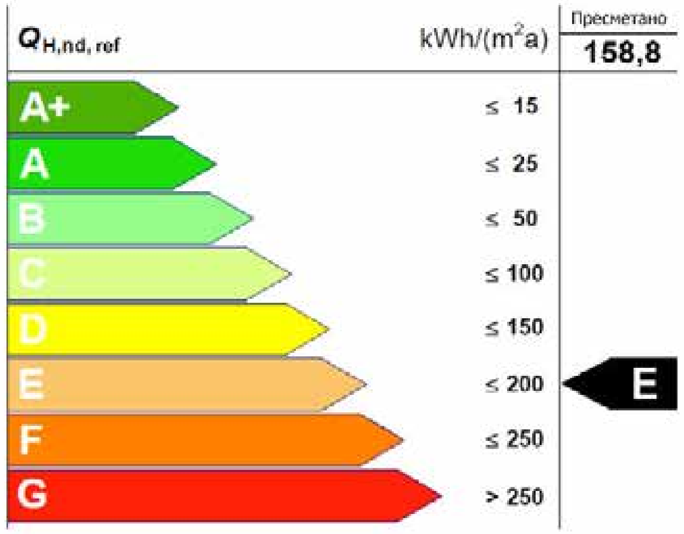


Fig. 10: Energy class of the building

According to local legislative, [2], all buildings undergoing 'substantial reconstruction' must reach at least "D" energy class.

In the example of preliminary energy audit of the Faculty of Technical Sciences – Bitola, the proposed measured would include:

- Thermal insulation of all external walls in order to reach maximum allowed U-value of 0,35 W/m^{2}K;
- Replacement of all windows and carpentry in order to reach maximum allowed U-value of 1,7 W/m^{2}K;
- Installation of additional thermal insulation for the roof in order to reach maximum allowed U-value of 0,25 W/m^{2}K;
- Replacement of the hot water boiler (which is around 35 years old) running on light oil fuel with high efficiency hot water boiler running on wood pellets.
- Replacement of fluorescent lighting tubes with LED lights;

Implementation of these measures would 'raise' building's energy class to "C".

Return on Investment (ROI) period for implementation of these measures was also calculated and it ranges from 2 years (lights replacement) up to 5,5 years (replacement of windows and corresponding carpentry).

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Building airtightness measurements are used for a variety of

Blower door test - Measurement protocol

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Abstract - A typical energy audit would involve an inspection of the entire building focusing on those areas which are typically responsible for energy loss. In the energy audit, and inspection of the building envelope to identify areas of air infiltration is also included. The Blower door method is a diagnostic tool designed to measure the airtightness of building envelope and to help locate air leakage sites. In this paper, the measurement procedure and application of Blower Door method for air leak detection of small house was presented.

Index Terms **– blower door test, airtightness, building envelope**

I. Introduction

The ventilation rates through the building envelope or the number of air changes is of great importance when determining thermal properties of the building as well as the definition of quality of internal comfort. Scientific studies and practical experience tell us that commercial and institutional buildings often have significant air leakage problems, regardless of their age, size or construction. For energy efficiency of high performance buildings there are some reasons for establishing airtightness of buildings envelope due to: reduction in energy consumption due to air leak, avoiding moisture condensation problems, avoiding uncomfortable drafts caused by cold air leaking in from the outdoors, determining how much mechanical ventilation might be needed to provide acceptable indoor air quality.

It is estimated that energy loss due to building envelope airtightness in EU countries (ex. in Belgium and Germany) is 10% of energy performance level [2]. Therefore, airtightness of building envelope is one of the most important aspects which have to be carefully considered in the design and construction phase. In the Former Yugoslav Republic of Macedonia, as in a number of EU countries examining the airtightness of buildings envelope at the whole object is not mandatory, but is recommended to be performed on each new building according to recommendations of standard MKS EN 13829:2000 [5].

purposes including:

- documenting the construction airtightness of buildings
- estimating natural infiltration rates in buildings
- measuring and documenting the effectiveness of air sealing activities
- measuring duct leakage in forced air distribution systems.

In this paper the application of Blower Door method for air leakage detection of family house was presented.

II. Definition of building envelope airthigness and influence of the number of air changes on energy consumption

Building envelope airtightness can be defined as the resistance to inward or outward air leakage through unintentional leakage points or areas in the building envelope. From a measurement standpoint, airtightness means measuring the flow through building envelope as a function of the pressure across the building envelope [1]. Due to the wide range of test methods and standards available for air leakage testing, a number of different reporting techniques for air leakage values are commonly used.

The flow of air through the boundary of the building envelope can be calculated from [4]

$$q_{\Delta pr} = C_L (\Delta p_r)^n$$

where:

$q_{\Delta pr}$ - the volumetric leakage airflow rate [m^3/h]

C_L - is the air leakage coefficient [m^{3}h^{-1}Pa^{-n}]

Δp_r - pressure difference across the building envelope reduced to the atmospheric pressure [Pa]

n - flow exponent, 0.5<n<1, typical value is 0.66.

Number of changes of total air volume at the specific pressure difference, Δp_r can be obtained when air flow rate through building envelope (calculated for atmospheric pressure 1.013 bar and temperature of 20°C) is divided by the heated building volume, V, [4]:

$$n_{\Delta pr} = \frac{q_{\Delta pr}}{V}$$

Specific air flow rate, $q_{\Delta pr}$, through building envelope at pressure difference Δ_{pr} was calculated, when the air flow rate through building envelope is divided by the surface area, A_e, of the heated building volume [4]:

$$w_{\Delta pr} = \frac{q_{\Delta pr}}{A_e}$$

According to the MKS EN 13829:2002 the above values are calculated for the pressure difference of 50 Pa and denote n_{50} and w_{50}. For the pressure difference between inside and outside air of 50 Pa, measured airflow reduced the volume of the heated air must be no greater than:

- n_{50} = 3.0 h^{-1} for the building without mechanical ventilation i.e. natural ventilation
- n_{50}=1.5 h^{-1} for buildings with mechanical ventilation i.e. forced ventilation.

For building that is ventilated by a mechanical ventilation system with the number of air changes greater than 0.7 h^{-1} and air flow greater than 2500 m^3/h, heat recovery of heat from the output air is compulsory. For energy passive house the value of n_{50} should lie below 0.6 h^{-1}.

After that, the influence of the number of air changes on energy consumption should be calculated. The amount of heat which per unit of time must be compensated due to the air mass flow rate can be calculated with equation [3]:

$$Q = \dot{m} c_p \Delta T = n \rho V c_p \Delta T \ \ [J/h]$$

where:

n [h^{-1}] - the number of air changes in the room per hour,
ρ = pM / RT - air density in these conditions, which are calculated for: p = 101325 Pa - normal pressure; M = 0.029 kg/molK - molar mass of air, R = 8.314 J/molK - universal gas constant and T = 293 K indoor temperatures in winter.

Based on these data the value for density of air ρ = 1.2 kg/m^3 was obtained. The volume of the room is V = a·b·h [m^3], where a [m], b [m] and h [m] are dimensions of the room, c_p = 1000 J/kgK, specific heat of air at constant pressure and ΔT [K] is temperature difference in winter.

On the basis of the above equation, the specific ventilation heat losses q (i.e., loss per unit of usable area, A = ab) are determined.

$$q = \frac{Q}{ab} = n \rho h c_p \Delta T \ \ [\frac{J}{m^2 h}]$$

If the room with height, h, is heated, s, hours per day [h / d] and, d, days per year [d / a] and when to change J to kWh, and taking into account that 1 J = (10^{-3}/3600) kWh [4]:

$$q = \frac{10^{-3}}{3600} \rho c_p \, nhsd \Delta T = 3.33 \cdot 10^{-4} nhsd \Delta T \ \ [\frac{kWh}{m^2 a}]$$

where ΔT = 5 K is average temperature difference.

III. MAESUREMENT PROCEDURE

The easiest way to measure building envelope airtightness is with a diagnostic set called a Blower Door. A basic Blower Door system includes three components: calibrated fan units, a door-panel system, and a device to measure fan flow and building pressure (fig.1).

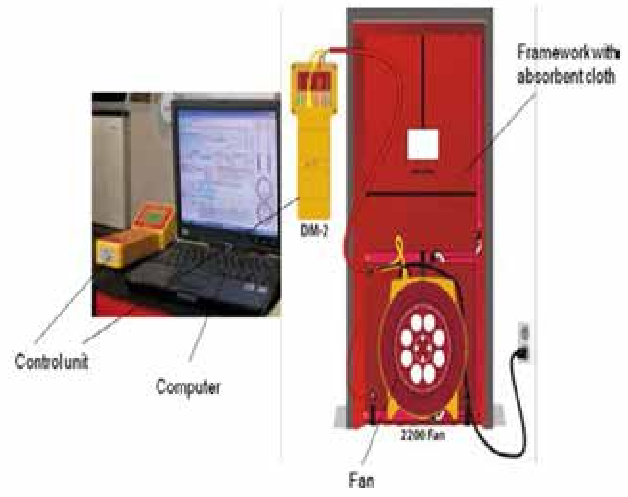
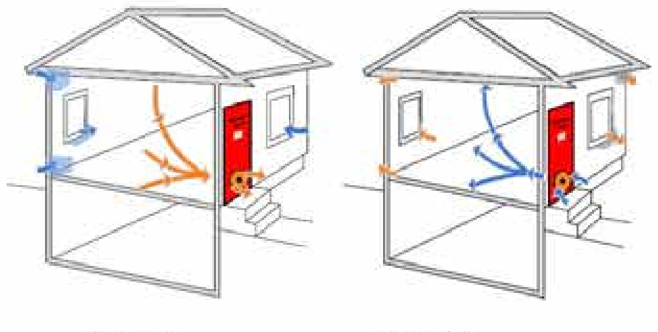


Fig.1: Commercial Blower door test installation.

A variable-speed fan is mounted in a doorway or other opening to pressurize (or depressurize) the house by specified amounts. To perform the test according to the MKS EN13829:2000 standard, at least 5 readings must be taken at different pressure points at no more than 10 Pa differences, e.g. 60 Pa, 50 Pa, 40 Pa, 30 Pa, 20 Pa.

According to MKS EN 13829:2000, there are two methods for airtightness measurement of the building, named method A and method B (fig. 2).

The main difference between both methods is in the openings in the buildings envelope that are sealed for testing. Method A applies for the airtightness measurement of the building in use, with the building envelope representing the conditions during the season in which heating and cooling systems are used [5]. Method B applies for the airtightness measurement of the building envelope in case when any intentional opening in the building envelope is closed or sealed [5].



Method A Method B

Fig.2: Air flow through building envelope

According to MKC EN13829:2000, for a blower door test to be acceptable, there are a number of conditions that need to be fulfilled [5]:

- the envelope of the building must be completed (or at least the part to be tested)
- wind speed must be of Beaufort scale 3 or less, or, if measured, 6 m/s or less
- the temperature difference between indoor and outdoor, in K, multiplied by the height of the building envelope, in m, if the result is larger than 500 m·K
- temperature difference in centigrade, with a result less than 500
- the static pressure (zero flow) difference between the inside and outside of the building with the envelope closed up, but without test equipment running, must be less than 5 Pa over a 30 second average.

Before a blower-door test can begin, the following preparation steps are necessary [5]:

- exterior windows and doors, fireplace and stove doors shall be closed, but not sealed, beyond the intended weather stripping or other infiltration control measures
- dampers including exhaust, intake, makeup air, backdraft and flue dampers shall be closed, but not sealed beyond intended infiltration control measures
- interior doors, if installed at the time of the test, shall be open
- exterior doors for continuous ventilation systems and heat recovery ventilators shall be closed and sealed
- heating and cooling systems, if installed at the time of the test, shall be turned off
- supply and return registers, if installed at the time of the test, shall be fully open
- doors which lead from upstairs into most basements should be open during the test, as basements are normally conditioned by supply registers, un-insulated ducts, pipes and the un-insulated floor above
- large garage doors shall be close. If the Blower Door is installed on the main door between the house and the garage it must be open. It should also be open if the air handler/furnace is located in the garage, or if there is an attic access in the garage ceiling which is being left open during the test.

IV. APPLICATION OF BLOWER DOOR TEST MEASUREMENT OF THE FAMILY HOUSE

The Blower Door test measurement was made for family house which was builded in 1970. The total calculated surface area of house envelope is A_e= 350 m^2, while the volume of heated area of the house is V=445 m^3. The outside temperature was 15°C and weather conditions during the test were with small wind speed. The results from conducted Blower Door test are shown in Table 1.

Table 1 Measurement results and calculated value of specific ventilation heat losses

	Pressurized	Depressurized
p_1[Pa] / t_{sr}[°C]	50/15	50/15
$q_{\Delta pr}$ [m^3/h]	1280	1350
n_{50} [m^3/h]	**2.88**	**3.03**
w_{50} [m^3/hm^2]	3.66	3.86
q [kWh/m^2 a]	42.57	44.78

For calculation of the specific ventilation heat losses q, the following values are used: h = 3 m, s = 16 h, d = 185 days per year and ΔT = 5 K. For easier visualization and designation of airflow macro location, the mini smoke puffers were used.

On figure 3, detected leaks on the connection of window with the wall and at the connection of the output window door with the wall are shown.

Fig.3: Smoke puffers being used to show airflow out of window and window door

V. Conclusions

Airtightness is an important component of building performance. The control of air infiltration through the exterior building envelope impacts building energy efficiency, the potential for moisture related damage, interior comfort, and indoor air quality. To test the airtightness performance of buildings a variety of techniques have been developed, but Blower Door test is the most applicabile.

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Energy performance analysis of pre- and post-retrofit households in Greece

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Abstract—**Buildings consume 40% of Europe's energy, thus energy efficiency in buildings represents the most cost effective potential for emission reductions. Clearly there is a growing justification and political commitment to tackle energy efficiency in buildings and this requires moving swiftly towards very low-energy retrofit and passive design new build en masse. In this context the research project 'Countdown to Low Carbon Homes' is proposed to investigate the construction and the build environment sector of residential buildings from the perspective of the key market actors bringing them together in a co-learning program. This paper presents initial results from a survey considering the energy performance of pre- and post-retrofit households in Greece. The survey is the first step of the research and development action of the project.**

Index Terms—**Residential building stock, energy performance, retrofit measures, survey.**

I. Introduction

The retrofit challenge is a major issue for all countries in Europe, as reflected in European Union (EU) policy on reducing energy consumption and emissions from existing buildings. Climate change agreements highlight the need to reduce carbon emissions and there is also concern about security of energy supplies to meet rising demand in the next decades. Energy poverty is on the rise and is a phenomenon increasingly recognized in EU countries, with consequences for health and well-being.

With economic downturn, the already low rate of replacement of buildings has reduced drastically, increasing further the significance of achieving deep carbon retrofit. Loss of work in the construction sector is both an additional socio-economic concern, and sets at risk the loss of valuable technical skills.

Good quality and appropriate retrofit is a win-win solution, but is complex to achieve in practice, especially in private housing, where it relies on significant levels of own investment by home owners, as well as selection and commissioning of potentially unfamiliar new technologies. Most repair and refurbishment is done by SMEs, and they also face many challenges and practical, financial, aesthetic and regulatory barriers. Other key actors in the supply chain are building suppliers, and local planning and building control personnel.

In this context, the research project '*Countdown to Low Carbon Homes*' supported by the European ERA-Net Eracobuild program, involving partners from UK, Greece and Cyprus is proposed. Scope of the project is to view the construction and the build environment sector of residential buildings from the perspective of the key market actors bringing them together in a co-learning program [1]. The project involves three EU countries, i.e. UK, Greece and Cyprus. The key actors include home owners and mainly SME involved in the retrofit supply chain, such as builders, installers, planning / building control and local building suppliers. This project will research and develop real practical experience, and produce evidence-based research conclusions as well as a practical guide for a local delivery model. This has the potential to kick-start an EU wide exchange on local retrofit of lasting benefit socially, environmentally, and economically. The high proportion of owner occupied homes in the EU makes this action a significant issue to understand better in terms of scaling up retrofit and reducing costs.

In line with the concept of the '*Countdown to Low Carbon Homes*' project, this paper presents initial results regarding the energy performance of households in the area of Thessaloniki, Greece. Contrary to previous works [2] - [4] the results of the elaborated survey are analyzed referring to the categorization of households to pre- and post-retrofit groups.

II. Action Research Approach

The research and development of the '*Countdown to Low Carbon Homes*' project is conducted at a local/regional level in each partner area to develop and validate a local delivery model and draw in knowledge and experience from key market actors. In the activities the following groups are involved:

- *Local installer groups:* locally active installers are included to encompass all the main technologies required for sustainable energy retrofit of homes in their area.
- *Post-retrofit household group:* Twenty households are recruited to provide their experience and record their own and their buildings energy performance after retrofit. An 'energy diary' approach will be established for self monitoring which will encourage the householders in the habit of monitoring consumption or external factors that impact upon it.
- *Pre-retrofit household group:* The analysis is focused on twenty households upon their intention to retrofit. Home owners are recruited for assistance with retrofit and to participate in detailed documentation of their experience. Each project partner will provide a home energy survey and advice, with a written report on home energy performance and recommendations for energy improvements. Follow on 'hand holding' advice is provided to help to get works done, including finance and installers, with recording of the experience by both householder and adviser.

III. The Survey

The first step of the research and development is to investigate the energy performance of the households. Therefore, a questionnaire was created, in order to collect energy data both of the pre-retrofit and the post-retrofit stage. This survey was conducted in the area of Thessaloniki, the second largest urban area in Greece, with a population of some 1,000,000 citizens. The questionnaire was filled in by means of door-to-door interviews, mainly in the Municipality of Thessaloniki, which is the biggest Municipality in the area. The total of the 40 participating residential building owners answered to the questionnaire, thus 50 % of them are planning to retrofit their houses and 50 % have already retrofitted.

The questionnaire structure is based on 5 sections concerning the typological and structural characteristics of the building, the determination of heating, cooling, domestic water system and electrical energy consumption. Especially, for the post retrofit group information about the interventions and renovation measures already implemented are also collected.

A. General results

Results considering the main characteristics of the buildings are summarized in Table I. Similar statistics are also presented in [2], revealing that are fairly typical for the representative households of Greek cities.

In this survey 28% of the households are detached houses, 6.5 % are maissonettes, 6.5% are double houses and 59 % apartments. A characteristic of main significance, considering the retrofitting options is the position of the household in the building envelope [2]. An overwhelming majority of households in apartments, namely 75 %, does not have a Pylotis, whereas as 25 % does. Furthermore, the majority of the sample does not have an attic, according to the typology of a typical block of flats in Greece [2]. The mean number of floors per building is three and more specifically 9 % has only one floor, 25% two, in 5 % three, whereas 31% has more than four floors per building. The mean floor area is 125 m^2 and households with surface less than 50 m^2 and 100 m^2 constitute 3% and 38 % of the sample, whereas the majority has an average surface of 163 m^2. Thus, the occupancy profile is varying from floor to floor. According to the statistical analysis the mean year of construction is 1980 with a dispersion analyzed in Fig. 1. The majority of the buildings, i.e. 53 % is constructed before the implementation of the Thermal Insulation Regulation in 1979, hence is uninsulated. Furthermore, it is shown that the most intense building period lies between 1970 and 1990 [2].

TABLE I. Main Characterstics of the Examined Households

Characteristics	Mean value
Number of floors per building	3.06
Year of construction	1979.5
Floor are in m^2 of the household	125.38
Inhabitants per 100 m^2	2.41

Another important parameter is the number of inhabitants per dwelling. In this analysis, 31.25 % refer to couples followed by families with four members (28.1 %). Households with three members and more than four members concern the 18.75 % and 12.5 % of the sample, whereas only 9.3 % is one-member households. The mean number of the inhabitants is 3.03 related to the mean floor area of 125.38 m^2. Therefore, the corresponding mean number of inhabitants per 100 m^2 is 2.41 for the examined sample, a value way too small from the corresponding number foreseen by KENAK [5], i.e. 5 but closer to the value of inhabitants calculated in [2], i.e. 3.04.

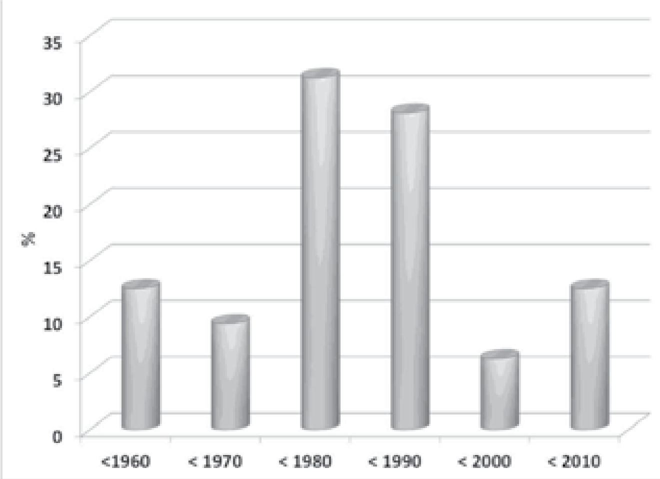

Figure 1. Histogram of construction building year

B. Heating systems

From the participating households only 31 % of the households use oil-fired central systems as the main heating source. The majority of the households is heated by central gas-fired systems, while a 9 % of the sample uses an individual gas system. Thessaloniki was the first city in Greece where natural gas was first introduced in 2002 [2]. Considering the rest answers less than 5 % uses heating oil boilers or air heaters and only an approximate of 9 % of the dwellings use heat pumps. Therefore, from the above analysis it is observed that central heating in general is the most common heating system in residential buildings as also confirmed by the results occurred in [2]. Furthermore, the heating systems age is 6-10 years and the average maintenance period is 1.5 years.

According to the pre- and post-retrofit categorization heating systems use is analyzed in Figure 2. Considering the central heating results are practically the same for the two groups. However, the use of heat pumps and local gas systems is significantly higher in the post retrofit group, while hot air heaters and local heating oil systems are mostly preferred in the pre-retrofit group.

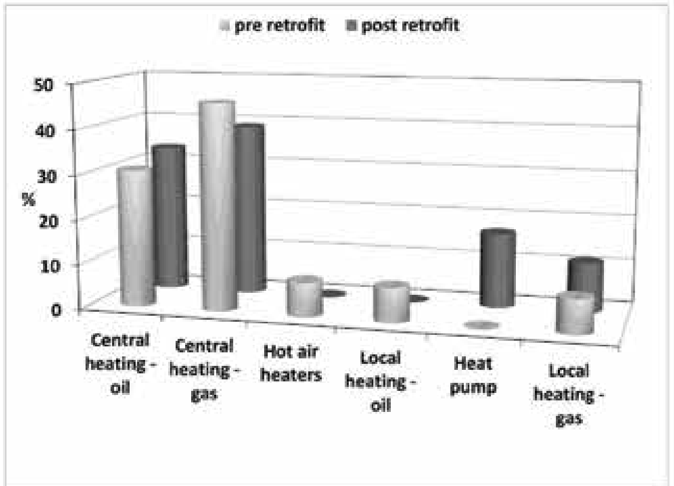

Figure 2. Household heating systems. Pre- and post-retrofit analysis.

Furthermore, from the participating households 58 % use additionally an auxiliary heating system apart from the main one. The different types of the auxiliary systems used are presented in detail in Figure 3, where it is shown that the most favorable are heating pumps and the fireplace. The majority of these systems (29 %) operate on average 3-5 hours per day, while next 13 % of them operate less than 2 hours.

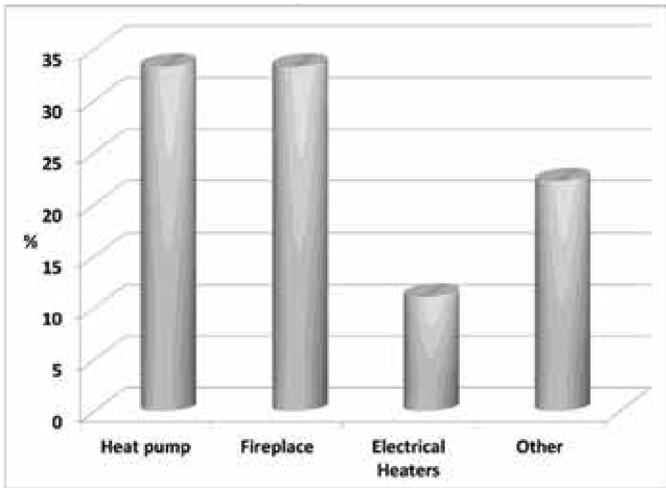

Figure 3. Auxiliary heating systems.

C. Space cooling systems

Buildings in urban areas are of particular interest, since the increased cooling demand, due to high outdoor pollution and the urban heat island effect encourage the use of air conditioning with a direct impact on the electrical energy consumption [3], [4]. This is more intense during the noon hours, where also the peak of the electrical load demand is recorded.

In the pre-retrofit group 61.5 % of the participants use an air-conditioning (A/C) system, while the rest 38.5 % uses either roof or portable fans or does not have any cooling or ventilation system installed. In the post retrofit group the percentage of the households that uses a cooling system is significantly higher, i.e. 83.33%, while only 16.66 % is not supported by a mechanical cooling system.

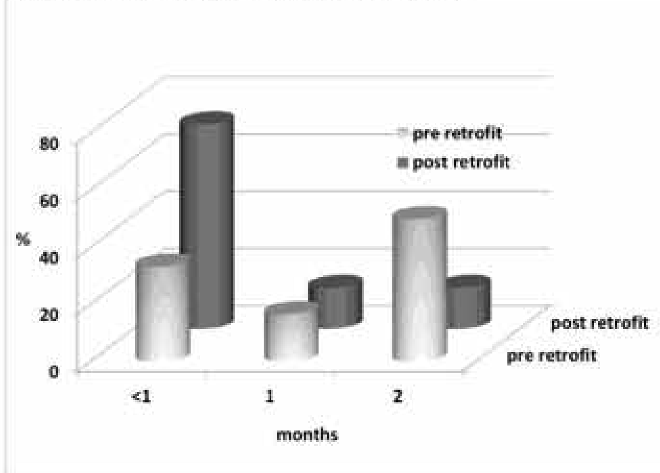

Figure 4. Months of operation of the A/C system during the summer.

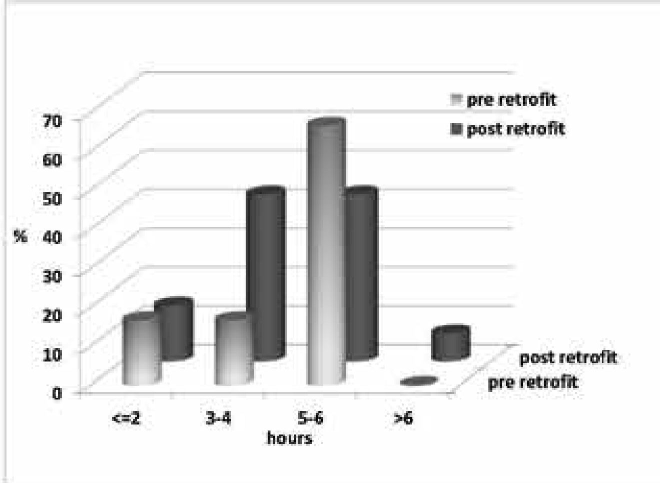

Figure 5. Average hours of operation per day of the A/C system.

In Figures 5 and 6 the distribution of answers to the questions '*How many months was operating the main cooling system during last summer?*' and '*How many hours per day was operating in average the main cooling during the last use period?*' are presented, respectively. Results are analyzed in pre- and post-retrofit groups. Finally, in the investigated sample the average rated power of A/C systems is 16,815 BTU/h and almost 50 % of them is equipped with an inverter system.

D. Domestic hot water

Considering the domestic hot water, results are categorized according to the period of use. In Figures 6 and 7 results are presented for the winter and the summer period, respectively. The majority of the post retrofit households uses both in winter and summer as a primary system a solar water heater. The corresponding needs during days with low solar radiation is covered by auxiliary systems, such as electricity, boilers, etc. More specifically, 77.8 % of the post retrofit households have an auxiliary hot water system, while the corresponding percentage for the pre-retrofit group is significantly lower at 28.5 %

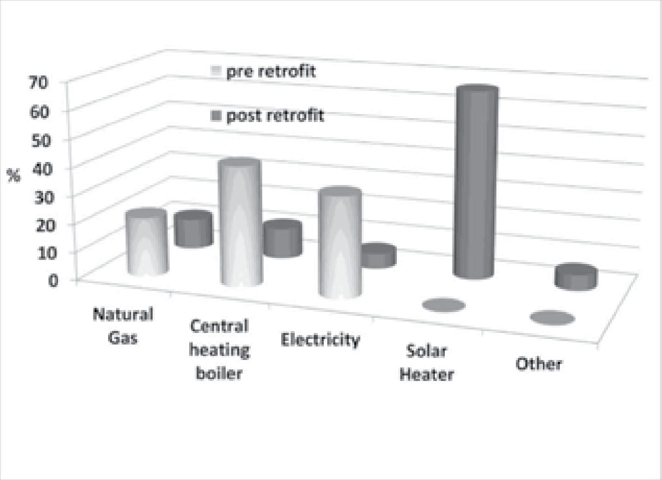

Figure 6. Primary system during winter.

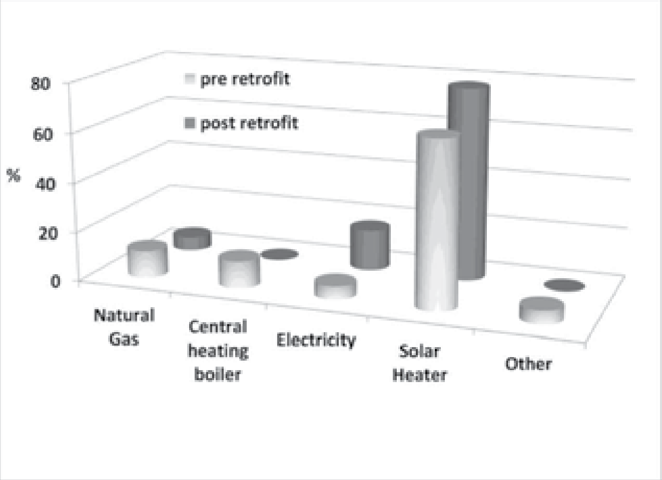

Figure 7. Primary system during summer.

E. Electricity

The majority of the households (60 %) has a three-phase electricity supply, while the rest are single-phase. In Figure 8 the distribution of the number of electrical devices in the examined sample is presented. Results reveal that 21.9 % of the households have two personal computers (PCs), whereas 12.5 % is equipped with more than two PC units. Since, PCs can operate on stand-by mode, the above results reveal significant possibilities for electrical energy waste elimination.

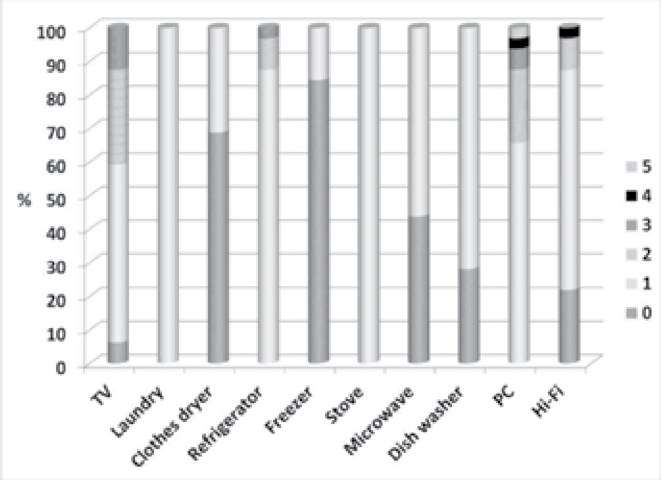

Figure 8. Electrical devices in the household.

IV. Conclusion

In this paper initial results are presented regarding the energy performance of households already retrofitted and intending to retrofit in the near future. Differences between the two household groups are observed and analyzed. This work is conducted in the framework of the research project '*Countdown to Low Carbon Homes*'.

Acknowledgment

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Energy Audits in Public Buildings

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***Abstract*— - A first step towards sustainable development and environmental protection is the carbon footprint estimation of buildings and the evaluation of their potential to decrease energy consumption. In this paper, the first step for decreasing energy consumption in public buildings is described: the energy audits with in-situ measurements. The required equipment, the procedure, the difficulties during the audits and the final results are presented.**

Index Terms **– Energy Audit, energy consumption, in-situ thermal conductance measurements, thermography.**

I. Introduction

The municipalities of Prespes and Resen belong to Region of Western Macedonia, Greece and Region of Pelagonia, the former Yugoslav Republic of Macedonia respectively. They are situated in an area of very cold climate where winters can last for up to nine months. Thus, there is a huge consumption of energy to cover mainly heating requirements. However, the only available fuels for heating are diesel and wood and in lesser degree the locally extracted lignite, which contribute to the pollution of the area significantly. Additionally, due to economical crisis in Greece, the tax over fuel prices increased considerably, turning heating expenses an extremely heavy economical burden for the local population. It is worth mentioning that in winter 2011/12, 50 % of the households in the region of Western Macedonia stopped purchasing diesel as heating fuel and adopted cheaper alternative heating methods.

The above facts indicate that common cross-border action could strengthen the weak co-operation of the two regions on environmental protection aspects. It could also offer to the local population valuable knowledge on best practices and experiences in energy efficiency in buildings.

The project "Promotion of Energy Efficiency in Buildings and Protection of the Environment" is an example of common cross-border actions on energy efficiency and environmental protection issues. It was approved under the 2nd call of proposals of the "Greece-the former Yugoslav Republic of Macedonia IPA Cross-Border Programme 2007-2013". Its technical part includes the detailed energy audit of 50 public buildings (25 at each region). It also includes the study and implementation of energy efficiency and renewable energy technologies at three of the above buildings (2 in Greece and 1 in the former Yugoslav Republic of Macedonia). The aim is to make these buildings almost zero-emission buildings.

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In this paper, the targeted buildings, the required equipment, the procedure, the difficulties during the audits and representative results are presented.

II. Description of the Buildings, the Required Equipment and Procedure

The 50 public buildings are mainly schools, municipality buildings, libraries, etc. A representative building from the 25 of the Greek area is the Primary school of Agios Germanos-Prespes Municipality (Fig. 1). On the other hand, a representative building from the 25 of the former Yugoslav Republic of Macedonia area is the Resen Highschool, Resen Municipality (Fig. 2). Both schools are also the two of the three buildings that will be submitted to energy efficiency improvements. These buildings incorporate almost all the characteristic differences between the buildings at the two areas: The public buildings of the former Yugoslav Republic of Macedonia area are enormous, at least two-floored and uniform, regarding their building materials. No major interventions were applied since most of the buildings at this area were declared protected. On the other hand, the public buildings of the Greek side are much smaller, but they have been damaged and rebuilt or expanded at least once. These special characteristics have played an important role at the energy audit procedure and duration of the public buildings, even at the determination of the required equipment.

More specifically, since most of the in-situ measurements require cold weather (at least 10 degrees Celsius between the ambient and the building heated rooms), all 50 buildings have to be measured in two-winter periods, regardless of their size and in-homogeneities. Thus, the equipment that can be used in practice during the energy audits at the 50 public buildings includes:

- Photography camera with video capture option.
- IR camera with an option of concurrent image saving of IR and real pictures under the same name.
- Distance-meter.
- Thermal conductance measurements device (i.e. Hukseflux TRSys 01)
- Notebook with installed interface of the IR camera and the thermal conductance measurement device.
- GPS device
- Laser mini temperature meter.
- Humidity meter

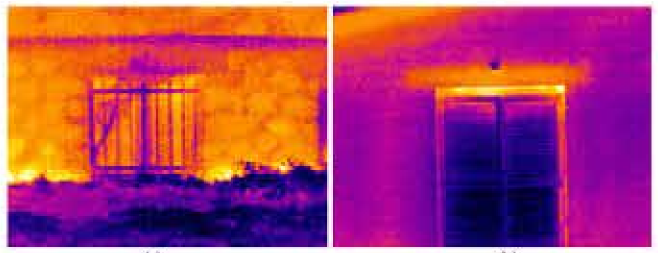
- Light meter (Lux)
- Digital waste gas analyzer

Fig. 1: The primary school in Agios Germanos - Prespes.

Fig. 2: The High-school at Resen.

Since no plans exist for most of the buildings, the energy audit procedure includes architectural measurements in order to develop the plans of the buildings.

Then, the building is scanned with the IR camera from the outside. It is recommended to scan the building from the inside too. This way, the thermal bridges that need to be captured with the IR camera, because they cannot be defined by the architect plans are detected. In Fig. 3 two representative IR pictures are shown. The first one is the wall of the ground floor of the Agios Germanos school, where the stones are very clearly distinguished. Sometimes, the number of thermal conductance measuring points is defined by the thermography of the building. However, the latter is defined mainly by the history of the building.



(a) (b)

Fig. 3: IR pictures of Agios Germanos school and Kindergarden

For example, the Primary School of Agios Germanos was build using stone in 1922. The two floors were destroyed in 1946-49 and it was rebuilt using small, compact, solid brick in 1955. It was expanded to include toilettes in 1974 using armed concrete and another brick arrangement. Thus, for this school, at least three thermal conductance measurements sets are needed. On the other hand, the Highschool in Resen appears to be uniform and despite its size, only one measurement set is required. In Fig. 4 the arrangement of the thermal flow measurement sensors are presented in two actual cases.

Fig. 4: Thermal flow measurement sensors in action.

Next, the heating system efficiency is estimated by the digital waste gas analyzer, the IR-camera scanning of the heating unit and the grid. In Fig. 5, IR shots by a typical heating unit and the procedure for the application of the waste gas analyzer are shown.

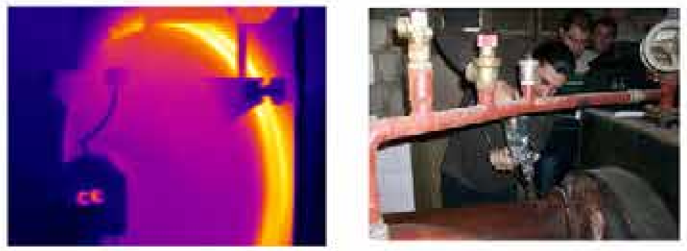


Fig. 5: Heating system efficiency estimation measurements.

III. Difficulties During the Energy Audits and Measurements Processing

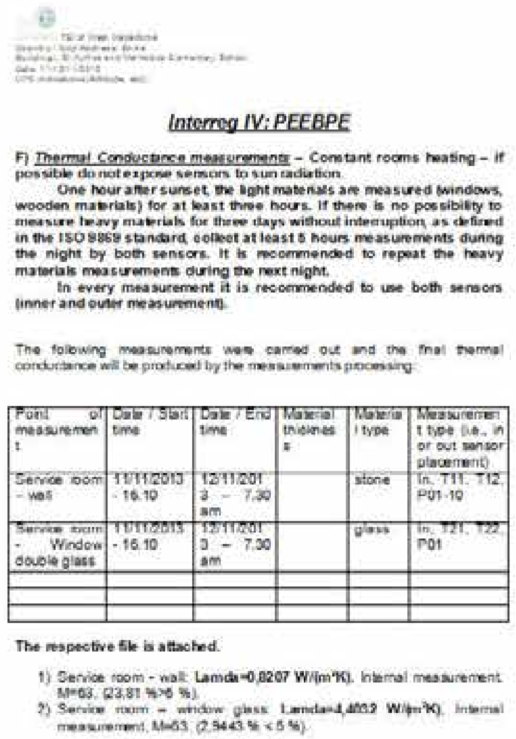
One of the most common problems that the teams had to face during the energy audits is the refusal of most buildings managers to keep the heating on during the measurements. In other cases, the heating system was inactive, since the buildings were not used at the specific period. This usual problem had negative effects to the thermography and the thermal conductance measurements procedure.

The next most common problem was the refusal to proceed to the waste gas analyzer application, since this requires drilling at two points of the waste gas pipe.

Another usual difficulty was the absence of datasheets of fuel consumption of previous years, especially when the fuel was wood, or when the same heating system was used for the energy needs of two adjacent buildings. This led to approximations of previous years' fuel consumption.

IV. Results

During the energy audits on-site measurements, datasheets designed specially for the project had to be filled. These sheets are organized in 7 categories: (1) *Architectural lay-out*, which contains information regarding the surroundings of the building, the total outer surface, volume, surface per material, etc, (2) *Building history and current usage*, (3) *Thermography*, in order to determine the thermal bridges that need to be captured with the IR camera, because they cannot be defined by the architect plans and the number of thermal conductance measuring points, (4) *Thermal bridges*, which includes IR pictures, (5) *Thermal conductance measurements*, which includes the thermal conductance coefficient calculation by in-situ measurements, (6) *The central heating source of the building*, which also includes measurements by the waste gas analyzer, (7) *The heating grid*, which includes estimation of pipes, radiators, boilers, (8) *Electricity consumption*, which includes devices and lighting recording, (9) *Solar collectors, PV panels*. An example is shown in Fig. 6.



Interreg IV: PEEBPE

F) Thermal Conductance measurements – Constant rooms heating – if possible do not expose sensors to sun radiation.

One hour after sunset, the light materials are measured (windows, wooden materials) for at least three hours. If there is no possibility to measure heavy materials for three days without interruption, as defined in the ISO 9869 standard, collect at least 5 hours measurements during the night by both sensors. It is recommended to repeat the heavy materials measurements during the next night.

In every measurement it is recommended to use both sensors (inner and outer measurement).

The following measurements were carried out and the final thermal conductance will be produced by the measurements processing:

Point of measurement	Date / Start time	Date / End time	Material thickness	Material type	Measurement type (i.e., in or out sensor placement)
Service room – wall	11/11/2013 - 16.10	12/11/2013 – 7.30 am		stone	In, T11, T12, P01-10
Service room – Window double glass	11/11/2013 - 16.10	12/11/2013 – 7.30 am		glass	In, T21, T22, P01

The respective file is attached.

1) Service room - wall: Lamda=0,8207 W/(m²K). Internal measurement. M=63. (23,81 %>5 %).
2) Service room – window glass: Lamda=4,4652 W/(m²K). Internal measurement, M=63. (2,9443 % < 5 %).

Fig. 6: Example of the energy audits datasheets.

After filling the datasheet for each building, processing of the data is necessary before proceeding to the Energy Efficiency Certificate (EEC) Issuance. First of all, the in-situ measurements by the thermal conductance sensors have to be processed by a Matlab algorithm that is developed specially for the project and implements the Dynamic Analysis Method, according to ISO 9869 [1]. The software derives the thermal conductance coefficient Lamda (W/m^{2}K) and is shown in Fig. 7.

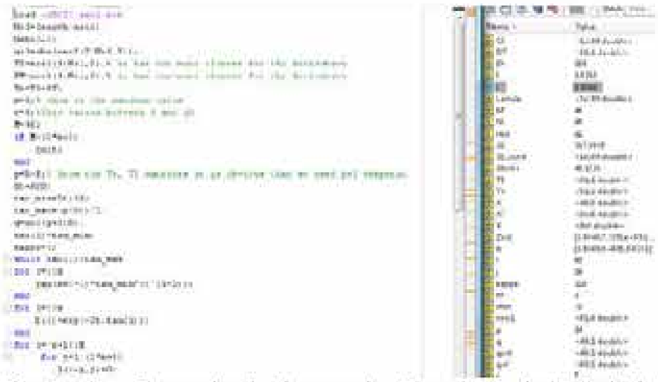


Fig. 7: The software that implements the Dynamic Analysis Method of ISO9869.

The next step is to insert all the data (Architect plans and data, thermal conductance coefficients, thermal bridges dimensions, electromechanical data) from the datasheets to special software that derives the EEC. The most common is the one that is developed by the Technical Chamber of Greece (TEE-KENAK) [2]. The EEC of the Primary school of Agios Germanos is shown in Fig. 8.

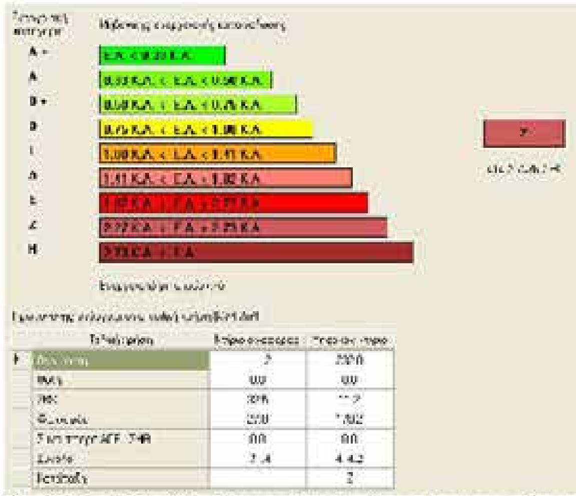


Fig. 8: The EECs of the Primary school in Agios Germanos-Prespes-Greece.

In Fig. 8, it is shown that the school belongs to category Z, in terms of Energy Efficiency and the current energy consumption data are shown at the right-hand side column of the table.

However, the following interventions can upgrade this school from Z class to B+, as shown at the EEC of the same building, after the application of the interventions.

- Installation of external thermal insulation – thickness 10cm.
- Redesign and construction of the heating network.
- Heat pump water-air.
- Installation of a smart heating management system

(developed by the Technological Educational Institute of Western Macedonia)

- Replacement of illuminants with type led.
- Building energy management system (KNX).

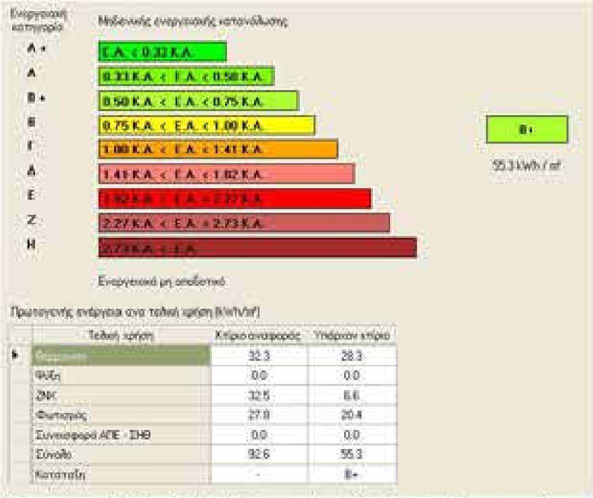


Fig. 9: The EECs of the Primary school in Agios Germanos-Prespes-Greece after the interventions.

It can be observed by comparing Fig. 8 and Fig. 9, that energy saving up to 90 % will be achieved. The application of the building's upgrade will take place during spring 2014.

V. Conclusions

In this paper, the first step for decreasing energy consumption in public buildings is described: the energy audits with in-situ measurements. The required equipment, the procedure, the difficulties during the audits and the final results are presented. Energy saving up to 90 % will be accomplished after the upgrade of the pilot buildings from class Z to class B+.

The results of this project will certainly form the basis for the improvement of the existing buildings and the designing and construction of future buildings in the region and will provide incentives for the reduction of the energy wastage of the country's public buildings. An adjacent benefit by the project, which can act as an incentive for other authorities too is the following: The issuance of Energy Certificates constitutes the buildings of the Municipality of Prespes directly exploitable.

VI. Acknowledgements

The described work is funded by the PEEBPE project, which is executed in the framework of the "Greece-the former Yugoslav Republic of Macedonia IPA Cross – Border program 2007-2013".

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Optimization-based Active Techniques for Energy Efficient Building Control Part I: Optimization Algorithms

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***Abstract*— Building Optimization and Control (BOC) deals with the deployment of *active techniques*, aiming at efficiently controlling the active elements of a building (HVACs, concrete activation elements, etc.): these techniques can result in tremendous energy savings, without the need for passive expensive solutions (new materials for passive insulation, the use of glass facades etc.). In this paper, we present a new approach for BOC system design - abbreviated as PCAO – with the following attributes: (i) providing extremely fast and in a "plug-n-play" fashion an efficient BOC system no matter how large-scale and complex the building is (ii) rapidly and efficiently adapting and calibrating itself so as to "quickly learn the best BOC policy" even in the case where a poor or no model for the building dynamics is available. This paper mainly deals with the algorithmic details of the proposed approach: real-life results coming from the application of PCAO in two large scale buildings are presented in a companion paper (part II: real-life experimental results).**

***Index Terms*-- Green buildings, large scale systems control, efficient building climate control.**

I. Introduction

The construction of new materials for passive insulation, the installation of internal "climating" appliances, the use of glass facades etc. are examples of *passive techniques* adopted to decrease the annual energy consumption of a building. However, redesigning or reconstructing parts of an existing building is a costly procedure that usually creates permanent damage to the insulation or the stability of the whole construction. *Building Optimization and Control (BOC)* deals with the deployment of *active techniques* aiming at efficiently controlling the active elements of a building (HVACs, concrete activation elements, etc.): these techniques can result in tremendous energy savings in everyday buildings, without the need for passive expensive solutions. Both extensive simulation studies and - most importantly - evidence from real-life applications indicate that the energy savings that can result from efficient and properly functioning BOC systems can be as large as 20-50% [1,2].

Unfortunately, the current state-of-the-art requires a tedious, and "expensive" design and calibration phase of the BOC system in order to provide the aforementioned savings. For instance, in the case where *a Building Energy Performance Simulation (BEPS) model for the building is available, the current state-of-the-art requires a tedious design phase involving extensive and time-consuming simulation and calibration tests using different choices for the BOC system parameters*. Attempts to apply "plug-n-play" techniques - through e.g., Model-Based, Model Predictive Control (MPC) [3-6] or Co-simulation [7-9] and implementation of popular Optimizers [10-13] - are not able to produce an efficient BOC system for buildings of medium or large size, due to dimensionality issues.

In addition to the problems in developing rapid and efficient BOC system designs using BEPS model, another important drawback *is the inability of the existing approaches to automatically calibrate the BOC system in real-time so as to be able to rapidly and efficient deal with the inevitable BEPS modeling inaccuracies and the variations of the building dynamics*. In fact, no matter how elaborate and detailed, no BEPS model can perfectly capture all the building dynamics. Additionally, minor or major changes in the building infrastructure, ageing and other factors render BEPS models more and more inaccurate as time elapses. Most importantly, in the vast majority of buildings, only a "rough" or no BEPS model is available. For all these reasons, *the BOC system needs to be embedded with powerful automatic calibration (adaptation) attributes that will render it capable of rapidly, efficiently and safely adapting and calibrating itself so as to "quickly learn the best BOC policy" even in cases where a poor or no BEPS model is available*

Embedding automatic calibration attributes in existing BOC design approaches is typically problematic, especially when it comes to BOC systems of large size: automatic calibration and adaptation approaches are known to work well only in small size problems [14-18].

In this paper, we present PCAO (P-Cognitive Adaptive

Optimization), a new approach that overcomes the above mentioned shortcomings of existing approaches for BOC system design. The approach is based on an adaptive algorithm aiming at solving the Hamilton-Jacobi-Bellman equation associated with the optimal control problem. PCAO, which originally proposed and analyzed for the control design of general systems [19-22], possesses the following two main features when it comes to its application for BOC system design:

1. ***BEPS-based PCAO***: In case a BEPS model is available, PCAO provides an efficient BOC system design based on this model, *no matter how elaborate, large-scale or complex the BEPS model is*. Contrary to other existing model-based tools, *PCAO accomplishes the BOC design extremely fast even in cases where state-of-the-art approaches totally fail* due to the large-scale nature and the complexity of the problem. Moreover, PCAO is of *"plug-n-play" nature,* driven by the measurements of the BEPS model, without requiring any preparatory analysis, calibration, interfacing, etc (see Table I).
2. ***Fully-Adaptive PCAO***: Most importantly, PCAO can provide with efficient and robust performance even in cases where *a very poor of even no BEPS model is available*. By employing its intrinsic self-adaptation mechanisms, *PCAO automatically and in real-time tunes itself so as to rapidly, efficiently and safely optimize BOC performance* (see Table II).

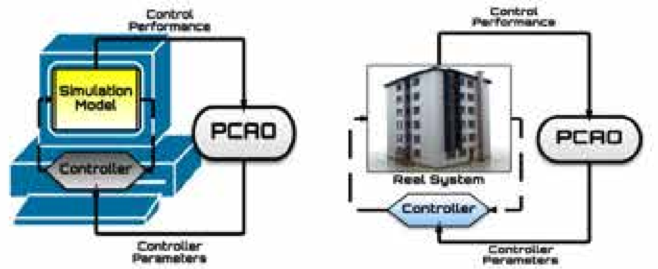

Figure 1. PCAO for BEPS-based control design (left) and Fully-Adaptive control design (right).

II. PCAO for BOC System Design

The basic structure of the BOC employed within the PCAO approach is shown in Figure 2: the BOC system of Figure 2 comprises of a set of *L linear controllers* and a *mixing scheme*. The mixing scheme is used to smoothly mix the control signals from the different controllers, according to *exogenous building operating conditions* (e.g., for different values of the ambient temperature). The use of different linear controllers around different operating conditions [23-25] reduces substantially the complexity of BOC system design: mathematically speaking, choosing a mixing scheme that depends only on the ambient temperature (T_{amb}) as follows:

$$\beta_i(T_{amb}) = \frac{e^{-\frac{(T_{amb}-\mu_i)^2}{2\sigma^2}}}{\sum_{j=1}^{L}\beta_j(T_{amb})}$$

where μ_i, σ denote the center and the width of the i-th mixing signal, exhibited efficiency in building applications. Typically, μ_i are chosen so as the mixing signals are spread uniformly over the ambient temperature range and σ is chosen so as there as is 30% overlapping between the mixing signals.

PCAO achieves to successfully deal with such a high--dimensional, complex optimization problem by suitably combining two different "ingredients":

- The so-called CAO approach [22], an adaptive optimization approach which is capable of rapidly and with minimum computational burden provide solutions to high-dimensional, complex control-related optimization problems. It is emphasized that the CAO approach has been successfully implemented in a variety of real-life control-related optimization problems including automated fine-tuning of large-scale traffic control systems [19] and control of swarms of unmanned aerial or underwater vehicles [20].
- A new control design approach [26] whose key-idea is to use the well-known in optimal control theory Hamilton-Jacobi-Bellman (HJB) equation [28] which, for each set of control parameters, can provide with a measure of how far these parameters are from their optimal values. Using such a measure and by appropriately enhancing CAO, the PCAO approach has been developed and analyzed in [27]. Contrary to existing control design approaches which update the control parameters so as to improve the overall performance of the system, PCAO updates the control parameters so as they "come" closer to their optimal values as dictated by the HJB equation.

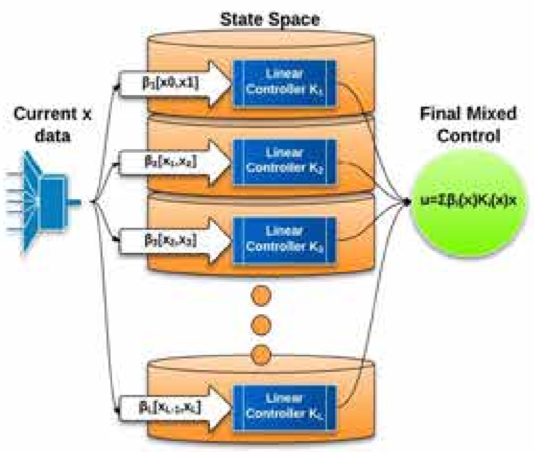

Figure 2. PCAO BOC system structure (x is the vector comprising the current sensor data and weather/occupant data measurements and forecasts).

III. BEPS-based and Fully adaptive PCAO

In the case of *BEPS-based PCAO*, the BEPS model of the system is connected to the controller of Figure 1 and PCAO updates the parameters of the controller by evaluating them through the use of the BEPS model by employing a *co-simulation approach*. More precisely:

(a) for each PCAO's choice of controller parameters, the closed-loop system is simulated under different scenarios

Table I. BEPS based PCAO algorithm

Initialize.

i. Set $k=0$. Let also T denote the simulation time of the overall *simulation period*.

ii. Choose positive constants $\varepsilon_1<\varepsilon_2$ and positive integers N, T_h.

iii. Initialize $\hat{P}(0)$ to be a positive definite matrix satisfying the constraints $\varepsilon_1 \le \hat{P}(0) \le \varepsilon_2$.

iv. Choose a positive scalar function $a(k)$ satisfying

$$a(k)>0,\ \lim_{k\to\infty} a(k)=0,\ \sum_{k=0}^{\infty} a(k)=\infty,\ \sum_{k=0}^{\infty} a^2(k)<\infty$$

[The reader is referred to [19], [20], [22] on guidelines for the choice of N; T_h; $a(k)$ as well as of the LIP estimator in Step 2; also in [26] guidelines are provided on the choice of the constants ε_1, ε_2].

Step 1. Apply the controller $\hat{u}=-B'M_z(x)\hat{P}(k)z(x)$ for the next *simulation period* and calculate:

$$\varepsilon\left(x(t),\hat{P}(k)\right)=\Delta\hat{V}(t)+\int_t^{t+\delta t}\Pi\left(x(s)\right)ds \text{, and}$$

$$E\left(\hat{P}(k)\right)=\sum_{t=0}^{T}\varepsilon^2\left(x(t),\hat{P}(k)\right) \text{ where}$$

$$\hat{P}(k)=\begin{bmatrix} P_1 & 0 & \dots & 0\\ 0 & P_2 & & 0\\ \dots & & \dots & 0\\ 0 & 0 & 0 & P_L \end{bmatrix},\ z(k)=\begin{bmatrix}\sqrt{\beta_1(x(k))}x(k)\\ \sqrt{\beta_2(x(k))}x(k)\\ \dots\\ \sqrt{\beta_L(x(k))}x(k)\end{bmatrix},$$

$$d\hat{V}(k)=z^T(k+1)\hat{P}(k)z(k+1)-z^T(k)\hat{P}(k)z(k)$$

Step 2. Construct a linear-in-the-parameters (LIP) estimator of $E\left(\hat{P}(k)\right)$ as follows:

$$\hat{E}\left(\hat{P}(k)\right)=\theta'\phi\left(\hat{P}(k)\right)$$

$$\theta=\arg\min_{\vartheta}\sum_{i=k-T}^{k}\left(E\left(\hat{P}(i)\right)-\vartheta'\phi\left(\hat{P}(i)\right)\right)^2$$

where φ,θ are the regressor vector and the parameters vector of the estimator and $T=\min(k,T_h)$.

Step 3. Calculate the best $\hat{P}$ obtained so far from all the previously applied to the model,

$$P_{best}(k)=\arg\min E\left(\hat{P}(s)\right), s=0,1,\dots,k$$

Step 4. Generate N perturbed candidates *(random perturbations)* of $P_{best}(k)$ as follows:

$$\hat{P}^{(i)}_{cand}=\left(1-a(k)\right)\hat{P}_{best}(k)+a(k)\Delta\hat{P}^{(i)}, i=1,2,\dots,N$$

where $\Delta\hat{P}^{(i)}$ are random block diagonal matrices where the diagonal elements are symmetric positive definite matrices satisfying $\varepsilon_1 \le \Delta\hat{P}^{(i)} \le \varepsilon_2$.

Step 5. The controller $\hat{P}(k+1)$ to be applied for the next simulation period, is:

$$\hat{P}(k+1)=\arg\min\hat{E}\left(\hat{P}^{(i)}_{cand}\right), i=0,1,\dots,N$$

Step 6. Set $k=k+1$ and GO TO **Step 1.**

Table II. Fully-Adaptive PCAO algorithm

Initialize.

i. Set $k=0$. Let also T denote the application time of the overall *experimental period*.

ii. Choose positive constants $\varepsilon_1<\varepsilon_2$ and positive integers N, T_h.

iii. Initialize $\hat{P}(0)$ to be a positive definite matrix satisfying the constraints $\varepsilon_1 \le \hat{P}(0) \le \varepsilon_2$.

iv. Choose a positive scalar function $a(k)$ satisfying

$$a(k)>0,\ \lim_{k\to\infty} a(k)=0,\ \sum_{k=0}^{\infty} a(k)=\infty,\ \sum_{k=0}^{\infty} a^2(k)<\infty$$

[The reader is referred to [19], [20], [22] on guidelines for the choice of N; T_h; $a(k)$ as well as of the LIP estimator in Step 2; also, in [26], guidelines are provided on the choice of the constants ε_1, ε_2].

Step 1. Apply the controller $\hat{u}=-B'M_z(x)\hat{P}(k)z(x)$ for the next *simulation period* and calculate: $\varepsilon\left(x(k),\hat{P}(k)\right)=\Delta\hat{V}(k)+\int_{k-1}^{k}\Pi\left(x(s)\right)ds$,where

$$\hat{P}(k)=\begin{bmatrix} P_1 & 0 & \dots & 0\\ 0 & P_2 & & 0\\ \dots & & \dots & 0\\ 0 & 0 & 0 & P_L \end{bmatrix},\ z(k)=\begin{bmatrix}\sqrt{\beta_1(x(k))}x(k)\\ \sqrt{\beta_2(x(k))}x(k)\\ \dots\\ \sqrt{\beta_L(x(k))}x(k)\end{bmatrix},$$

$$d\hat{V}(k)=z^T(k+1)\hat{P}(k)z(k+1)-z^T(k)\hat{P}(k)z(k)$$

Step 2. Construct a linear-in-the-parameters (LIP) estimator of $\varepsilon\left(x(k),\hat{P}(k)\right)$ as follows:

$$\hat{\varepsilon}\left(x(k),\hat{P}(k)\right)=\theta'\phi\left(\hat{P}(k)\right)$$

$$\theta=\arg\min_{\vartheta}\sum_{i=0}^{k}\left(\varepsilon\left(x(i),\hat{P}(i)\right)-\vartheta'\phi\left(\hat{P}(i)\right)\right)^2$$

where φ,θ are the regressor vector and the parameters vector of the estimator and $T=\min(k,T_h)$.

Step 3. Generate N perturbed candidates *(random perturbations)* of $\hat{P}(k)$ as follows:

$$\hat{P}^{(i)}_{cand}=\left(1-a(k)\right)\hat{P}(k)+a(k)\Delta\hat{P}^{(i)}, i=1,2,\dots,N$$

where $\Delta\hat{P}^{(i)}$ are random block diagonal matrices where the diagonal elements are symmetric positive definite matrices satisfying $\varepsilon_1 \le \Delta\hat{P}^{(i)} \le \varepsilon_2$.

Step 4. Obtain $\hat{\varepsilon}^{(i)}\left(x(k),\hat{P}^{(i)}_{cand}\right)$ using the estimator form Step

The controller $\hat{P}(k+1)$ to be applied for the next iteration, is:

$$\hat{P}(k+1)=\arg\min\hat{\varepsilon}\left(x(k),\hat{P}^{(i)}_{cand}\right), i=0,1,\dots,N$$

Step 5. Set $k=k+1$ and GO TO **Step 1.**

(e.g., simulating the controller for many days with different weather characteristics) so as to make sure that the optimized controller is able to efficiently handle many different possible real-life situations;

(b) a quantitative performance measure is provided by the BEPS model so as to be able to evaluate the efficiency of the closed-loop system under the aforementioned choice;

(c) such a quantitative measure is then used by PCAO in order to update the controller parameters.

Steps (a)-(c) are repeated until no further improvement in the BOC system performance is obtained.

In the case of *Fully Adaptive PCAO*, the actual building is connected to the BOC system and PCAO adapts/tunes the parameters of the controller by evaluating them on the actual building. Contrary to BEPS-based PCAO where the evaluation was accomplished by employing simulations, in the case of Fully-Adaptive PCAO, the real sensor measurements from the building are used in order to evaluate the BOC system performance. By using this evaluation, the Fully Adaptive PCAO updates the controller parameters at each controller time-step (i.e., every 10-15 minutes).

IV. Results

This paper presented a new approach for BOC system design - abbreviated as PCAO. The approach is based on an adaptive algorithm aiming at solving the HJB equation associated with the optimal control problem. Two versions of the PCAO algorithm have been exposed. Experimental results, coming from the application of PCAO into two large scale buildings, show extremely fast convergence and rapid and efficient adaptation. Due to lack of space, such results are presented in a companion paper (part II: real-life experimental results).

V. Acknowledgments

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Optimization-based Active Techniques for Energy Efficient Building Control Part II: Real-life Experimental Results

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***Abstract*— In this paper the experimental results coming from the application of a novel Building Optimization and Control (BOC) technique in two different large-scale buildings are exposed. This novel BOC technique, described in a previous companion paper (part I: optimization algorithms) and denominated as PCAO, shows (i) its ability to provide extremely fast and in a "plug-n-play" fashion an efficient BOC system no matter how large-scale and complex is the building and (ii) its ability to rapidly and efficiently adapt and calibrate itself so as to "quickly learn the best BOC policy" even in the case where a poor or no model for the building dynamics is available. It has to be emphasized that the two different buildings where the PCAO approach is applied and evaluated correspond to "difficult to control buildings", i.e., efficient BOC system design for these two buildings is significantly more complex than that of an "average building".**

***Index Terms*-- Green buildings, large scale systems control, efficient building climate control.**

I. Introduction

Below, we provide details of real-life experiments conducted in two large-scale buildings, using the PCAO-based BOC system. The PCAO strategy and algorithm has been exposed in a companion paper: this paper focuses on experimental results. It has to be emphasized that the two buildings that have been used for experiments are very different one another. First of all, they belong to different weather zones (Greece and Germany). Besides, they consider two opposite control problems, efficient cooling during Greek summer, and efficiently warming during German winter. Finally, the two buildings have been constructed according to very different construction criteria: the Greek building is a conventional building with no passive techniques for insulation; the German building is a new generation building employing many passive techniques for insulation, natural ventilation, etc. For these reasons, demonstrating the performance of the PCAO with such "extreme" environments would be of practical importance in order to assess the efficiency and the applicability of the PCAO-based BOC system. We start the exposition by providing some details on the two Test Cases used. Then the experimental results will be showed, the improvements will be evaluated, and finally some conclusions will be drawn.

Figure 1. Test Case Buildings: Test Case 1 (left) and Test Case 2 (right).

II. Experimental Test Cases

Test case 1: 10-office building (Chania, Greece)

A 10 office building located in Chania at the Technical University of Crete (see Figure 1 on the left) was used for validating the PCAO control strategy. The energy consumption of the specific building is quite high, 130 kWh/m^2, based on energy audits and simulation results. All 10 offices of the building are equipped with indoor temperature, humidity and occupancy sensors as well as split type air conditioning units. A Building Energy Management System (BEMS) has been installed which - by using the office sensors' measurements - can control the set points of the 10 different A/C units. The BEMS system is also connected to a weather station so as to receive measurements about current as well as forecasted weather data. The building is also equipped with a photovoltaic (PV) panel, providing solar energy to the building: the building does not present any energy storage device for the solar energy. An elaborate BEPS model for the building has been developed using EnergyPlus [1,2]. This model was validated using real-life data collected during spring 2010.

Test case 2: 22-office building (Kassel, Germany)

The FIBP Building, built in 2001, located at the campus of the University of Kassel, Germany is an exemplary low-energy building (see Figure 1 on the right). The biggest amount of energy consumption is spent during winter period for heating up the interior offices. FIBP can be considered as a very well equipped building with passive elements for energy saving (thick and well insulated external walls). The FIBP Building is equipped with radiant slabs in the ceilings and floors in every room. Thermostats are used for the activation of the radiant slabs. Finally, as in the case of Test Case 1, a BEMS operates in the building which can control the thermostat set points in each of the offices by using the temperature, humidity and occupancy sensor measurements from each of the offices as well as weather current conditions and forecasts. An elaborate BEPS model for the building has been developed using TRNSYS [3]. This model was validated using real-life data collected during winter 2010.

III. Results from Simulation-Based Experiments

Due to lack of space, the simulation-based results will concentrate mainly on Test Case 1 (Chania building).

Cost Function

The cost function to be minimized by the BOC system is a combined criterion which takes into account the energy consumption and the user comfort:

$$Total_{score} = t * Energy_{score} + (1-t) * Comfort_{score}$$

where $0 < t < 1$ regulates the importance of one term respect to the other. The $Energy_{score}$ is evaluated by reading the actual energy consumption of the building using Wattmeters. For Test Case 1, in order to check if the savings can be significantly higher through a BOC system that implements efficient Demand Shaping (DS) [4,5], two different forms of the $Energy_{score}$ are considered:

1. The $Energy_{score}$ is equal to the total power consumed (*Power without DS*).
2. The $Energy_{score}$ is equal to the total power consumed subtracting the available solar energy from the PV. If the solar energy is greater than the power consumed, then $Energy_{score}$ is zero. (*Power with DS*)

As far as it concerns the comfort score, two different types of $Comfort_{score}$ are considered, namely the "Fanger index",

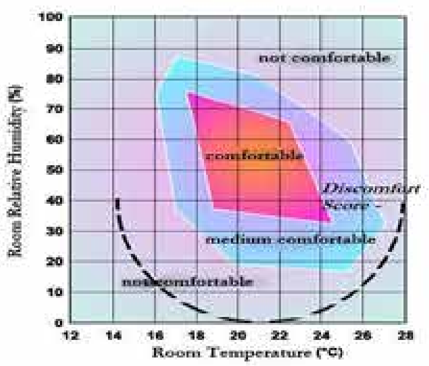

Figure 2. Discomfort score model based on German standards.

which evaluates the Predicted Percent of Dissatisfied people [6] and a second discomfort score that is based on German standards for user comfort (see Figure 2). This second index has been chosen because it can be measured in real-life using only temperature and humidity measurements, while the Fanger index requires additional sensors which are available in the simulation model, but that are not currently installed in the actual buildings.

Best Practice/Base Case BOC

For comparison purposes, the PCAO strategy is compared with rule-based controllers (shortened as RBCs), currently used in the buildings. These RBCs employ simple control strategies, which consist of keeping the HVAC set points constant during the office hours, and turn the HVACs off outside office hours. The Base Case RBCs are as follows:

- For Test Case 1, the RBC that operates the set points at 24°C during office hours (RBC1) and the RBC that operates the set points at 25 °C during office hours (RBC2) were used as the base cases.
- For Test Case 2, the RBC that operates the set points at 21 °C during office hours is the best among all RBCs and is the one that is currently employed in the building.

PCAO BOC system

Contrary to what assumed in many simplified designs, in the PCAO control strategy each zone is not considered independent of the others. In order to identify and respond to inter-zone heat exchange dynamics, every controller's action depends on the whole state vector. The BOC feedback vector also includes some forecasts for the next hours. This is done in order to include in the feedback vector some sort of information regarding the future. Having information of the future is beneficial in the present, in order to apply a smart control action (pre-active control). Summing up, in Test Case 1, the PCAO feedback vector is composed of the following components:

- 3 measurable external weather conditions: outside temperature, outside humidity and solar radiation.
- 6 forecasts for the outside temperature in the next 6 hours.
- 6 forecasts for the solar radiation over the next 6 hours.
- The office temperatures of the offices.
- The office humidities of the offices.

Test Case 2 employs a similar feedback vector, whose dimension is different because of the fact that the FIBP building comprises 22 offices, and because of the fact that the forecasts are made over the next 48 hours (due to the bigger thermal mass of the building).

BEPS-based PCAO

The results of the application to the BEPS-based PCAO to the Chania building are given in Tables I and II. These tables show the PCAO improvements, a typical summer sunny week, with respect to RBC1 (Table I) and RBC2 (Table II). The weight factor t, regulating the balance between the energy and the comfort score was chosen to be 0.5. Two PCAO controllers, the first one obtained with $L=1$ and the second with $L=4$, are compared with both RBCs. It can be concluded that PCAO controller achieves consistent improvements with respect to both RBCs. Both the energy absorbed from the grid and the Fanger index are improved. Figure 3 shows the HVAC set points for all offices, under the PCAO system. A first observation is that PCAO "plays" with such set points, in contrast with the RBCs which keep them constant. The mechanism which lies beneath the PCAO set points leads to reduced energy consumption with satisfactory Fanger. The PCAO controller "plays" with the HVAC set points in an energy-efficient way, so as to shape the energy demand.

Table I. Test Case 1 simulation results (during a typical sunny week)

Simulation Experiment	Power (no DS) [kW]/ Improve [%]	Power (with DS) [kW]/ Improve [%]	Discomfort (Fanger)/ Improve[%]
RBC=24°C	90.2/0%	19.7/0%	10.2/0%
BEPS L=1	82.7/8.3%	10.0/49.2%	6.7/34.3%
BEPS L=4	84.2/6.6%	9.8/50.2%	5.3/48.0%

Table II. Test Case 1 simulation results (during a typical sunny week).

Simulation Experiment	Power (no DS) [kW]/ Improve [%]	Power (with DS) [kW]/ Improve [%]	Discomfort (Fanger)/ Improve[%]
RBC=25°C	78.7/0%	13.5/0%	14.8/0%
BEPS L=1	82.7/-5.1%	10.0/25.9%	6.7/54.7%
BEPS L=4	84.2/-7.1%	9.8/27.4%	5.3/64.2%

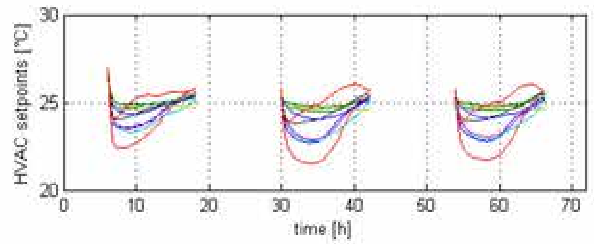

Figure 3. HVAC set points for 3 days for all 10 zones (during office hours).

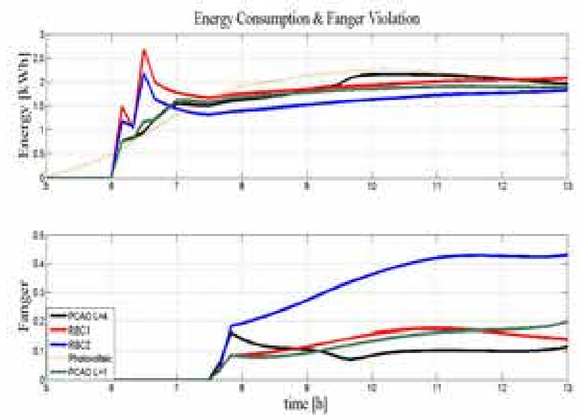

Figure 4. Power Consumption and User Comfort for PCAO and RBC: PCAO achieves to efficiently "shape the demand".

Figure 4 exhibits the result of such an intelligent "demand shaping" mechanism: PCAO achieves to optimally exploit the energy coming from the PV without sacrificing user comfort. Note also that the more complex (larger L) is the PCAO BOC, the better is its demand shaping characteristics: the PCAO controller with $L=4$ achieves better performances than $L=1$ because better demand shaping is achieved.

IV. Results from Real-Life Experiments

Together with simulation-based experiments, real-life experiments have been performed in both buildings. The main findings of these experiments can be summarized in the following points:

1. Rapid, "Plug-n-Play" BEPS-based BOC Design

In order to be able to compare PCAO with state-of-the-art approaches, we have also used a large variety of optimization algorithms (e.g., genetic algorithms, gradient descent, pattern search, fmincon, etc) to accomplish the BEPS-based BOC system design. The results were quite impressive: in both Test Cases, popular optimization algorithms were unable to provide with an efficient BOC design, even after thousands of iterations. On the contrary, PCAO achieved to obtain very efficient BOC systems after a few iterations. Table III summarizes the findings of the comparative evaluation for BEPS-based BOC system design.

2. Substantial energy savings are achieved only through very intelligent and delicate decisions and AGILE is able to "catch" such decisions

Careful inspection of the BOC system decisions in all of the simulation and real-life experiments, reveals that efficient BOC system design is by no means an easy task: an efficient BOC system must be capable of varying the HVAC set points in a very delicate manner which must take into account various different factors such as thermal losses, thermal interactions between the building rooms as well as the weather/occupants behavior. Such a delicate and intelligent behavior cannot be realized by employing rule-base logics - which are used in the vast majority of BOC systems today - no matter how elaborate these rule-base logics are.

3. Real-Life Experiment (Test Case 1): PCAO achieves significant improvements, with its Fully-Adaptive version very quickly "learning the best BOC policy"

Both the BEPS-based and the Fully-Adaptive PCAO were implemented and evaluated through *real-life experiments* conducted in Test Case 1. Figure 4 (upper subfigure) exhibits the performance of the two versions of PCAO as compared to the Best Practice (best rule-base control among the ones currently implemented in Test Case) for three different sets of experiments. *What is really interesting is that the Fully-Adaptive PCAO exhibits significantly better performance than the BEPS-based PCAO.* The reason for this is that the BEPS-based design is "sensitive" to simulation model inaccuracies as well as non-measurable user behavior (e.g., opening of windows). It is worth noticing that the BEPS model was extensively tuned and validated before the experiments, exhibiting quite accurate modeling of the actual building dynamics. Apparently, the BEPS model became non-accurate enough when the experiments started, mostly due to the difference in the weather conditions during BEPS validation (spring time) and BOC system experiments (summer time).

Table III. BOC DESIGN USING BEPS MODELS

Test Case 1 (BEPS using EnergyPlus) and Test Case 2 (BEPS using TRNSYS)			
Method	*Iterations*	*Energy Savings with respect to the Best Practice (for the same user comfort conditions)*	
PCAO	100-300	30%-50%	Test Case 1 (with DS)
	~50	20%-35%	Test Case 2
Popular Optimization Algorithms	>10000	0%	Test Case 1 (with DS)
	>10000	0%	Test Case 2

4. Real-Life Experiment (Test Case 2): BEPS-based PCAO can provide significant improvements in case of highly accurate/validated BEPS-models

The BEPS-based PCAO was implemented and evaluated through real-life experiments conducted in Test Case 2. Figure 4 (lower subfigure) exhibits the performance of BEPS-based PCAO as compared to the Best Practice (best possible rule-base control) and the Current Practice (the rule-based control that is employed in the building). Due to space limitations the results of the experiments conducted in Test Case 2 are just sketched, and more details can be found in [7]. We only emphasize here that BEPS-based PCAO exhibited quite impressive improvements for the parts of the building for which an extensively tuned and validated BEPS model was available, while its performance degraded for these parts of the building for which the BEPS model was not validated/tuned.

V. Conclusions

Complex systems, such as buildings, require more intelligent control decisions than rule based control strategies for optimal performance. Rules and expertise personnel can control satisfactorily such systems but not in an optimal manner. Optimality in highly nonlinear, large scale systems can be achieved through optimization algorithms. The PCAO algorithm, applied to two different large scale buildings, showed excellent performance and rapid convergence, resulting in large amounts of energy savings and discomfort level improvements in both buildings.

VI. Acknowledgments

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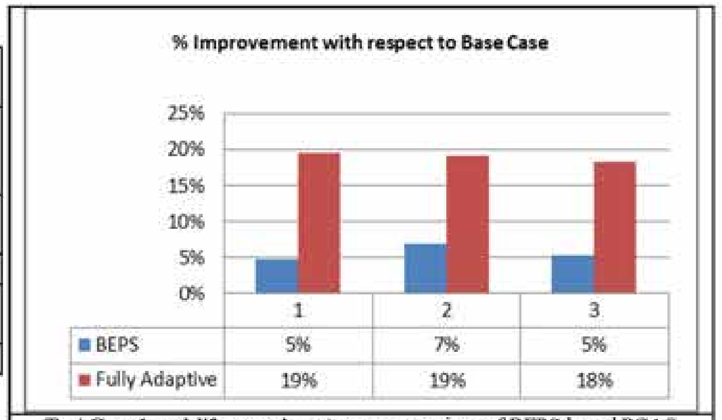
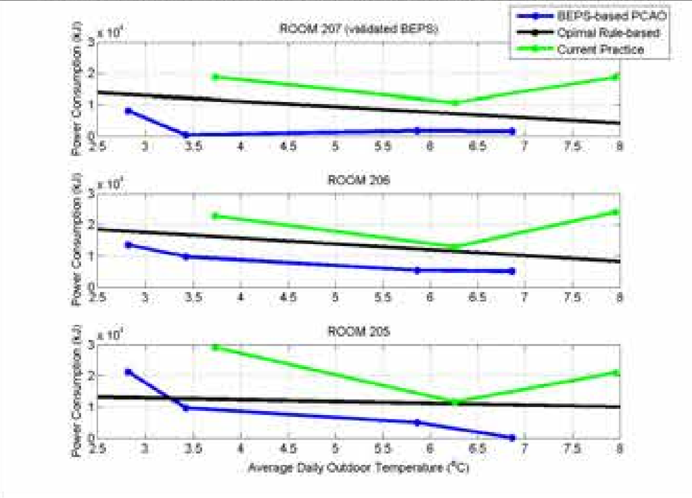


Test Case 1 real-life experiments: energy savings of BEPS-based PCAO (blue) and Fully-Adaptive PCAO (red) as compared to the Best Practice (Base Case). In all experiments BEPS-based PCAO and Best Practice provided about the same comfort conditions. The Fully-Adaptive PCAO provided better comfort conditions than both BEPS-based PCAO and the Best Practice.



Test Case 2 real-life experiments: Energy performance of BEPS-based PCAO (blue) for 3 different rooms and different outdoor temperatures and its comparison with the Best possible Rule-based Control (black) and the Current Practice (green). The PCAO performance improves wrt both strategies.

Figure 5. Summary of real-life experiments in the two Test Cases. PCAO for BOC Design

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Thermal Insulation Characteristics of the Building Shell according to the New Legislation for Decreasing Energy Consumption in Buildings in Greece

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***Abstract*—In 2010, a new legislative framework for decreasing energy consumption in buildings was introduced in Greece in accordance with the European Directive 2002/91/EC on the energy performance of buildings. Since the implementation of this framework, the only regulations related with the thermal performance of building were the national Thermal Insulation Regulation introduced in 1981 and the Technical Codes related with the installation of heating and cooling systems. The paper examines the thermal insulation properties of building shell that practice the conventional construction requirements in accordance with the new legislation. By comparing the thermal insulation properties of the "new" building shells with those complying with earlier specifications, result different conclusions that indicate the outcomes of the new legislation in energy performance of buildings and new construction methods and materials use in Greece.**

***Index Terms*—building, building materials, construction, energy consumption, energy efficiency.**

I. Introduction

The energy and environmental performance of a building is influenced by many factors such as climatic conditions, architectural and constructional characteristics. The thermal insulation behavior of the construction materials in the building shell quantifies an important contribution to the energy performance of the building by affecting the energy consumption for heating and cooling the indoor space.

In October 2010, was introduced in Greece a new framework of laws and measures drawn up as a response to the EU Directive 2002/91 on the Energy Performance of Buildings, intended to promote energy efficiency in new and existing buildings [1]. The principal provisions of this legislative framework determine:

- the calculation methodology for the energy performance of buildings;
- the content of building energy performance studies;
- specifications for sustainable architectural design and the thermal properties of the structural elements in the building shell;
- the minimum energy performance requirements and the classification of buildings according to their energy performance;
- the energy audit procedure;
- the format and the content of buildings energy performance certificates.

According to the new "Energy Performance Building Directive", known with the abbreviation KENAK which comes from its initial letters in Greek, maximum U-values of the buildings shell in relationship with the different climatic zones (Fig. 1) should not exit the values indicated in Table I.

Figure 1. Climatic zones according to KENAK

TABLE I. MAXIMUM U- VALUES ACCORDING TO KENAK

Exterior Wall Component	U-value $[Wm^{-2}K^{-1}]$			
	Climatic Zone			
	A	*B*	*C*	*D*
Roofs	0.50	0.45	0.40	0.35
External Walls	0.60	0.50	0.45	0.40
External floors	0.50	0.45	0.40	0.35
Floor over ground	1.20	0.90	0.75	0.70
External walls in contact with the ground	1.50	1.00	0.80	0.70
Openings	3.20	3.00	2.80	2.60
Glass Facades	2.20	2.00	1.70	2.80

Since the implementation of KENAK, there were not any specific regulations defined in Greece regarding the energy performance and the evaluation of buildings. The only regulations related with the thermal performance of buildings were the national Thermal Insulation Regulation introduced in 1980 and the Technical Codes related with the installation of heating and cooling systems [2], [3]. Thermal Insulation Regulation set the minimum requirements of thermal insulation for three different climatic zones (Figure 2) in Greece according to the Table II.

Figure 2. Climatic zones according to the Thermal Insulation Regulation of 1980

TABLE II. MAXILUM U-VALUES ACCORDING TO THE THERMAL INSULATION REGULATIONS OF 1980

Exterior Wall Component	U-value $[Wm^{-2}K^{-1}]$		
	Climatic Zone		
	A	*B*	*C*
Roofs	0.50	0.50	0.50
External Walls	0.70	0.70	0.70
Floor over ground	3.00	1.90	0.70
External walls in contact with the ground	3.00	1.90	0.70
Roofs	0.50	0.50	0.50

In February of 2013, in accordance with the Directive 2010/31/EU, a new legislation on buildings energy performance was introduced in Greece. The objective of the new legislation is to determine, define and improve the regulations regarding energy performance and evaluation of buildings in Greece. Moreover, the new Directive requires, by the end of 2020, from all European member countries to ensure buildings energy performance towards 'Nearly Zero-Energy Buildings' [4].

This study represents the effectiveness of thermal insulation thickness in a typical exterior wall section in Greece in accordance to the new legislation. In particular, estimates the U-value of a typical building shell in line with the previous national Thermal Insulation Regulation considering the effectiveness according to the new legislation. In case these factors do not achieve the required U-values, different construction decisions have been done. Each decision claims different options according the thickness of thermal insulation material, using the specific type of external wall section. The objective of this study is to evaluate the new requirements of U-value in relationship with the climatic zones and how are affected by the insulation material thickness. The evaluation of U outputs allows to make different decisions of building shell use. The first option, which considers new constructions, examines a different thickness of insulation use in order to achieve the most effective thermal insulated building shell where, the second reviews the requirements of the new legislation with additional thermal insulation in the existing section wall. In both cases thermal insulation thickness should be in correspondence with those available in the market, and suitable for the relevant application as well as.

II. U-VALUE CALCULATION

According to the above mentioned, three different cases of exterior wall section were chosen as representative types of building shell. In each case the exterior wall construction consists of paint, plaster 2 cm in the interior and the exterior, two layers of brick plus they are insulated with extruded polystyrene. The distinction between each case lies with the thickness of thermal insulation material and the thickness of each brick layer. It should be mentioned that in case where thickness of each brick layer varies, different position of each brick layer does not affect the effectiveness of wall thermal insulation.

Estimating the U-value given from the equation [5]:

$$U = \frac{1}{R_i + \sum_{j=1}^{n} \frac{d_j}{\lambda_j} + R_a} \qquad (Wm^{-2}K^{-1}) \qquad (1)$$

Where:
n is the sum of all building materials in the constructional element (-),
d is the thickness of any construction material (m),
λ is the thermal conductivity in any construction material $(Wm^{-1}K^{-1})$,
Ri is the external thermal surface transfer resistance (m^2KW^{-1}). Its value is approximately considered constant = 0.04 m^2KW^{-1},
Ra is the internal thermal conductance resistance (m^2KW^{-1}). Its value is approximately considered constant = 0.13 m^2KW^{-1}.

Listed thermal conductivity values for the construction materials that are used for the elements under examination are in compliance with the tables given in the new legislation [1]:

Plaster: $\lambda_a = \lambda_e = 0.87\ Wm^{-1}K^{-1}$

Brick 1200 kg/m^3: $\lambda_b = \lambda_d = 0.52\ Wm^{-1}K^{-1}$

Expanded polystyrene: $\lambda_\gamma = 0.03\ Wm^{-1}K^{-1}$

A. 1st Case:

The first case of a typical cross section exterior wall component chosen consists of a double row of bricks of 9 cm and 14 cm separated by thermal insulation (extrude polystyrene) 4 cm (Fig. 3) .

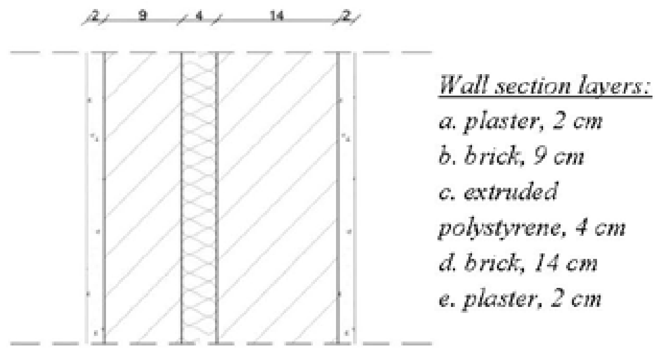

Figure 3. First case of a typical exterior wall cross section

The 1st wall component's U-valueis estimated, according to the equation (1):

$$U = \frac{1}{0.04 + \frac{0.02}{0.87} + \frac{0.09}{0.52} + \frac{0.04}{0.03} + \frac{0.14}{0.52} + \frac{0.02}{0.87} + 0.13} = 0.50\ W\,m^{-2}K^{-1}$$

This U-value is suitable for the previous Thermal Insulation Regulation in each climatic zone, while, in accordance with KENAK, it is acceptable only for zone A and zone B (Table III).

TABLE III. U-VALUES ACCORDING TO THE 1ST CASE

	U-value $(W\,m^{-2}K^{-1})$	Climatic Zones			
		A	*B*	*C*	*D*
1st Case	0.50	v	v	x	x
Replacement of thermal insulation thickness(5cm)	0.43	v	v	v	x
Replacement of thermal insulation thickness(6cm)	0,38	v	v	v	v
Additional external thermal insulation (3cm)	0.33	v	v	v	v

v acceptable, x unacceptable

The 1st option, in order to achieve the desired U-value regarding the new legislation, thermal insulation thickness had to be increased. As it is noticed, in case the thickness of the existing building insulation was set in 5 cm, the wall section becomes acceptable, in terms of thermal insulation capacity, for all climate zones, apart for zone D. A layer of 6 cm of extruded polystyrene should be applied in order to meet the minimum requirements of U-value for zone D.

In the 2nd option, the improvement of the building shell with additional thermal insulation of 3 cm of thickness meets the quitrents of U-value for each climatic zone.

B. 2nd Case:

In this case, exterior wall component chosen consists of a double row of bricks of 9 cm and 19 cm separated by thermal insulation (extrude polystyrene) of 4 cm (Fig. 4).

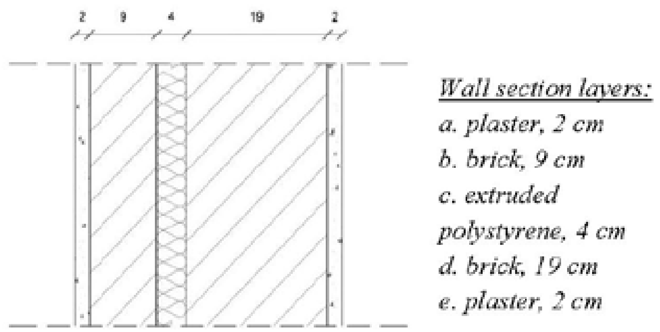

Figure 4. Second case of a typical exterior wall cross section

According to the equation (1):

$$U = \frac{1}{0.04 + \frac{0.02}{0.87} + \frac{0.09}{0.52} + \frac{0.04}{0.03} + \frac{0.19}{0.52} + \frac{0.02}{0.87} + 0.13} = 0.48\ W\,m^{-2}K^{-1}$$

It can be noticed from the Table IV, that in this case improvement of brick thickness was considered. The U-value in relation with the requirement of each climatic zone does not meet significant improvements.

TABLE IV. U-VALUES ACCORDING TO THE 2ND CASE

	U-value $(W\,m^{-2}K^{-1})$	Climatic Zones			
		A	*B*	*C*	*D*
2nd Case	0.48	v	v	x	x
Replacement of thermal insulation thickness (5cm)	0.41	v	v	v	x
Replacement of thermal insulation thickness (6cm)	0.36	v	v	v	v
Additional external thermal insulation (3cm)	0.32	v	v	v	v

v acceptable, x unacceptable

As it is noticed, the additional insulation thickness of 1 cm is still insufficient for zone D. In this option, more than 5 cm of extruded polystyrene should be placed. Regarding the decisions made, the 2nd option achieves the desired U-value for all climatic zones.

C. 3rd Case:

In this case, exterior wall component consists of a double row of bricks of 9 cm and 9 cm separated by thermal insulation (extrude polystyrene) of 5 cm (Fig. 5).

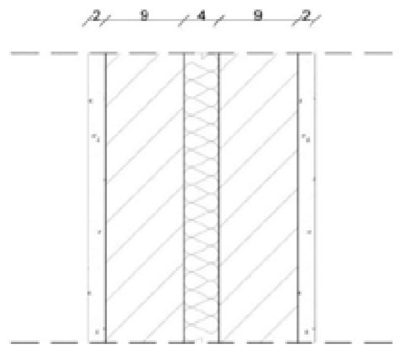

Figure 5. Third case of a typical exterior wall cross section

$$U = \frac{1}{0.04+\frac{0.02}{0.87}+\frac{0.09}{0.52}+\frac{0.05}{0.03}+\frac{0.09}{0.52}+\frac{0.02}{0.87}+0.13} = 0.45\ W\,m^{-2}K^{-1}$$

In this case, externals wall thermal insulation capacity is higher than the previous two. As a consequence, meets the requirements related to zone A, zone B and almost can be applied in zone C. As a first option, by increasing thermal insulation thickness by 1cm (extruded polystyrene of 6cm), U-value can work properly for zone D. Moreover, as a second option, additional thermal insulation in the exterior part of the wall, U-value is applicable for all climatic zones (Table V).

TABLE V. U-VALUES ACCORDING TO THE 3RD CASE

	U-value ($W\,m^{-2}K^{-1}$)	Climatic Zones			
		A	*B*	*C*	*D*
3rd Case	0.45	v	v	v	x
Replacement of thermal insulation thickness(6cm)	0.39	v	v	v	v
Additional external thermal insulation (3cm)	0.35	v	v	v	v

v acceptable, x unacceptable

Considering all the above cases of examination, it is evident that the insulation capacity of the building element can be improved either by increasing the brick's thickness or by reducing the thermal conductivity of the building construction materials.

III. CONCLUSIONS

The aim of this study was to understand the conceptions of buildings shell energy performance, regarding the requirement of the thermal insulation legislations in Greece and construction decision that should be followed to transform a typical exterior wall section to a more effective thermal insulated component of the building. The evaluation of climatic zone and thermal insulation thickness are important factors affecting U-value. Thermal insulation thickness was studied by means of improving U-value linked with the needs of each climatic zone. The above study leads to the conclusion that since the introduction of KENAK, often, typical exterior wall sections applied in conventional building constructions in Greece did not correspond to the requirements related to the buildings shell thermal insulation. As it was noticed, working only with the insulation thickness, in order to archive the desired U-value according to the new legislation, changes of the insulation thickness are required to improve the building shell. The U-value rates vary by increasing thermal insulation thickness from 1 to 2 cm. Especially, in case where thermal insulation thickness has been increased by 2 cm, U-value exceeds the requirements provided for the examined building shell components, in all climatic zones. In case of additional external thermal insulation of 3cm, accelerates the same conclusion. Construction methods along with the decisions on the thermal insulation materials used, can lead in to a high energy performance of the building shell.

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Energy Management System and Substitution of Fuels and Energy Sources in Public Buildings

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Abstract— **Energy is one of the greatest challenges of modern humanity and fundamental condition for progress in a number of areas and technologies.**

Paper presents fundaments of Energy Management System and substitution of fuel or energy source, as a measure to decrease financial costs for consumed energy, and in that order to improve energy efficiency and decrease degree of environment pollution.

Index Terms – **Energy Management System, energy consumption, fuel/energy sources substitution, CO_2 emission.**

I. INTRODUCTION

Energy costs are becoming larger in the daily operation and maintenance of facilities, whether it refers to a buildings or industrial plants.

However, awareness of the possibilities for the application of energy efficiency measures and practical activities related to reducing energy consumption is still not satisfactory. Previous experience in implementing energy efficiency measures in the former Yugoslav Republic of Macedonia show that a very small number of entities have the correct information regarding the energy efficiency of their property and power consumption.

This especially applies to the public sector, ie cities, municipalities, ministries and public enterprises.

II. ENERGY MANAGEMENT SYSTEM IN PUBLIC BUILDINGS - BASICS

A methodology called energy management system (EnMS) is developed in order to achieve positive changes in the area of energy efficiency and energy management.

Energy management system has aim to monitor energy consumption in a specified way, so that at any time we can know the answers to the following questions:

- **Where** do we spend our energy? - Facilities such as residential and office buildings, hospitals, barracks, faculties, police stations, schools, kindergartens, processes and operations in industry, transport sector etc.;
- **How do** we spend our energy? - In systems for: heating, cooling, ventilation, lighting, preparation of hot sanitary water, food preparation, etc., in the production of goods and services, for transport of people and goods, etc.;
- **What** kind of energy do we use? - Electrical energy, natural gas, oil, wood, heat energy, water etc.;
- **How much** energy do we spend? - How much we use electrical and thermal energy - [kWh], oil - [l], natural gas or wood - [m^3] etc., and how much funds are spent for the purchase of such energy.
- **Who** is responsible for energy management? - Team responsible for energy efficiency (EE) and technical staff and superintendents at the facility.
- **How to** manage energy? - With weekly and monthly tracking, monitoring and analysis of energy consumption through information system for energy management (ISEM), through planning and implementation of energy efficiency measures and continuous training and motivating a energy efficiency team and other staff.

Managing energy consumption by reducing energy costs has an impact on reducing maintenance costs and improving environmental protection.

Namely, Energy management system involves continuous improvement of working procedures, thus reducing the need for preventive and particular corrective maintenance, and consequently achieves a reduction of maintenance costs.

Furthermore, energy consumption is closely related with environmental pollution. During the combustion of fossil fuels (oil, gas, coal) many pollutants are emitted in the atmosphere, especially CO_2, which is considered as the main cause of global climate change. Therefore, every irrational use of energy basically means pollution of the environment.

III. STRUCTURE OF ENERGY CONSUMPTION IN PUBLIC BUILDINGS

Undeniable fact is that for every object, whether it is private or owned by the city or municipality, at the end of the month bills for consumed energy must be paid. The initial step is to understand the structure of energy consumption, as given in Fig.1.

The consumption of electrical energy engage all electrical devices in the building or outside (in example, public lighting). In general, heating bills apply only to buildings connected to district heating or buildings which are heated by hot water networks. Individual boilers which produce heat for heating, cooking or heating of sanitary hot water can use firewood, pellets, oil, coal or natural gas etc. as fuels, and in order to form energy costs structure the financial costs for these energy sources should be also taken in to account.

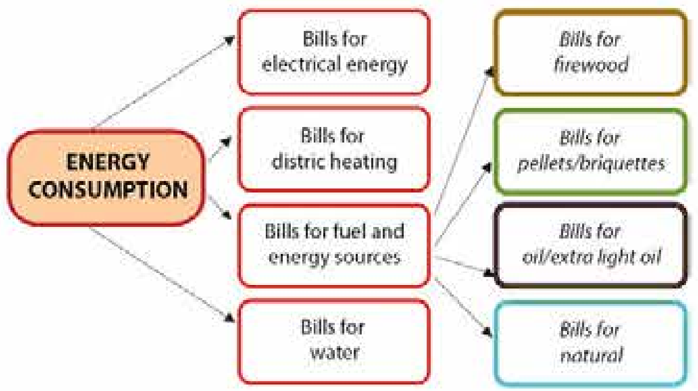

Fig.1: Common categories of energy consumption in public buildings

During the implementation of the overall energy audit it is necessary to make an analysis of prices and tariff systems under which in certain analyzed building energy and water are supplied. Very often in this segment there is significant potential for energy efficiency improvement, especially in larger facilities. Also, it is important to emphasize that in this area we can talk for improvement of economical rather than energy efficiency. As an example, changes in tariff model for electrical energy purchase doesn't mean saving energy, but just saving money.

Figure 2. gives the necessary input parameters and expected results from energy supply system analyses. Prices and tariffs for electrical energy, thermal energy, oil and oil products and natural gas in the former Yugoslav Republic of Macedonia are brought by the Energy Regulatory Commission, and all information on this matter can be obtained from the agency's website (http://www.erc.org.mk).

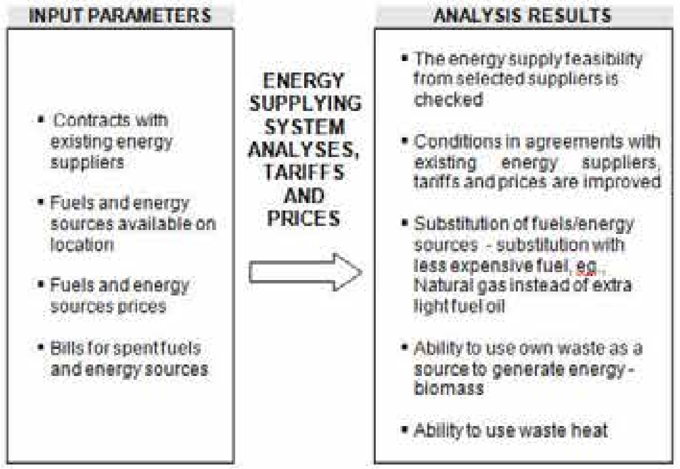

Fig.2: Analyzed elements from of energy supplying system

IV. Energy Sources Substitution

Numbers of heating systems, especially in older buildings, are still using oil or crude oil as an energy source. Nowadays rarely can be find systems that use coal, although this possibility should not be excluded. Also object heating using electrical energy is particularly unfavorable form of heating in terms of efficient use of energy sources and fuels.

The previous mentioned systems are not only energy inefficient, but also have a negative impact on the environment. They especially contribute to local air pollution due to emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter and carbon dioxide (CO_2). Therefore it is desirable that these fuels can be replaced with fuels that have a lower content of sulfur and carbon, as natural gas. Certainly if the object is in a location where there is an opportunity to join the pipeline, the heating system can be adapt to natural gas. However, if such a pipeline is not available, other possible solutions can be found. This specially relates to the use of liquefied petroleum gas (LPG). Liquefied petroleum gas can be stored in small tanks, above or under the ground, that are placed near the facility and supplied with pipeline system leading to various devices that are placed in it. It should also be noted that the use of gas for heating is the most cost-effective option.

Moreover, we should assess the possibility of using renewable energy sources, especially during major object reconstructions, and when there is a possibility such systems can be effectively integrated into the new building constructive solution.

Taking into consideration above mentioned analysis of the possibility of replacing a energy resource for the heat production in the Faculty of Technical Sciences - Bitola object is made. In the next part of this paper energy, economic and environmental effects are analyzed achieved by energy source substitution in this object.

V. Example of An Energy Sources Substitution

The building where Faculty of Technical Sciences - Bitola is placed has total heated area of 6000 [m^2], and for energy production for heating and obtaining domestic hot water extra light fuel oil is used.

The analysis considers an option that may be available in the future, replacing extra light fuel oil with natural gas.

- **Current Status**
  - To produce thermal energy for heating and preparation of domestic hot water extra light fuel oil is used.
  - Annual consumption of extra light fuel oil for heating and preparation of domestic hot water is 55 [tons per year], with an extra light fuel oil energy value of 42.300 [kJ/kg] and density 860 [kg/m^3].
  - Pipeline and the heating elements are in good condition, reconstructed two years ago and they have thermostatic radiator valves.
  - The development of the infrastructure in the object location made natural gas available for use.
  - The existing boiler room according to the characteristics doesn't meet the requirements of the Regulation on technical standards for the design, construction, operation and maintenance of natural gas boiler rooms (SFRY Official Gazette 10/1990 and 52/1990).

- **A description of the measures taken**
  - Substitution of extra light fuel oil and instead using natural gas for heat production.

- **Necessary Investments**

Based on the bids submitted by potential contractors a certain amount of necessary investments is equal to a total of 13.530.000 MKD (220.000 Euro).

This amount includes investments in the following items:

- Station for measurements and natural gas pressure reduction (MRS).
- Electrical and mechanical equipment in boiler room (boiler, burner, circulating pumps, mixing valves, gas connection, stack elements etc.), together with the costs of dismantling the old and installation of new mechanical equipment.
- External gas network.
- Internal gas network.
- Construction and reconstruction works.
- Projects for: Station for measurements and natural gas pressure reduction (MRS), gas pipeline and connections, gas boiler room.

- **Estimation assumptions**
  - The natural gas energy value is 33.400 [kJ/m^3], and its density 0,69 [kg/m^3].
  - Heat energy consumption doesn't depends from fuel type used, and thermal energy which should be provided by natural gas is equal to the thermal energy provided by extra light fuel oil, $E_{el.od} = E_{n.g.}$, i.e.,

$E_{el.od}$ = *60.000 x 42.300 = 2.538.000.000 [kJ per year]*

$E_{el.od}$ = *705.000 [kWh per year] = 705 [MWh per year]*

- An assumption that long-term price of natural gas will be maintained at the current level of 28,8 [MKD/m^3] (0,49 [$Euro/m^3$]), VAT included, that is 3,10 [MKD/kWh] (0,05 [Euro/kWh]), is taken into account.
- The price of extra light fuel oil is 54,5 [MKD/liter] (0,89 [Euro/liter]), VAT included, that is 5,4 [MKD/kWh] (0,09 [Euro/kWh]).

- **Savings**
  - *Savings in heating energy (SHE):*

SHE = 0 (Heat energy consumption doesn't depends from fuel type used) .

- *Financial savings (FS):*

FS = Costs for extra light fuel oil ($C_{el.od}$) - Costs for natural gas ($C_{n.g.}$)

$FS = E_{el.od} \times 5{,}4\ [MKD/kWh] - E_{n.g.} \times 3{,}1\ [MKD/kWh]$

FS = 1.621.500 [MKD/year]= 26.366 [Euro/year]

- **Investment return period (IRP):**

IRP = Total investments / Financial savings per year

IRP = 13.530.000 / 1.621.500 = ***8,3 years***

IRP = 220.000 / 26.366 = ***8,3 years***

VI. Energy Sources Substitution Influence on CO_2 Emissions Rate

Energy Management System (EnMS) is also directly related to environmental protection. Useful forms of energy (such as electrical or heat energy) are commonly obtained from combustion of fossil fuels (coal, oil and natural gas).

Therefore, by reducing the consumption of electricity or heat energy through Energy Management System (EnMS) burning of fossil fuels can be decrease, and thus the emission of harmful gases in the atmosphere.

Fuels contain a certain amount of carbon which in some part is turned into carbon dioxide during their combustion. Fuel combustion contributes to flue gases emission in to the atmosphere, including carbon dioxide, CO_2, sulfur dioxide, SO_2, and nitrogen oxides, SO_x, etc.. Carbon dioxide (CO2) that occurs as a result of fossil fuels combustion has the greatest impact on global warming.

Due to this fact, the impact of reduced energy consumption on global warming is observed primarily through the decreased CO_2 emission.

We can use previously analyzed example, considering energy source substitution in the Faculty of Technical Sciences object, to make assessment on the impact of this change on the CO_2 emission level from this facility boiler room, before and after the fuel substitution happens.

Used methodology:
CO_2 emissions per unit of fuel [kg CO_2/kg (or m^3)]

As the relevant ratios of CO_2 emissions are taken following:

- 3,13 [kg CO_2/kg] for extra light fuel oil and
- 1,90 [kg CO_2/m^3)] for natural gas

Extra light fuel oil consumption: 55 [tons per year]

CO_2 emission as a result from extra light fuel oil combustion:

55.000 [kg] x 3,13 [kg CO_2/kg] = 172.150 [kg CO_2]

Natural gas consumption:

2.538.000.000 [kJ/year] / 33.400 [kJ/m^3] = 75.988 [m^3/year]

CO_2 emission as a result from natural gas combustion:
75988 [m^3/year] x 1,90 [kg CO_2/m^3] = 144.377 [kg CO_2]

- CO_2 emission reduction (ERED) :

ERED = CO_2 emissions using extra light fuel oil - CO_2 emissions using natural gas

ERED = 172.150 - 144.377 = 27.773 kg CO_2 per year = 28 [t CO_2 per year]

VII. Conclusions

Today we are witnessing the enormous energy consumption and its impact on the global economy and climate.

Energy management system offers us an opportunity to improve efficiency in energy consumption of different shape at the whole society.

In this way we can significantly contribute to the preservation and extension of the availability of energy, from any kind, as well as environmental protection and climate change mitigation by reducing the level of greenhouse gases, primarily carbon dioxide.

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DG and EV Penetrations for Future's Smart Network in Turkey

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Abstract— **Electrical energy consumption keeps growing worldwide. Smart grid is an evolved power grid to provide more efficient and sustainable usage of electrical energy. It enables more penetration of distributed generation, DG, so thus provides improved system reliability and power quality. Therefore, one of the critical grid transformation issues is the construction and integration of DG units. In Turkey, electric power system is at the initial state of grid evolution and not any significant strategy has not determined yet. However, there has been an intensive work to constitute a deregulated environment during the last decade. This paper focuses on the management of the penetration of DG and EV technologies to evolving smarter distribution grid in Turkey.**

Index Terms-- **Distributed Generation, Electric Vehicle, Smart Grid, Turkish Power System.**

I. Introduction

Before the restructuring process almost all electrical energy was being generated with bulk generators near the energy sources and transmitted to the customers using long transmission lines. Furthermore, power system operation and management (generation, transmission, and distribution systems) was centralized. Today, electric power network is much more complex than it was in the past and hence generation, transmission and distribution chain includes so many actors providing the technical and economical couplings between the separate parts of the system. Therefore, electric power networks have been so much loaded that such a case has never been observed before. Under these circumstances, management of the grown and developed power systems plays the crucial role in terms of system reliability. Because of the technological developments in electric power system, centralized power grid has not responded anymore the customer needs which are in terms of economical electricity and system reliability.

Electric power systems have been evolving all over the world. Increased unit cost of fossil fuel energy sources have brought the necessity of restructuring electric power industry by which energy sources would be used efficiently and effectively. At first, deregulated operation was first approved in many countries, since rigorous regulations had prevented efficient utilization of energy resources. Later, open-access environment was established where the consumers were allowed to choose their electrical energy providers. Demand and supply of electrical energy are more flexible then it was in the past. This flexibility is expected to increase in the future power systems. However, this flexibility has brought the overloaded transmission lines and congestion problems in many countries. Therefore, some problems which affect power quality and system reliability like as voltage instability and blackout have been observed.

Several problems of the restructured power systems enforced the authority to enhance the current power system facilities, in accordance with customer requirements. One of the leading ideas for improved operating conditions was to let and encourage the customers to generate their own energies and to provide selling the excess energy to the system. It was obvious that such an enhancement required some changes in traditional power systems. Those changes have resulted in a new environment which is known as smart grids.

Smart grid was actually an improved power network having some monitoring, analysis, control, and communication capabilities. It can intelligently integrate the behavior and actions of all users connected to it in order to efficiently deliver sustainable, economic and secure electricity supplies. However, control, operation and metering of those new smart grids were more complicated than of the traditional ones.

One of the main challenges of the smart grids was to strengthen the grid enabling smaller scale distributed generations (DGs) to operate harmoniously with the total system and capturing the benefits of DG and storage. In the new constituting structure, DGs which have low investment costs in addition to their green and highly flexible operating flexibilities become an attractive generation type. Also, DG simplified the integration of renewable energy sources to the grid [1]. Moreover, smart grids were thought to be efficient means of accommodating the supply needs of electric vehicles (EVs). EV consumption will be of great importance due to its mobile and highly dispersed character and possible massive deployment in the future. On the other hand, EVs are expected to be an effective distributed generating capacity for future power systems and EV's main impact will be on local distribution system to which they connect [2]. Therefore, smart metering equipment and communication tools were important for this power system evolution.

Power grid in Turkey is at the beginning stage of smart grid evolution. Several steps have been performed in order to evolve from a passive network to an intelligent one. Regulations have been achieved to integrate renewable and domestic energy sources to the grid. Distributed intermittent generation was allowed up to power rating of 1 MW without any license requirement. This had increased the interest of the individuals and companies. So many applications regarding wind and solar generating units are still being evaluated for proper integration to the system. Electric power distribution system was divided into 11 parts and they have already been privatized. However, most of the generation units are still been managed by public regulatory authority. Coordination of protection, switching and metering devices are being re-coordinated for perfect bilateral power-flow.

II. SMART GRID, DG CONCEPTION, AND EV

Electrical energy management has become more important with increasing energy generating facilities and with increasing energy consumption. In today's world, electric power networks have enormously grown and enhanced, hence the isolated operation and management of generation, transmission and distribution parts was not any more effective. Instead, they had to be coupled for a cost effective and reliable supply of electricity.

Main goal of smart grids is to intelligently integrate the behavior and the actions of all participating units from generators to customers included in the system. In general, smart grid is an evolved power system which includes communication, advanced metering and measurement infrastructures as well as a complete decision support. The attractiveness of the smart grid comes from the fact that generation, transmission and distribution networks become more efficient, flexible, and reliable due to intelligent operating conditions. In addition more renewable and variable energy sources integrate into the grid and consumers get greater information and the capability to control their electricity consumption and costs [3].

Smart grid is an evolved power grid integrated with hardware, software, monitoring and control technologies, and modern communication networks. Many new challenges trying to solve the problems those face to transform the conventional grid into a smart grid because of renewable energy integration, communication errors and smart meter disturbance. In order to efficiently deliver sustainable, economic and secure electricity supplies, smart grid becomes a need for power networks of every country. Smart grid is not created all at once. Instead, it has been evolving over many years from the existing infrastructure through the development and integration of intelligent systems.

There are two main infrastructures included in the smart grid; namely, electrical infrastructure and intelligent infrastructure. Generation, transmission and distribution parts of the system comprise the electrical infrastructure and are upgraded and improved with the intelligent infrastructure. The authority of many power grids stated their action plan for smart grid evolution [4].

The DG is defined as smaller and environmental friendly generators whose power ratings are less than 10 MW. They are connected to the substation, distribution feeder, or customer load level. As being near to the loads, they serve as economical solution of load consumption. DG technologies include conventional and nonconventional energy technologies such as diesel engine driven generators, photovoltaic, wind turbines, fuel cells, micro, and small size hydro turbines [5], [6]. Single line of a power system including DGs and electrical vehicles is illustrated in Fig. 1.

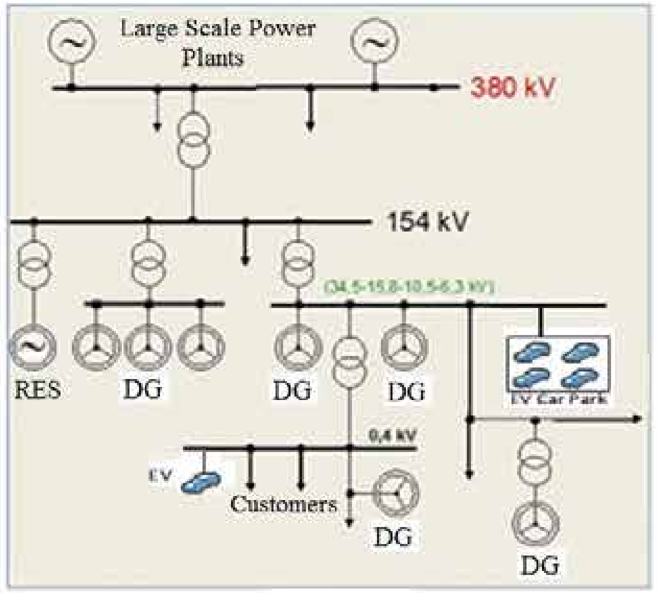

Figure 1: Single-line diagram of a power system including DGs and EVs

DGs are generally built at customer sides. Therefore, they reduce the transmission and distribution cost of the power grid [7]. In addition, the interest of DG is increased due to their shorter construction time and lower operational cost. In the grown, developed, and deregulated power systems, DGs provide positive contributions to system reliability and power quality. In spite of their benefit, they have some negative impacts on the system. Increased short circuit power of the system, protection problems for bilateral power-flow (Fig. 2), changing the structure of the traditional distribution system and bringing many uncertainties to system topology are the main disadvantages of DGs. Furthermore, some renewable DG energy sources (solar, wind etc.) are intermittent and unpredictable sources. This brings the necessity of detailed evaluation of the system from the point of distribution system reliability [7] – [10].

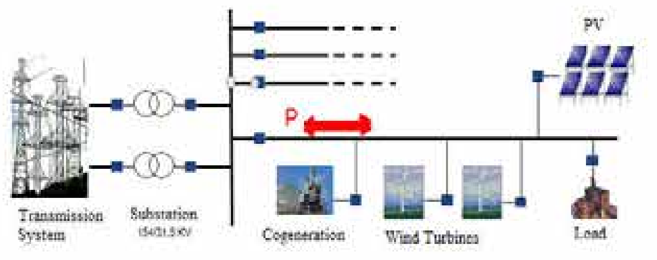

Figure 2: Bilateral power-flow

DGs include combined heat and power systems, standby power operations, peak shaving applications, grid support and islanding operations. A combined heat and power DG is the cogeneration type operation mode and generally gas turbines are used for this type of DGs. A stand by power DG operates to supply the interrupted customers for a limited time period. It provides to prevent long time interruption to the power grid. Diesel generators are widely used for this operation mode. The installation of standby generators is an economic choice based on extremely high interruption cost for specified customers.

A peak shaving DG operates during peak load conditions. The cost of utility power generally varies hourly depending upon the demand level and the availability of generation assets and incorporated transmission systems. It is obvious that energy costs during peak load conditions (times) will be higher than of the other time scales. The strategy of peak shaving operation is to supply the system with higher prices [11] – [14].

Finally, in case of some faults, the distribution network is generally divided into several islands through the operation of switching devices. An islanded sub distribution system including a DG can be supplied by that DG, provided that DG capacity is higher than the load. This operation mode is known as islanding operation and it provides that fault can be isolated [15]. An islanded operation mode is shown in Fig. 3.

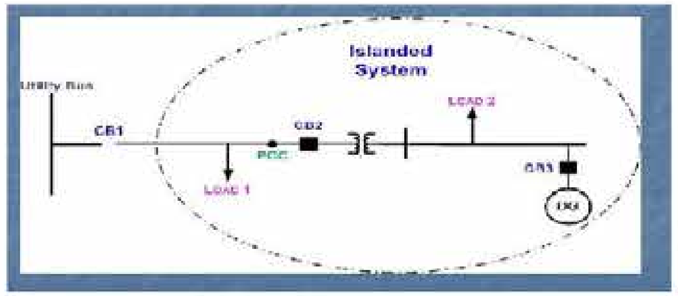

Figure 3: Islanded system

To integrate micro generation and on-site generation of intermittent renewable sources while minimizing electrical power transfer from the main grid will achieve to maximize the benefit of the renewable sources, and to minimize the impact of the renewable generation on the main grid. Also, DG is a very important part of the smart grid to introduce renewable energy sources to power distribution system. The new smart power system not only transmits the power from generation to costumers but also communicates with every step of the grid. When DGs deploy the grid, the energy flow will become bilateral between the grid and the consumers with renewable energy generations. At peak load duration, the utility could buy power from the distributed generators to supply grid power. Utility companies gain increased reliability power quality, and prevented interruptions, while distributed generator owners sell the energy at peak prices [14].

Electric vehicle (EV) technology is a new game-changing venture which can provide significant benefits to our economy, environment, and energy security, and upend the traditional means of transportation as we are familiar with. EVs will reduce the impact of fossil fuel based transportation since the electricity will become an important fuel in the transportation industry. Furthermore, EVs represent a new opportunity for DG to manage the power demand and will be an important part of power grid with vehicle-to-grid (V2G) technology (Fig. 4).

EVs charged at off-peak (night) times can effectively be used as distributed sources during the peak load periods. This will not only provide additional distributed sources but also increase the usage of wind power since the wind power is more effective during the night times. That is, EVs serve as efficient storage sources which decrease the uncertainty of renewable energy sources. It is obvious that such an effective implementation can only be achieved by aggregating those storages sources in a car park. Electric vehicle parking lots will therefore be used as peak shaving power DG. However, this will require practical and innovative solutions to overcome technology, market, and infrastructure challenges. Smart grids will make simpler to V2G concept. This choice does not reduce the dependence on oil, but it could stabilize grid fluctuations and increase the system reliability and power quality [16] – [18].

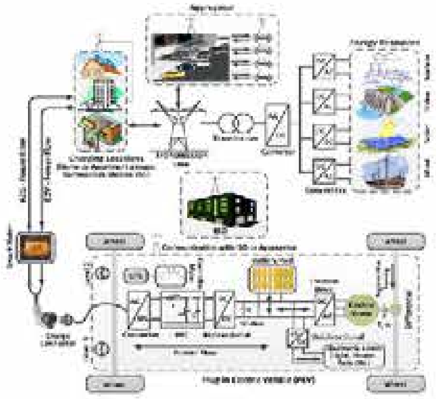

Figure 4: V2G concept

III. TURKISH POWER SYSTEM

Energy Market Regulatory Authority (EMRA) was established in 2001 with the purpose of regulating the energy market in Turkey. Since then, EMRA has been working to constitute a deregulated environment for electricity market.

Turkish Electric Power Distribution System has already been divided into 20 regions and privatized. On the other hand, almost half of the 62 GW total generation capacity is still under the control of public utility. However, these units are arranged to be privatized. A little part of generation, 4 % is DGs which are mainly based on cogeneration and wind energy. However, recent decreases in installation costs resulted in fast increase in photovoltaic generation. PV generation is expected to dominate the distributed generation in the near future especially in south-east and south part of the country.

Power grid in Turkey is in the beginning stage of smart grid evolution. Several legislation and organizational changes as well as some hardware improvements have already been performed to pass into a smart environment. However, transformation of the existing system to a smart grid is still estimated to take almost thirty years.

At this initial phase, some nuclear power plant projects and on-site generation from renewable sources have already started due to the fact that the basic priority of Turkish Power System is supply security. The works of structuring competitive deregulated market is going on to ensure supply security. Turkey is a major energy importer [19] and almost 65% of the electricity consumption is supplied from these imports [20]. Like any other developing country, Turkey's energy demand is in continuous increase with an average increasing rate of 8%. Under these conditions, in order to gain energy independency and to provide healthy and sustainable growth, Turkey must invest in national and renewable energy sector.

The extension of distributed and renewable energy generation was the most important attempt for shifting generation plant constructio from regulatory authorities to the investors. Both the geographical location and its climate provide various advantages for renewable energy investments and production in Turkey. The share of renewable resources in electricity generation is expected to exceed 30% by 2023 [21].

Wind energy is one of the most valuable renewable energy sources in Turkey. Feasible wind sources for power generation are located in the western, north-western and south-western side of Turkey and dominant wind regime is from northern west to southern east.

Turkey has a perfect position for solar power generation as being located in the Mediterranean sun belt. Solar radiation values are similar to Spain, Portugal and Greece. Solar Energy is therefore the most important alternative clean energy resource in Turkey. The yearly average solar radiation is 1311 kWh/m^2 per year and 3.6 kWh/m^2 per day. The total yearly insulation period is approximately 2460 hours per year and 7,2 hours per day. However, solar energy has been used for heating purposes so far. Recent decreases in installation costs, created a big interest to PV based generation especially at the southern and south-west part of the country.

Wind farms and PV generations can be used as DGs. However, there are some problems to be solved to integrate those sources to the national distribution grid. Distribution systems have been designed according to unilateral power-flow from bulk generations to the loads. When DG is integrated the grid, distribution system should be evolved according to bilateral and variable power-flow. Furthermore, protection and switching devices should be re-coordinated for bilateral power-flow [8].

Voltage and frequency control is the one of the crucial task for the perfect power system management. In present, DG is not used for voltage and frequency control. This control is achieved by large scale generators. As increasing the number of integrating renewable DG in distribution system, DGs should be used for voltage and frequency control too [9].

EMRA removed the license obligation to build a cogeneration and renewable energy generation units up to 500 kW on March 2012. Then, this regulation was extended by 1 MW in 2013 [22]. The aim of this regulation was to increase the private investment for DG construction. Following these regulations, there was a significant increase in new DG unit installation applications. However, all the applications were for the regions where the wind and PV potential were feasible.

On the other hand, Northwestern part (Thrace region) is the most power consuming part of Turkey suffers. However, most of this region suffers from lack of wind and PV generations not only because of source unavailability but also because of land costs. Part of this region is under the responsibility of Bosphorus Electric Distribution Corporation (BEDAS) and includes European site of Istanbul.

TABLE I. EXISTING DG LIST in BEDAS

Power Plant	Fuel Type	Capacity (MW)
Atateks Tekstil	Natural Gas	8.445
Baydemir Tekstil	Natural Gas	9.309
Eczacıbaşı - Baxter	Natural Gas	1.033
Ekolojik Enerji	Recycle Gas	0.980
Halkalı Kağıt Karton Sanayi	Natural Gas	5.066
Kemerburgaz Hasdal Çöp Gazı	Recycle Gas	4.240
Kilsan Otoprodüktör Tesisi	Natural Gas	3.168
Koç Üniversitesi	Natural Gas	2.332
Poliser	Natural Gas	2.128
Turcas	Natural Gas	1.580
Ertürk Teperes	Wind	0.660
Atik Pasha Turizm A.Ş.	Natural Gas	1.165
Polat Tur. Otelcilik Tic. ve San. A.Ş.	Natural Gas	1.660
Anadolu Japan Turizm A.Ş.	Natural Gas	2.250
Altınmarka Gıda San. ve Tic. A.Ş.	Natural Gas	2.096
Mercedes-Benz Türk A.Ş.	Natural Gas	8.000
Sunjüt Sun'i Jüt San. ve Tic. A.Ş.	Wind	1.200
Tav Iistanbul Terminal Işletmeciliği A.Ş.	Natural Gas	9.780
Evyap A.Ş.	Natural Gas	5.120
Ortadoğu Enerji	Biogas	28.300
Lodos Elektrik Üretim A.Ş.	Wind	24.000
Çırağan Sarayı İşl. Geliştirme İnş. Tur. A.Ş.	Natural Gas	1.358

This study is mainly concentrated in BEDAS region, where there were 22 DGs whose total capacity was 123.87 MW before specified EMRA regulations (Table 1). It can easily be understood from the table that most of the existing DG are natural gas based cogeneration units. On the other hand, total electric energy consumption of the region along 2013 was 24 billion kWh [23]. If compared, DG based energy penetration to the system was about 1.5 percent. This was really a little part of total capacity and not enough for an effective contribution to the system.

Following the EMRA regulations, 82 DG applications have been received up to February 2014 in BEDAS region. 66 applications with a total capacity of 46.5 MW have already been approved. 39 of those DG applications were wind power based, 18 were PV based, 7 were cogeneration units, and 2 were wave generation. Until now, bilateral contract has been signed only six of these applications. However, total distributed generation capacity with those additional units is still very low for BEDAS region. The most important reason for the reluctance in DG based generation is the high price of terrains which can be installed a DG in Istanbul. Therefore, the private investors do not show interest in DG [24].

Population density of BEDAS region is very high that almost nine million people lives in the area [25]. But, it suffers from lack of photovoltaic, fuel cells, wind turbine and CHP based DG in the region. Therefore, the region cannot make use of expected benefits from the point of system reliability and power quality of DGs. However, electrical vehicle car parking seems to be an alternative DG source as in other metropolitan cities. As of March 2014, 26 car parking lots are being operated by ISPARK in BEDAS territory and 215 car parking lots have being planned to construct in a five year period. Existing and future car parks in the region have an average size of 300 cars. Assuming that half of those cars will be EVs, and each EV has an average capacity of 25 kWh; one car park may serve as a temporary generating unit of 1.2 MW along 2-3 hours. In addition, both the increasing percentage of EVs among all cars and increasing storage facilities show that parking lots will be more effective DG sources in the future [26].

Such a capacity brings the usage of car parking lots as a peak shaving DGs. Peak load period in a year is almost thousand hours for the region. In order to consume the peak loads, EV parking lots can be used as cheaper and more reliable sources than the power plants having high installation costs. However, such a usage involves proper modeling of those sources. Capacity of EV parking lots depends on some uncertain parameters and a proper stochastic modeling is required to achieve the expected improvements.

On the other hand, uncertainty of the source can be decreased using some incentives. Probably the most efficient incentive will be a price promotion. For example, daily average parking fee is about 7 USD in the region. Initial calculations show that the usage of parking lot will provide more than 60% of daily parking expenses. Therefore, 30% of decrease in parking fee seemed to be effective.

Transportation services serve as a community service in Turkey and are not anticipated to pay off the construction cost in a short time. The time paying off differs with respect to the investment and operation cost of the parking lots. Some car parking lots pay off in 10 years. some of in 35 years in Istanbul. It is clear that, integration of parking lots to the distribution system as DG sources will provide a significant economy and their pay off times will decrease significantly.

IV. Conclusions

Turkey electric power system is at the initial state of grid evolution. Although DGs are expected to improve distribution system reliability and power quality, BEDAS region seems not to have sufficient PV, wind, etc. based DG units. On the other hand, the usage of EVs is increasing day by day and EV percentage is expected to reach a significant amount in the near future. Moreover, metropolitan cities require parking lots both from the point of extending public transportation as well as traffic arrangement. Therefore, EV parking lots can be thought as efficient DG/storage sources. For BEDAS region, it is expected that 300 MW of DG parking lot based DG capacity will be available in 5 years. Those parking lots will contribute for high quality and reliable power supply while decreasing their pay off times. At this point Turkish Government has to take the intensive legislations not only for conventional DG investments but also for parking lots.

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An Advanced and Efficient Sun Tracking System based on a Novel Algorithm for Maximum Electrical Power Generation on Solar Array

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Abstract—**Photovoltaic (PV) panels, with a fixed orientation towards the sun, turn solar energy to electrical with a sun power loss which may reach to 45%! The problem is greater for electric power systems based on Concentrating Solar Power (CSP) technologies. Solar tracking systems give the solution as they follow the sun movement during a day. They are based on different tracking techniques and methods and one can find them on the market. We introduce a novel solar tracking algorithm with advantages relative to today's methods for tracking systems. The suggested algorithm is based on real time sun tracking, on season's data and on a mathematical estimation of daily sun position for a long period of days, regardless of the presence of clouds. Finally this algorithm introduces a precise, reliable and flexible tracking system for applications like a single and autonomous tracker, a master tracking unit and CSP Systems.**

Index Terms--**solar tracker, photovoltaic panel, photodiode array, Concentrating Solar Power.**

I. Introduction

Modern world culture is based on technology investments and products. Public transport with buses, trains, metro, airplanes and ships, private cars, entertainment with home cinemas and televisions, sports with mechanical means usage, air conditioned systems for houses and large multi-storey buildings, all these require a lot of energy to work. Electrical energy is on the top of energy sources for all these appliances, but primary energy resources for electrical generators are mainly oil and natural gas. Oil deposits gradually diminish by continuous pumping and the growing demand of energy as well as the cost per energy unit is increasing rapidly. Besides these, environmental pollution from exhausts and temperature increase of earth are two great factors affecting the ecosystem, our lives and whole Earth.

Scientific and technical community turned their interest to other kinds of energy resources to overcome all these sinister and unforeseen consequences after oil burning. This is the Green Energy resources, like sun, wind, geothermia, biomass and tidal waves on sea. Today's energy saving demands and power consumption minimization are the two goals on green energy solutions in ECC. A lot of technologies and systems have been developed to produce electric energy from these green energy resources.

II. Photovoltaic Panels and Their Application Techniques

A. Fixed systems

Photovoltaic (PV) panels, built with cells based mainly on silicon semiconductors, convert solar energy to electrical. These panels form an array and are placed on a fixed base with permanent orientation against the sun, on a photovoltaic (PV) plant. Orientation depends on local geographical coordinates and is chosen so that the panels have the maximum average efficiency per year. Most efficiency is derived when the sun is normal to the PV surface, but as the angle between sun and surface of a panel is changed through the daytime, efficiency reduces dramatically for fixed PV system. On the contrary, fixed orientation PV systems are often chosen for installation, as they are cheaper and easier to install. Beyond the cost degradation of such a construction, this choice leads to a PV power system with a sun power loss which can reach as high as 45% to 50% [1]. If someone thinks that solar panels have an average efficiency of about 15%, the final power degradation is sufficiently large.

B. One axis and two axes systems

One axis trackers developed to move the panels east-west with a fixed tilt. They have much more efficiency, reaching 90% and more, but two axes trackers have the maximum efficiency, approaching 100% comparing to previous trackers. Two axes trackers move the panels east - west and change their tilt so that they face directly to the sun, regardless its position on the sky. Tracking systems work with different mechanical structures and are based on operational algorithms with more or less durability stability, reliability and finance cost. Many companies produce solar tracking systems for more than 15 years, for small or large PV plants, all over the world.

C. Techniques and algorithms presently employed

The techniques and algorithms for implementation of these tracker systems are based on the following technical approaches, which are deeply analyzed and explained in [2].

✓ Closed loop technique. The tracker follows the sun movement with the usage of electro-optical sensors [3], like photodiode sensors and corrects its position continuously by minimizing the relative error between sun and panel's position [4]. Primary disadvantages of this method are

- The orientation loss, when a cloudy sky or a cloud remains for a long period of time over the area of the installation and the system is unable to move the PVs, but when the clouds have gone, the system needs a period of time to turn its surface normal to the sun and 'lock' its movement with that of sun. This is an important limiting factor of performance.
- The panels start moving from west back to the east during the sun rise period in the morning, with a time delay, depending on topology, design and electro-mechanical parts, so having an impact at performance.

✓ Open loop technique. This is based on algorithms and mathematical equations [5] for earth orbit around the sun. Solving these equations, the system predicts sun position on sky at any day, at any season, for a whole year. Disadvantage of the method is

- It's not possible to correct its tracking position if parameters, like its coordinates or real time clock are lost or wrong. Basic parameters of such a system are its geographical coordinates, the real time clock, date of the year and a reference point based on the geometry and construction of the system for any calculation of its position relative to the sun and, in case of a faulty reference point, it forces the tracker to move on a more or less wrong orientation. A GPS is usually applied to the construction to avoid the first malfunctions but a mismatch between sun and PV orientation still could happen and give wrong estimation of sun position, too.

✓ Composite technique. This combines both above techniques for maximizing stability and performance of a tracking system and by minimizing the corresponding disadvantages of individual methods [6], but it still may have a problem, depending on the design of the tracker.

- If a relatively large orientation difference occurs between the above two techniques and the sun is obscured by a cloud for a time, then the system could be forced to a useless movement, from sun direction as it was controlled by circuits with photodiode sensors, to the estimated position as it comes from the above open loop technique.

III. An Advanced and Innovative Tracker

We introduce a solar tracking system which overcomes the disadvantages of all methods as they described above. Advanced topology of photo detectors make this system to have a very small error during sun tracking, so it is suggested not only for PV panel applications, but especially for Concentrating Solar Power and Concentrating PV (CPV) systems.

This is a composite, autonomous and reliable two axes tracking system, for azimuth motion and for inclination of PVs respectively and this is the best choice for modern trackers. On the way of operation this is a closed loop system with photodiodes for sun tracking and an open loop system, in case of a cloudy weather, capable to compute and predict the sun position with an innovative algorithm, independent of geographical coordinates or real time clock, without complicated mathematical equation solutions. The program size on system memory is not only less but also more efficient. Additionally to all these, the described system detects wind speed and consequently controls panel surface slope. This happens when wind exceeds a predefined limit, then the panels move to get parallel to ground and air pressure is minimized on PV's, avoiding possible damage.

An approach to system technical aspects and procedures

The system operates based on the following innovative concept and operations making it independent of geographical coordinates or real time clock and free of complicated mathematical equation solutions. Consequently this system is more efficient and reliable. An explanation to system technical aspects and procedures follows on different scenarios of operation:

Closed loop operation

The system is controlled by an optical array of photodiodes, which focus to the sun. Electro-optical signal from this array of photodiodes have the largest priority and handle the management and control of tracker, continuously correcting its relative orientation to the sun.

1. Initial operation

At the initial operation, the system is oriented in the direction of sun. This is achieved after processing real time signals from an array of photodiodes, responsible for keeping it on tracking with the sun continuously and the following procedures take place in system:

- It identifies if initial orientation to sun happens before noon or after, based on advanced firmware. It's achieved with a reference point on system orientation based on local coordinates.
- It calculates the position (coordinates) of sunrise, for next day morning (second day of operation) and moves to this orientation before sunrise. This is achieved by a computational algorithm which is developed for this tracker, with analysis of the data recorded on the day before (first day of operation).

2. Daily operation

On a daily basis, as the tracker follows the sun, a set of data is recorded; consist of coordinates of azimuth and tilt of tracker. This operational circle repeats for a period of 15 days and after suitable manipulation of these data, the tracker:

- calculates and predicts its position and motion, relative to sun, for any time and day, on overcast sky.
- calculates its position and motion during a day, for at least 15 days to provide the worst-case cloudy sky, e.g. during continuous cloudy sky for a week.
- does not need a real-time clock, like the aforementioned commercial systems, which calculate the trajectory with the help of mathematical equations to tune up on the actual orbit. The system will always move in the right direction to track the sun, as it is mentioned above.

Open loop periods

When the tracker operates on open-loop technique (cloudy sky period), it is self-corrected on the calculated orbit by comparison with the real one, after removing the clouds and this is based on an intelligent 'self learning' algorithm.

It collects and stores all data during daily movement of sun and is capable to compute (with minimal fault) the correct track of sun motion for next 15 days, regardless of cloud presence for most of a day or days. This algorithm makes the system independent of continuous presence of sun for a whole day and the aim is its faculty to estimate sun position for a great number of days, expanding it in whole season period and finally for a year period. This is an innovation since the tracking system predicts sun position without solving complicated mathematical equations or without knowing its geographical coordinates of its position.

System is controlled by an optical array of photodiodes, which focus to the sun and merely whole PV assembly focuses to the sun, too. Data from this array of photodiodes have the largest priority and handle the management and control of tracker, while it's not obscured by clouds. Parallel to this the sun estimated position by algorithm is compared with the real one (from photodiodes). The final goal of this comparison is the correction of estimated sun position and auto correction of parameters in algorithm, if the error overcomes an experimentally approximated limit.

Some additional advanced operations of tracker

Tracker is capable to estimate the seasons of a year with its advanced algorithm, after data processing during the culmination and by measuring ambient temperature, too.

For power conservation reasons, when a heavily cloudy sky is detected by the system, then

• if tracker operates on winter period and the system orientation is somewhat less than midday sun position, just before heavy clouds appear, then tracker should be oriented after a while to the half of the remaining of sun orbit to the west. When system orientation is more than midpoint sun position, then tracker is locked at that last orientation

• if it is on spring or autumn season, the tracker moves following time steps of one hour as the clouds leave quickly.

The system will operate normally with its photodetectors when it's on sunlight period, as expected. Otherwise tracker operational parameters might be changed; depending on application demands and/or latitude of the area it is installed.

A practical and useful application

Another very useful application of this tracking system is the operation in large solar parks with a lot of PV arrays, installed on many trackers. It can be used as the main unit (master tracking unit) and all other systems will be passive, they will only have the mechanism of movement, without any electronic units, like microcontroller board, photodiode array, photo amplifiers etc. The main unit will control all these trackers, separately and will check their orientation. A base station is introduced for this PV park with a computer connected to the master tracking unit to keep data of all the individual tracking systems in the park and will be possible to make statistical curves, daily based, for sunlight, the clouds, the produced energy and many other parameters that are useful in a large installation.

IV. Conclusions

Obviously the new design approach for the tracker, with this innovative concept, gives the chance for developing systems with higher efficiency, more reliable, simpler on operating method and safer. The prescribed solar tracking system has immediate implementation on photovoltaic market and will be competitive for its benefits including its easier initialization when installed. From this point of view it could be the starting point for using this design method for applications on common PV tracking systems but it is a challenging to install such a system for advanced PV implementations with light focusing (lenses) and Fresnel type light concentrators, because of its great reliability and small error, adjusted to the demands and depending on the topology of the design and the drift of the parameters used for computing the coordinates of panels (azimuth and tilt).

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Implementation the tasks of the Renewable Energy Directive 2009/28/EC in EU Members and the former Yugoslav Republic of Macedonia as a country-candidate

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Abstract— - **This paper elaborated the main objectives of the Directive 2009/28/EC on renewable energy sources and tasks for the EU Member States and candidate countries for EU membership. RM largely realizes planned strategic objectives arising from the requirements of the Directive. Standardization listed renewable energy sources and strategic energy data and the plan as rounded outline are given in the paper. The comparative analysis provides a snapshot of the current state of progress of the former Yugoslav Republic of Macedonia in terms of increasing the share of energy from renewable sources.**

Index Terms – **renewable energy, Directive 2009/28/EC, renewable energy sources substitution, CO_2 emission.**

I. Introduction

With established the Renewable Energy Directive 2009/28/EC, the European Union has adopted a very ambitious plan to increase the share of renewables in their energy consumption to 20% by 2020, including a 10% goal for the use of renewables in transport alone. Renewable energy for distribution on infrastructure could come from a variety of sources, but for transport area, the main source is biofuel. The Renewable Energy Directive 2009/28/EC, which sets these goals, will therefore trigger a large increase in the consumption of biofuel in the EU. Critics argue that biofuels could have negative social implications because they could lead to an increase in food prices. This is particularly relevant for today's first generation biofuels, which are based on biomass that could otherwise be used for food purposes, or on biomass produced on land otherwise suitable for food production. The environmental effects of biofuels are also controversial. Although in principle CO2-neutral, the use of biofuel never leads to a 100% reduction in greenhouse gas (GHG) emissions compared to the use of fossil fuels and could, in extreme cases, even lead to an *increase* in emissions. To address the possible negative environmental concerns, the Directive lays out sustainability criteria that biofuels have to fulfill. These relate to overall efficiency in terms of emission reductions, but also specify which type of land can be used to produce the feedstock. Some critics have argued that making a distinction between biofuels based on such criteria is incompatible with WTO disciplines. This paper examines the Directive's biofuel sustainability criteria and their WTO-consistency within the framework of specific WTO Articles, with a particular emphasis on the general exemption clause (Article XX of the GATT).

II. Background to Directive 2009/28/EC

Directive 2009/28/EC on the promotion of the use of energy from renewable sources (the Directive) was adopted on 23 April 2009. The Directive entered into force on 25 June 2009 and mandates implementation by Member States by 5 December 2010. The EU Renewable Energy Directive pursues a dual objective of increased security of energy supply and reduced GHG emissions through replacing fossil fuel with renewables. This Directive is distinct from previous directives in that it provides a stronger regulatory framework by introducing legally binding targets for renewable energy at the EU level.

Directive 2009/28/EC lays out mandatory country-specific targets for each EU Member State for the overall share of energy that has to come from renewable sources by 2020. The targets, which will increase in several steps until 2020,3 vary widely between Member States (between 10% for Malta and 49% for Sweden) and are set such that a Community average of 20% will be reached compared to 1990 levels.4 The target applies to energy used for electricity generation, heating and cooling and transport. Article 3.4 of the Directive sets a mandatory target of a 10% share of renewable energy used for transport in each Member State.

In order to reach these targets, Member States are encouraged to implement domestic support schemes 'that promote the use of energy from renewable sources by reducing the cost of that energy, increasing the price at which it can be sold, or increasing, by means of a renewable energy obligation or otherwise, the volume of such energy purchases'.5 These support schemes can include, amongst others, financial means such as 'investment aid, tax exemptions or reductions, tax refunds, [14], and direct price support schemes including feed-in tariffs and premium payments'. Biofuels and other 'bio liquids' not produced according to the sustainability criteria set by the Directive will not be counted towards the share of renewable energy in overall energy consumption nor towards the 10% share in transportation.6 Moreover, non-sustainable biofuels are not eligible for 'financial support' from the domestic support schemes.

The Renewables Directive sets mandatory national targets for renewable energy shares of final energy consumption in 2020 which are calculated on the basis of the 2005 share of each country plus both a flat-rate increase of 5.5 % per Member State as well as a GDP-weighted additional increase to come up with the numbers as outlined in the table below [14]:

Table 1: Mandatory national targets set out in the Directive (2005 and 2020)

	Share of energy from renewable sources in final consumption of energy, 2005	Target for share of energy from renewable sources in final consumption of energy, 2020
Belgium	2.2%	13%
Bulgaria	9.4%	16%
The Czech Republic	6.1%	13%
Denmark	17.0%	30%
Germany	5.8%	18%
Estonia	18.0%	25%
Ireland	3.1%	16%
Greece	6.9%	18%
Spain	8.7%	20%
France	10.3%	23%
Italy	5.2%	17%
Cyprus	2.9%	13%
Latvia	34.9%	42%
Lithuania	15.0%	23%
Luxembourg	0.9%	11%
Hungary	4.3%	13%
Malta	0.0%	10%
The Netherlands	2.4%	14%
Austria	23.3%	34%
Poland	7.2%	15%
Portugal	20.5%	31%
Romania	17.8%	24%
Slovenia	16.0%	25%
The Slovak Republic	6.7%	14%
Finland	28.5%	38%
Sweden	39.8%	49%
United Kingdom	1.3%	15%

Contribution of RES to Final Energy Consumption Eurostat Convention (Mtoe)

Given the present state of market progress and strong political support, the European Renewable Energy Industry is convinced it can reach and exceed the 20 % renewable energy share in final energy consumption by 2020. The estimates by the Renewable Energy Industry are based on a moderate annual growth scenario for the different technologies. Strong energy efficiency measures have to be taken to stabilize the energy consumption between 2010 and 2020.EREC and its members assume that a 20% share of Renewable Energy of final energy consumption by 2020 is a realistic target for the EU under the condition that certain policy developments will occur and a continuation of the existing policy instruments are ensured. The individual sector projections are based on moderate estimates, some of the sectors forecast much higher numbers for their sectors by 2020.

Table 2: Contribution of RES to total final energy consumption (Mtoe)

	2005		2006		Projection 2010		Targets 2020	
Type of energy	Eurostat	%	Eurostat	%		%		%
Final Energy Consumption [1] (Trends to 2030) [*] (Combined RES and EE) [**]	1,211.5		1,214.8		1,272		1,378 1,266	
Wind	6.06	0.50	7.05	0.58	15.13	1.19	41	3.0-3.2
Hydro [2]	29.82	2.46	30.71	2.53	30.95	2.43	33	2.4-2.6
Photovoltaic	0.14	0.01	0.22	0.02	1.72	0.14	15.5	1.1-1.2
Biomass	67.31	5.57	74.11	6.02	102.60	8.07	175.5	12.7-13.9
Geothermal	1.10	0.09	1.16	0.10	3.86	0.30	9.4	0.7
Solar thermal	0.68	0.06	0.77	0.06	1.5	0.12	12	0.9-1.0
Solar thermal elect.	0		0		0.16	0.02	2.2	0.2
Ocean	0		0		0.08	0.01	0.4	0.03
Total RES	105.3	8.69	113.07	9.30	156.0	12.3	289	20.9-22.8

A development of all existing Renewable Energy Sources and a balanced mix of the deployment in the sectors of heating and cooling, electricity and biofuels guarantee the start of a real sustainable energy mix for Europe. The table below gives an overview of the resulting contribution of renewable energy in the electricity, heating and cooling and biofuels sectors towards attaining the overall 20% target.

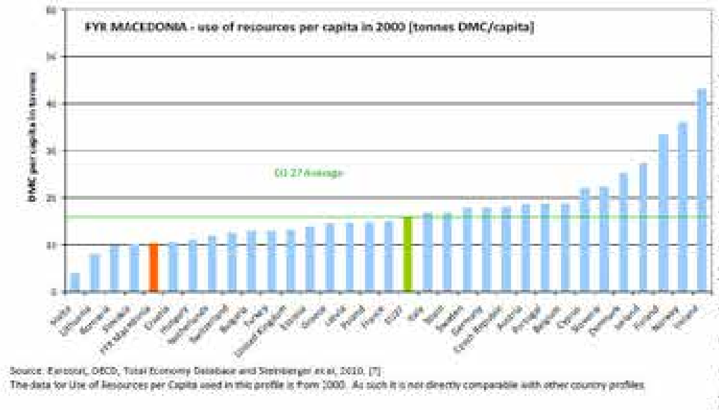
Table 3: Contribution of RES to Total Final Energy Consumption by sector (Mtoe)

	2005		2006		Projections 2010		Targets 2020	
Type of energy	Eurostat	%	Eurostat	%		%		%
Final Energy Consumption [*] (Trends to 2030) [**] (Combined RES and EE) [***]	1,211.5		1,214.8		1,272		1,378 1,266	
Electricity	43.36	3.6	46.19	3.8	60.5	4.8	116	8.4-9.2
Heating and Cooling	58.81	4.8	61.45	5.0	79.5	6.2	139	10.1-11.1
Transport biofuels	3.13	0.3	5.38	0.5	16.0	1.3	34	2.5-2.7
Total RES	105.3	8.7	113.02	9.3	156.0	12.3	289	20.9-22.8

III. Implementation the Tasks of Directive 2009/28 in the former Yugoslav Republic of Macedonia

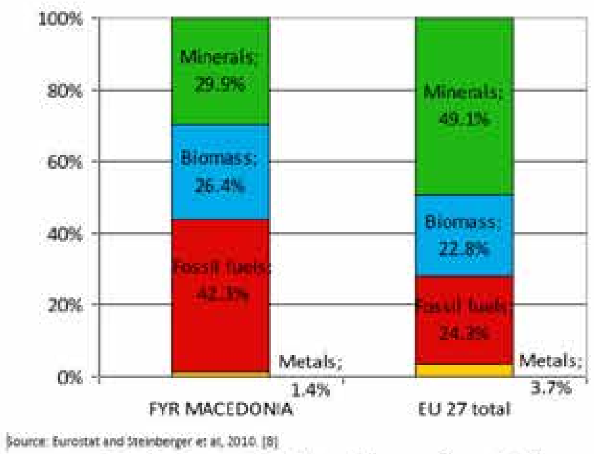
Facts and figures on resource efficiency for the former Yugoslav Republic of Macedonia

Use of resources per capita 2000 [tones DMC/capita]



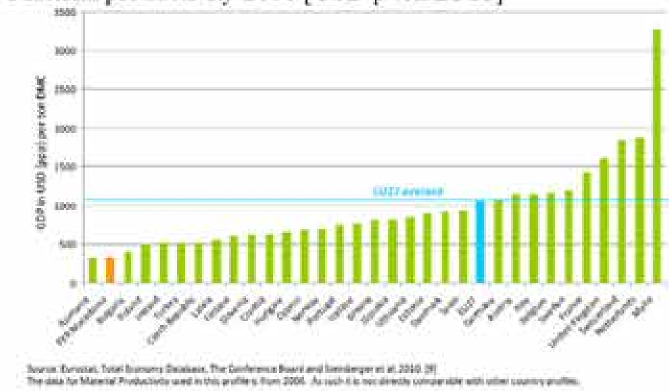
sl1. Comparative data of resources per capita

Breakdown of DMC by type of materials (2000)



sl2. Comparative data of type of materials

Material productivity 2000 [USD p/ton DMC]



sl3. Comparative data of material productivity

From the Strategy for sustainable development of the former Yugoslav Republic of Macedonia 2010 [10], and the Strategy for increasing energy efficiency in the former Yugoslav Republic of Macedonia until 2020 [13] :

- Decreasing the dependence on energy imports and decreasing the unproductive consumption of electricity;
- Progressive change in the usage of current energy sources (emphasis on usage on natural gas and other renewable energy sources in the production of electricity);
- Stimulus for structural Industrial changes, with benefits for lower energy intensive industries, improvement in technologies, equipment and the systems that control the production, distribution and consumption processes;
- Promotion of the combined production of heating and electricity energy;
- Stimulus for the participation of the private sector in securing services for improvement of the energy efficiency from commercial aspects;
- Introduction of market prices for energy (rationalization of energy prices) as a means to improve the operating condition of the energy producers which should result in significant motivation for saving energy (public and private).

Defined goals in the energy sector: from the Strategy for increasing the energy efficiency in the former Yugoslav Republic of Macedonia until 2020[13], and from the Strategy for use of renewable sources of energy in the former Yugoslav Republic of Macedonia until 2020 [12]

- Energy savings amount to 9% of the average consumption registered in the period of five years (2002-2006) until year 2018, with continuous promotion of energy efficiency and monitoring until 2020; 2011 survey of resource efficiency policies in EEA member and cooperating countries –the former Yugoslav Republic of Macedonia
- Energy savings amount to 9% of the average consumption registered in the period of five years (2002-2006) until year 2018, with continuous promotion of energy efficiency and monitoring until 2020;
- Increasing the share of renewable energy sources from 13,8% in 2005, up to 21% in 2020, in the total energy consumption;
- Consumption of bio-fuels until 2020 is planned to reach 10% of the total fuel consumption in the transport sector.

Indicators in the energy sector: from the Strategy for increasing the energy efficiency in the former Yugoslav Republic of Macedonia until 2020 [13] and publication Environmental Indicators in the former Yugoslav Republic of Macedonia 2008 [12]

- National indicator for energy savings on the basis of the average final consumption of energy for the five years 2002-2006 (ktoe/yr);
- Calculation of the indicative goal of energy savings in the residential sector 2002-2006 (ktoe/yr);
- Calculation of the indicative goal of energy savings in the commercial and services sectors (public buildings and facilities) 2002-2006 (ktoe/yr);
- Calculations of the indicator for energy savings in the industrial sector 2002-2006 (ktoe/yr);
- Calculation of the indicative goal for energy savings in the transport sector 2002-2006 (ktoe/yr);
- Energy consumption in the transport sector in the former Yugoslav Republic of Macedonia; types of energy and types of transport 2000-2006 ktoe/year);
- Final energy consumption by sector 1995-2005 (ktoe/yr, %);
- Total energy intensity 1995-2005 (%);

- Total energy consumption by fuel 1995-2005 (ktoe/yr, %);
- Renewable energy consumption 1995-2005 (ktoe/yr, %);
- Trend gross electricity consumption and renewable electricity 1995-2005 GWh;
- Electricity production from renewable sources 1995-2005 (%).

IV. Energy Sources Substitution In the former Yugoslav Republic of Macedonia

Renewable energy sources

With a share of renewable energy sources (RES) of 13.8% in the final energy consumption in 2005, the former Yugoslav Republic of Macedonia belongs to the countries with a relatively high utilization of this type of energy. Having in mind that these are environmentally acceptable domestic resources, the maximal possible utilization of RES is one of the priority activities envisaged in the Strategy.

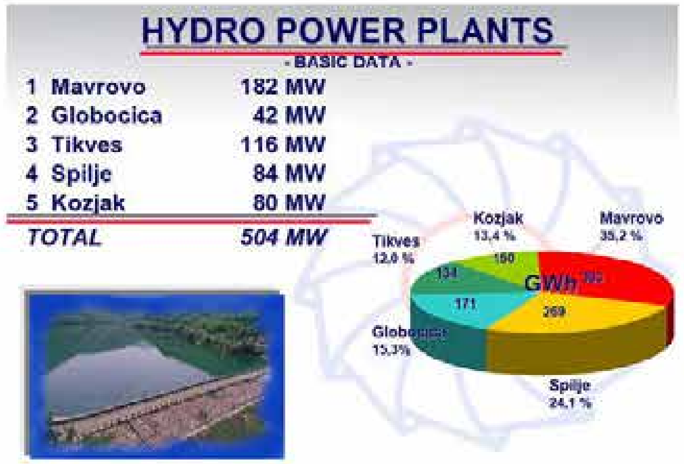
In the past period, out of the renewable sources, the former Yugoslav Republic of Macedonia primarily used hydropower (for production of electricity), biomass (mostly wooden mass for heat in the residential sector), the geothermal energy (mostly for heating the greenhouses), and some solar energy (for hot water in the households) and biofuels. In the future the plan is to increase the previously mentioned RES and to additionally use wind and solar power and biogas for production of electricity as well as waste biomass for combined heat and power generation.

Hydropower

The former Yugoslav Republic of Macedonia has available technical potential for hydropower for generation of about 5500 GWh (473 ktoe) of electricity per year in average hydrologic conditions. From this potential, the total installed power of the existing hydropower plants is 580 MW and their average annual generation is about 1500 GWh (129 ktoe) which is 27% of the available potential. According to the Study, construction of new hydropower plants with an annual generation of about 2500 GWh (215 ktoe) is planned, which would make the total production reach a level of 4000 GWh (344 ktoe) or 71% of the available technical potential.

The Strategy plans for the construction of 6 new large hydropower plants in the period to 2020 (HPP Sv. Petka until 2010, HPP Boshkov Most until 2015, Lukovo Pole with HPP Crn Kamen and HPP Galishte until 2016, HPP Gradec until 2017 and HPP Chebren until 2019) with a total installed power of about 690 MW (plus Sv. Petka) and with average annual generation of about 1200 GWh. Having in mind that the concession awarding activities (tenders) have not been successful, there is a possibility for delaying the construction of these power plants. If their construction is delayed by about a few years, it can be expected that the construction of HPP Gradec and HPP Chebren will finish after 2020. In that case, the generation of the new large hydropower plants in 2020 would be 600 GWh (52 ktoe). The available potential for construction of small hydropower plants on possibly 400 locations is assessed89 at 255 MW. According to the average generation of available small hydropower plants, the annual production of these new 255 MW would be 670 GWh (58 ktoe). The Ministry of Economy has issued three tenders for construction (concession) of a total of 71 small hydropower plants with a total power of 65 MW.

Their annual production would be about 175 GWh (15 ktoe). In spite of some administrative problems as well as problems related to the unclear hydrology of the locations, the Strategy stipulates a realistic expectation to construct a total of 80 MW of small hydropower plants until 2020 with an annual production of 210 GWh (18 ktoe). At the same time the Strategy envisages an optimistic scenario, which involves the construction of 120 MW of small hydropower plants with an annual production of 310 GWh (27 ktoe).



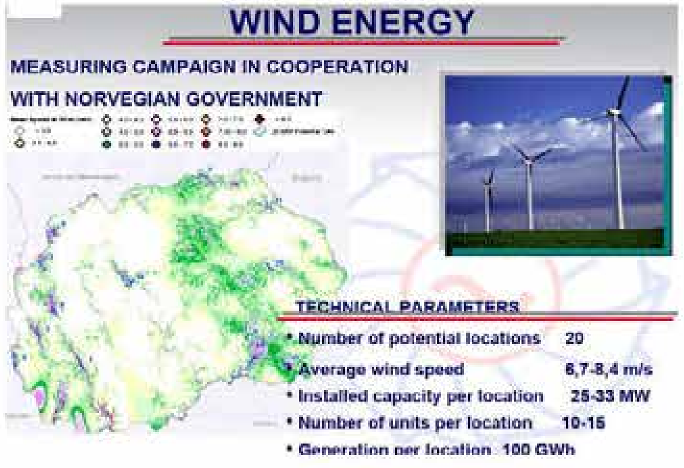
sl. 4. Hydro resources (power plants) in RM

Wind energy

In the past period several studies have been made to determine the wind energy potential in the former Yugoslav Republic of Macedonia and to select most favorable sites for wind power plants construction. In accordance with the prepared wind energy atlas a selection has been made of 15 most favorable locations for construction of wind power plants. Detailed measurements have been made in four locations and data are being processed.

Preparations for measurements on additional five locations are underway. In addition, a study is being prepared for absorption capacity of the electricity and power system of the former Yugoslav Republic of Macedonia for wind power plants.

Based on past investigations, one may realistically expect the construction of 90 – 180 MW wind power plants to 2020 with annual generation of 180 – 360 GWh (15.5-31 ktoe).



sl. 5. Wind energy in RM

The lower limit is at a level of 5% of the electricity generation capacities in the former Yugoslav Republic of Macedonia in 2010 and according to past experiences this would not cause any problems for the electricity and power system. The capacity of systems similar to ours is estimated at 10%. The planned upper limit of 180 MW wind power plants would be 6% of the planned electricity generation capacity of the former Yugoslav Republic of Macedonia in 2020.

Photovoltaic Solar Energy

The former Yugoslav Republic of Macedonia has available a solid solar potential and has high feed-in tariffs for electricity obtained from solar energy, however the former Yugoslav Republic of Macedonia does not have its own production of this technology and the cost of the feed-in tariffs is fully covered by the electricity consumers without an indirect benefit to the economy. Therefore, high penetration of photovoltaic in the former Yugoslav Republic of Macedonia is not planned in spite the high interest for their construction due the high tariffs. The Strategy also envisages the construction of total of 10 – 30 MW photovoltaic to 2020 with an annual production of 20 – 60 GWh (1.2 - 3.6 ktoe).

Waste biomass for combined heat and power generation

Activities are under way in the former Yugoslav Republic of Macedonia to determine this type of potential, however there are still no specific results. According to our estimates it is possible to construct a total of 5 – 10 MW to 2020 with an annual production of 25 – 50 GWh (2.1 - 4.3 ktoe).

Biogas

The potential for electricity generation from biogas has also not been sufficiently investigated. The Strategy envisages that these facilities will have a total power of 7 – 10 MW to 2020 with an annual generation of 20 – 30 GWh (1.7 - 2.6 ktoe).

Biomass for combustion

Biomass for combustion participates with 11.8% in the final energy consumption (final energy without losses and own consumption) in the former Yugoslav Republic of Macedonia in 2006 and it is a significant fuel for fulfilling the energy demands. The biomass is especially present in the residential sector and it fulfills 30% - 33% of the total energy demand. About 430000 households (76%) use biomass for heating.

Out of the total biomass used for energy purposes, the share of wood and wooden coal is 80%. The former Yugoslav Republic of Macedonia uses part of the grape wine branches, rice shells and branches of fruit trees for energy purposes, but most of the straw is mainly used for fertilizers, fodder and for production of cellulose. Therefore it is unavailable for energy purposes.

The planned utilization of biomass for combustion which will be used as heat in 2020 is greater, by less than 10% than the consumption in 2006 when the registered and unregistered consumption are taken cumulatively. Table 6.5.1 presents statistical information92 for 2005 which does not include the unregistered consumption. In the period until 2020 the unregistered consumption is expected to gradually decline and to become registered. Having this in mind, the total consumption for the period 2006 - 2020 will increase by only 10% which at the level of the available potential in spite of the fact that the registered consumption will increase by more than 40%.

According to the baseline scenario, the consumption of biomass for combustion in2020, which will be used as heat, will be 236 ktoe (2740 GWh) which is approximately equal to the available potential.

The scenario with strengthened energy efficiency measures envisages a growth of the consumption of biomass for combustion for this purpose, in the period 2006 – 2020 of only 5.7% to an amount of 227 ktoe (2640 GWh) in 2020.

If the waste biomass for combined heat and power production is taken into account, then the consumption of biomass for combustion in 2020 will be 244 – 249 ktoe (2840 – 2900 GWh). This represents an increase of the consumption of biomass for combustion in the above period by 12 - 14%.

Solar Energy as Heat

In the past period the utilization of solar energy as heat was at a low level in the energy balance of the former Yugoslav Republic of Macedonia. At the same time, the former Yugoslav Republic of Macedonia uses very little solar power both with respect to the countries from the region as well as with respect to much more northern countries. With only about 4000 collection systems for utilization of solar power for heating of water in 2006, the share of the solar power in the total final energy consumption was just 7.4 GWh (0.6 ktoe) or 0.04%.

Since 2007, the Government is financially supporting the introduction of solar collectors however this is not enough for a more massive introduction of this fuel in the former Yugoslav Republic of Macedonia. The main reason is the low price of electricity and therefore the funds invested in the introduction of solar power as heat in the residential sector have an investment return period of 10 years.

To achieve a larger penetration of solar energy for production of heat in the residential sector it is necessary to increase the financial support and change the subsidy method from ad hoc into a continuous support mode. The support by the Government would reduce as the electricity price increases until the time when it reaches market value. One of the measures to stimulate the introduction of solar collectors could be the provision of soft loans to exchange asbestos roofs and in the same time install solar systems.

Regarding the greater level of introduction of solar systems in industry especially in the industries that consume larger quantities of hot water (dairy, meat and textile) where the return on the invested funds is of the order of 2 to 3 years it is necessary to stimulate the domestic producers for massive production of solar systems and facilitate the export and administrative procedures. This would improve the quality of the systems and would achieve economic benefits.

The strategy envisages utilization of solar power as heat primarily in the residential sector. Until 2020, 60000 - 90000 installations in the residential sector are planned and the total utilization of solar power (together with the commercial sector and industry) would be 60 – 90 GWh (5.2 - 7.7 ktoe) per year.

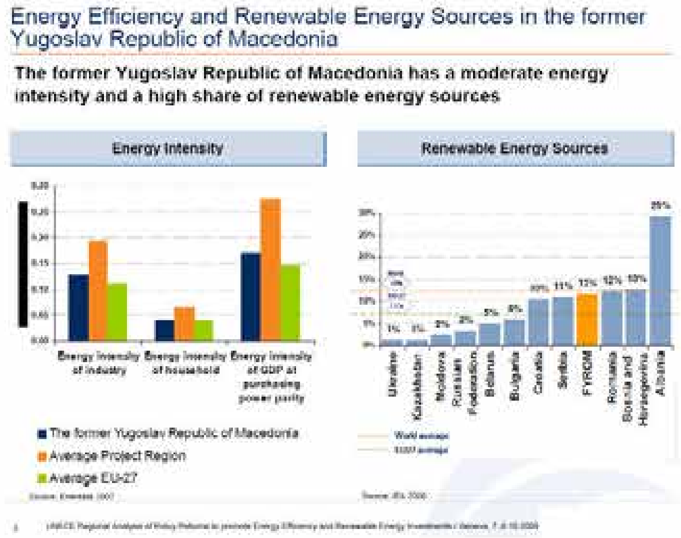
Biofuels

The participation of biofuels in the total fuel consumption in traffic in 2008 was a modest 0.2%.

With the fulfillment of the obligations stipulated in the Directive for participation of biofuels at a level of at least 10% in the total petrol and diesel fuel consumption in traffic in 2020, the share of this type of fuel should be 560 – 655 GWh (48 - 56 ktoe).

The provision of biomass for production of biofuels has not been sufficiently investigated and special studies and stimulating measures are needed to resolve this issue. According to the analysis so far, the maximum capacities of the former Yugoslav Republic of Macedonia for production of biomass for that use, together with recycling of the used oils and the utilization of animal origin fat, could yield production of biofuels in the amount of around 12 ktoe per year. However, we should not neglect the possibility to exceed this amount with the development of new technologies for biofuel production. In addition to the incentives for production of raw materials, it is especially significant to introduce incentives for production and use of biofuels. Having in mind that the directive allows import of biofuels the stimulations and obligations to use biofuels should be most important.

V. Comparation Datas: EU Region VS the former Yugoslav Republic of Macedonia



VI. Conclusions

The former Yugoslav Republic of Macedonia has considerable potential of renewable energy sources, namely small hydro power, geothermal, solar, biomass and also wind power. The draft energy strategy currently under revision does not foresee any targets for renewable energy sources other than large hydropower.

• The elaboration of a Renewable Energy Action Plan combined with periodic monitoring forms the foundation for the implementation of policy instruments promoting renewable energy growth in the former Yugoslav Republic of Macedonia. The Action Plan should cover renewable heating/cooling, electricity and biofuels and become an integral part of the National Energy Strategy.

• Topics to be covered within the renewable energy action plan comprise:

• Summary of national renewable energy policy

• National overall target and sector targets

• Planned Measures including time schedule of implementation and evaluation of the expected contribution to reach the national target

• Specific measures for the promotion of the use of energy from biomass

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Supply-side Ancillary Services at a Microgrid-based Smart Grid Topology

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***Abstract*—The ancillary services that could be provided by the supply-side of microgrids are expected to give great added value to microgrid-based smart grid topologies. In this paper, one very simple PV-plant control technique and the associated iterative control algorithm, operating in a microgrid environment are presented. This microgrid control scheme can supply different ancillary services to the grid, such as fast active power compensation, voltage regulation, back-up supply can be applied easily to existing facilities. The control scheme is applied to a small-scale microgrid during islanded or interconnected operation conditions. The experimental results show that supply-side management can provide various ancillary services to the grid, if they are supported by control algorithms of microgrid-based smart grid topologies.**

***Index Terms* – Grid Ancillary Services, Distributed Generation, Smart Grids, Microgrids, Renewable Energy Sources.**

I. Introduction

One of the most important parts of future smart grids topologies seems to be the microgrid, which is defined as a distribution grid including distributed generation, such as PV plants, energy storage units (battery banks or biomass-based plants) and controllable loads [1]. The ancillary services that could be provided by the supply-side or the demand-side of a microgrid are expected to give great added value to the future smart grid [2], [3]. Load levelization and demand-side management in general are extensively used to provide services like active power compensation, voltage regulation and even energy saving for islanded microgrids [3]-[6]. On the other hand, many researchers focus on controlling the active and reactive power of PV facilities in order to supply ancillary services to the grid [7]-[14]. Most of these efforts concern changes inside PV-inverters, constituting them expensive solutions, especially for existing facilities. The rest involve adding control circuits between PV-inverters and PV strings, thus risking the PV-plant reliability, in case of malfunction. In this paper one very simple PV-plant control technique and the associated microgrid iterative control algorithm are presented. This control scheme is compact, very cheap and easy to install. Its main parts are installed inside the PV strings circuits, thus avoiding substitution of the inverters and intersecting between the inverters and the PV strings and consequently risking the system reliability.

The PV-plant control scheme can supply different ancillary services to the grid, depending on the control strategy: In islanded operating condition, the cooperation with metering infrastructure and an iterative control algorithm can assist to fast active and reactive power compensation, voltage and frequency regulation and back-up supply.

The control scheme is applied to a real microgrid, during islanded operation conditions. Constant local voltage level supervision, as well as an iterative control algorithm are used to trigger the PV-plant. Experimental results show that the above control scheme can easily provide all the aforementioned ancillary services to the grid.

II. Description of the Smart Distribution Grid Topology

In a proposed by the authors microgrid-based smart distribution grid topology [5], [6], every DC load, generator or energy storage device is equipped with its DC-AC inverter and connected to the AC microgrid via a smart device called special control unit (SCU). SCUs are also necessary for the AC loads (or group of loads) and AC generators as well, as shown in Fig. 1 [5], [6]. The special control units (SCUs) are categorized in load SCUs (L-SCUs), storage SCUs (S-SCUs), generators SCUs (G-SCUs) and interconnection SCUs (I-SCUs), for connecting the small grid of the ac-bus to the remaining grid (SD). All SCUs consist of a simple metering module, a communication module, an activation module (actuator) and a "smart" module that is responsible for the decision making of each SCU. The last module is integrated into software that runs on a microgrid-dedicated PC. This topology is implemented at the facilities of the Technological Educational Institute of West Macedonia (TEIWM) and is shown in Fig. 2.

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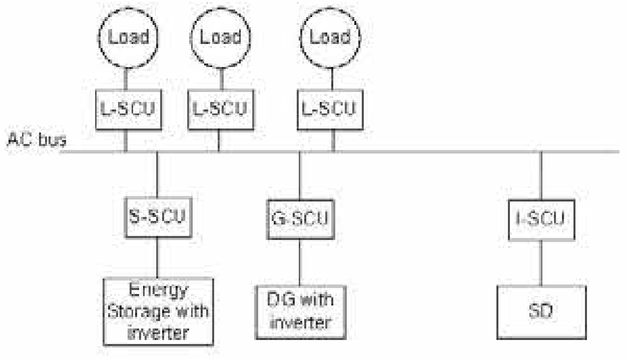

Fig. 1: A microgrid-based smart distribution grid topology.

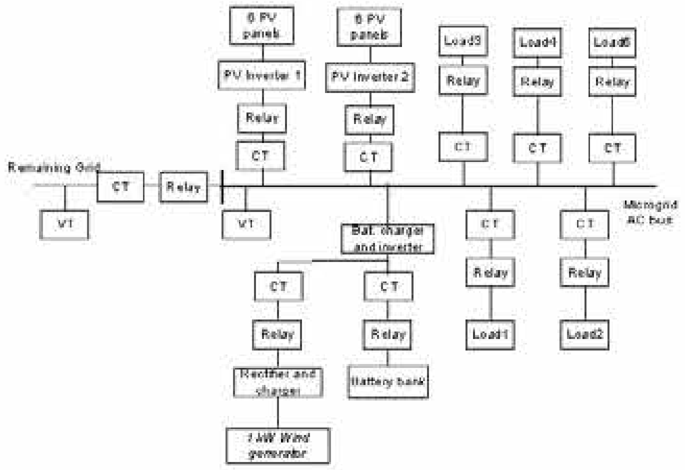

Fig. 2: Implementation of the smart distribution grid topology. TEIWM microgrid.

The microgrid consists of two PV-inverters of 1 kW each, with 6 connected PV panels each, five loads of approximately 2500 W maximum consumption, a 600 Ah battery bank with its inverter and one wind generator of 1 kWp with its rectifier-charger. Ten SCUs are needed: Two for the PV plants, five for the loads, one for the battery bank, one for the wind generator and one for the interconnection to the remaining grid. Each SCU contains one current transformer (CT), one voltage transformer (VT), one actuator-relay and communicates with the microgrid-dedicated PC via cables and a Data Acquisition Card (DAQ: NI6008). However, due to the common AC bus, only one AC VT is needed and one DC VT for the battery bank. At the microgrid-dedicated PC, a software application in Labview processes the input data, incorporates the control algorithm written in Matlab and derives the proper output commands every second or less. In Fig. 3 the laboratory set-up is shown and in Fig. 4 the Labview application.

III. The PV-Plant Control Technique and the MatLab Control Algorithm

The PV-Plant control technique consists of proper actuator-relay combinations that are applied at the PV strings circuits. The number of selected actuators depends on the required PV power to be controlled.

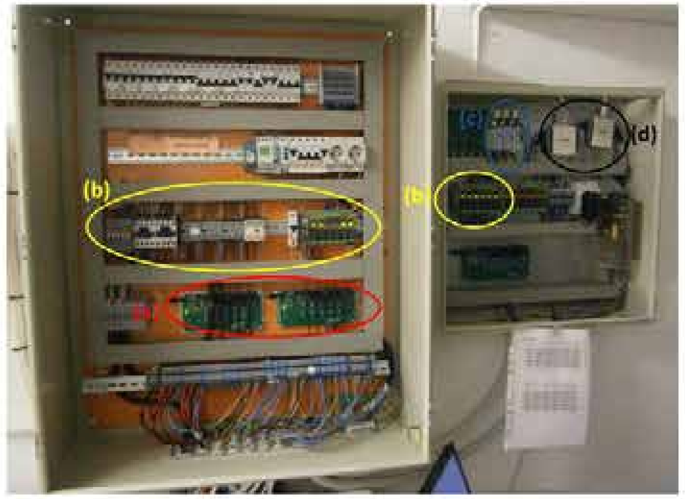

Fig. 3: The laboratory installation of the microgrid: (a) The ten CTs, (b) the relays, (c) the ac voltage sensors, (d) the DAQ cards.

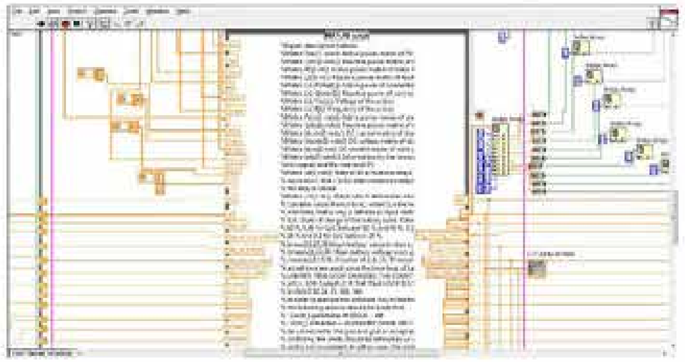

Fig. 4: Part of the Labview application and the MatLab control algorithm.

At Fig. 5, one example of the applied control on a typical PV plant is demonstrated. At the specific example, the PV output power can vary theoretically between 70 % and 100 % of the PV-plants capacity, with 3.3 % steps. It is obvious that the output power step can be different if the actuators are installed at one or three panels. The interruption of the string circuits during the change of the relays state does not affect the continuous PV power supply due to the dc-side capacitors of the PV inverters.

At this technique, one drawback is spotted: In practical applications, where MPPT option is in operation, the output power step (3.3 % at Fig. 5) cannot be predicted exactly. However, this drawback can be overcome by the iterative nature of the control algorithm. The relays can be triggered following various patterns, depending on the desired ancillary service to be supplied. In this paper, the PV relays are managed by the Labview application that collects energy measurements from the microgrid and determines the desired PV plant power production. The software application that is developed at TEIWM is executed every second or less and uses feedback variables from its previous execution.

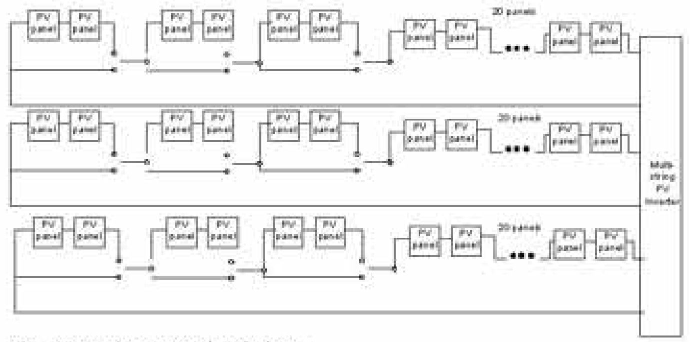

Fig. 5: PV-plant control technique.

IV. Experimental Results

The PV control technique is applied on both PV strings of Fig. 2. Since the lower voltage operation limit of the PV inverters is 150 V, one (1) actuator is installed at equal number of the six panels of each string. Each relay of the PV-strings is triggered by the respective digital output of the DAQ cards.

The real-time voltage and frequency surveillance and correction step of the control algorithm (sub-Section III.A) had an excellent response during island operation conditions: The maximum discharge current was deliberately set to 70 A. Load No5, a 1 kW electric motor was switched on at t_1=15h:49min:07sec, leading the batteries to discharge in a current bigger that 70 Amps. Fig. 6 shows the batteries discharge current over time (mean values over 1 second periods). Fig. 7 presents the power production of the two PV plants and the power consumption of the five loads. Three seconds after t_1 (t_2=15h:49min:10 sec), the motor's power consumption reaches the nominal value of 1000 W. Fig. 8 shows the PV-relays and the less critical loads-relays state over time. The PV-relay1 is activated immediately during the motor start-up (15h:49min:08 sec), since the battery discharge current reaches 72 Amps. Due to the PV inverter's MPPT, the PV1-plant power production is not increasing rapidly. At t_2, after the motor's start-up, the battery discharge current is still beyond 70 Amps (83.63 Amps), leading to the activation of PV-relay 2, as shown in Fig. 8. The increased PV plants power production is not enough to drop the battery discharge current below 70 A, leading to the rejection of the motor at t_3=15h:49min:11 sec. At t_4=15h:49min:13 sec, the power production of the PV plants starts to reduce due to weather conditions, leading to battery discharge current beyond 70 Amps at 15h:49min:14 sec. Immediately, the load4 relay is deactivated, leading to the rejection of the fourth load. At Fig. 9, the load profile is also presented.

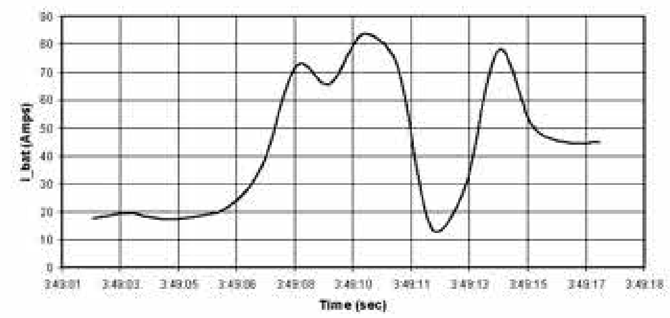

Fig. 6: Battery discharge current over time.

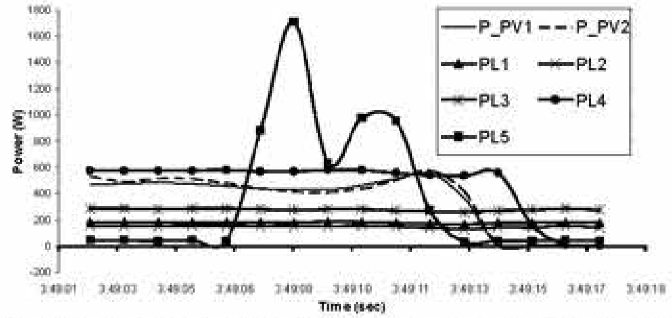

Fig. 7: Power production of the PV plants and power consumption of the five loads.

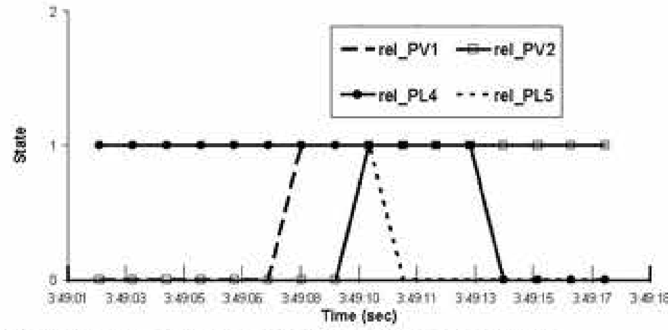

Fig. 8: PV-relays and the less critical loads-relays state over time.

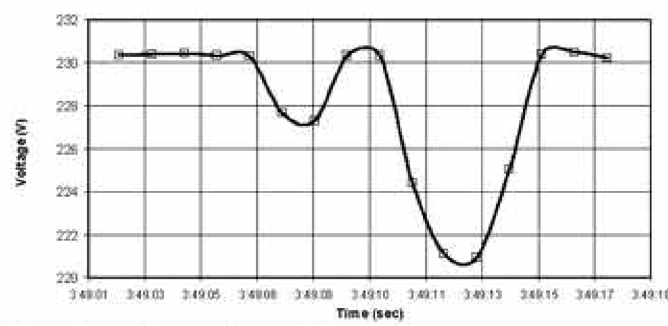

Fig. 9: Microgrid's AC voltage profile.

The load shedding policy (sub-Section III.B) was implemented successfully and resulted in increased reliability operation. Fig. 10 shows the load power consumption profile, with and without the PV-plants ancillary service application. At the same figure, the PV-plants power production is depicted. The microgrid was operating in island mode until 11.30. At that time exactly, the connection to the grid was planned to be established again. However, at 11.28 am, the batteries' State of Charge (SoC) changed state, due to the previous long batteries discharging period. It is obvious that with the PV ancillary service application, the change of the SoC state led to the PV1-plant relay activation. Thus, the PV1-plant increased power production from 619 to 719 W, and any load rejection was avoided. On the other hand, without the PV-plants ancillary services application, the change of the SoC state led to the rejection of the less critical load of the system. At 11.30 am, the sudden decrease of the power production by the PV-plants is due to the voltage disturbance that occurred during the connection of the microgrid to the remaining grid, as it is shown at Fig. 11.

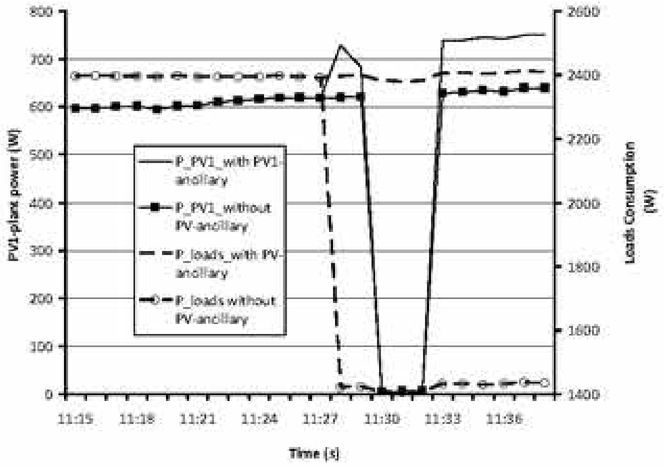

Fig. 10: Load power consumption profile and PV-plants power production, with and without the PV-plants ancillary service application.

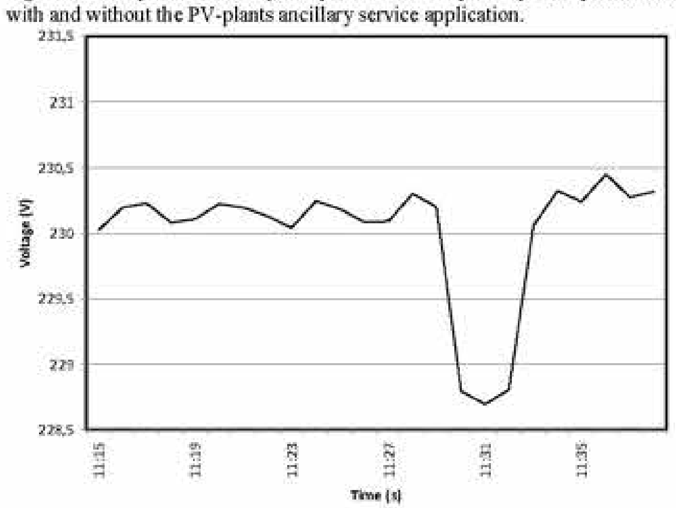

Fig. 11: Microgrid's AC voltage profile

V. Conclusions

The ancillary services that could be provided by the supply-side or the demand-side of microgrids are expected to give great added value to microgrid-based smart grid topologies. In this paper, one very simple PV-plant control technique and the associated control algorithm, operating in a microgrid environment, are presented. This control scheme is compact, very cheap and easy to install. Its main parts are installed inside the PV strings circuits, thus avoiding substitution of the inverters and intersecting between the inverters and the PV strings and consequently risking the system reliability. The iterative nature of the control algorithm permits correction actions until the desired operation condition is met.

The PV-plant control scheme can supply different ancillary services to the grid, depending on the triggering mechanism and the control strategy: In islanded operating condition, the cooperation with metering infrastructure and control algorithms can assist to fast active power compensation, voltage regulation and back-up supply.

The new PV-plant control technique together with the accompanied control algorithm are applied to a microgrid and the experimental results indicated that they can supply voltage control and assist in less load rejection during island operating conditions, thus improving significantly the reliability indices of the electric grid.

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Comparative analysis of selection suitable feedstock for biodiesel production in the former Yugoslav Republic of Macedonia

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Abstract - As a country which aspires to EU, the former Yugoslav Republic of Macedonia is trying to keep up with current regulations as part of renewable energies, and the limitations of the components of exhaust emissions. Regarding biofuels the country has taken some steps to produce biodiesel, which is far from enough, primarily because of raw material imports. Here we consider the possibility of producing biodiesel from industrial culture that is conducive to growing in our region. It is made comparative analysis between tobacco and oilseed rape bearing in terms of their suitability as raw material for biodiesel production. Adopted conclusions are based on the made analysis .

Index terms – biodiesel, biofuels, renewable energy, tobacco, oilseedrape

I. Introduction

The national strategies for the development of energy and environmental investments, emphasized that country has the potential for green energy which is not used enough and in the same time, there are obligatory conditions that at least 20 percent of the total energy to be produced from renewable sources, untill 2020.

In this segment of the thesis is given analytical research on the suitability for growing raw material for biodiesel production. Arguments are offered subject to a SWOT analysis, where we come to the conclusion which one of the offered two cultures is more appropriate for this region as feedstock for biodiesel.

II. Methodology

The study methodology is made by comparative analysis or comparison of the characteristics of both cultures (tobacco and oilseed rape), the amount of oil that can be obtained, yield per hectare, the impacts on soil, etc.

Conclusions are made on the basis of the preliminary SWOT (Strength-weaknesses-opportunities-threats) analysis.

III. Tobacco use as feedstock for biodiesel

Tobacco is traditionally a strategic product for this region because of its social aspects (it is the main cash crop and hire a significant workforce in rural areas) and the relevant factor of export trade. EU guidelines for finding environmental green energy as a renewable source, is an extension of the campaign against smoking, witch leads to conversion of tobacco to a raw material for biofuels.

Production and marketing of tobacco and tobacco products accounted for 3.2% of gross domestic product. The tobacco industry accounts for 3.9% of total industrial production and 4.1% of total employment in the industry. Tobacco accounts for 69% of the total area under industrial crops.

Fig.1 Plantations of tobacco

The standard varieties of tobacco seeds which are raise in Pelagony region, reaches yield 500kg to 1.500kg per hectare. Tobacco seeds contain 39.0% to 41.2% oil, which can be extracted to about 32.0% technical oil suitable for biofuels. The rest of the extraction, about 70.0% is such call as "kjuspe" that substantially contains 32.0% to 44.0% protein, 8.0% to 15.0% oil, moisture 6.0% to 10.0%, fibers up to 25.0%.

Tobacco is a valuable raw material for oil, which is the basis for biodizel production. The experiments carried out at the Institute for Tobacco Prilep obtained are varieties of seeds, whose yield of one plant reached up to 242 grams per one blade. Their experts are working on the prototypes of tobacco , with high level of extracted oil, later used for biodiesel production. Tobacco gives 50 to 240 grams of seed stalk.

According to the findings of previous research in this region, is a possible seed yield of 3.0 to 4.0 t/ ha, which means from 900 to 1,200 kg/ ha of technical oil for producing biofuel.

Experiments are done in an institute in Italy, derived varieties of tobacco whose provide up to 6.0 tonnes of seed per hectare, and it means that tobacco is among of oilseed crops with the highest yield of oil, far beyond rape, sunflower.

According to these characteristics and analyzes made in The Tobacco Institute Prilep, it is obvious that "kjuspe" will represent excellent basis for food production for small and big goods, chicken, fish. You can also use other parts of the plant. The waste is used for animal feed, and the leaves of chemicals for pharmaceuticals, vitamins and antioxidants.

- *The tree* is a good raw material for the production of paper and organic waste. It contains long and thin fibers, which makes it excellent basis for getting on quality paper.
- *The leaf* of tobacco we can consider as a treasure of a series of alkaloids and chemicals that can be the basis for applications in the pharmaceutical and chemical industry.
- *The biomass* that can be obtained from the unit area can be considered as an important component in the production of biogas and organic fertilizer.

SWOT Analysis - Tobacco

Strengths

- Good environmental production conditions
- Long tradition of tobacco production
- The oil of tobacco does not use as a food
- Achieved high quality
- High yield of planted areas
- The tree is a good raw material for the production of paper and organic waste
- The tobacco leaves contain good usefull in the pharmaceutical and chemical industry.
- Obtaining high-protein feed
- Existence of natural growth potential of this crop - climate (especially Pelagonian region)
- Highly qualified staff, who will work on further development of this culture

Weaknesses

- Lack of legislation for modified varieties
- Yields of seed per hectare is not very high
- Yields of oil seeds in the existing varieties of tobacco are not so high
- It is necessary appropriate machinery for efficient collection of cups with seeds
- Tobacco goods saps nutrients from the soil, so it must be plant over one year on the same soil

Opportunities

- Introduce greater incentives to increase production
- Biomass which can be obtained from the unit area can be considered as an important component in the production of biogas and organic fertilizer
- Opportunities for development of small private businesses, especially in Pelagonian region (especially the Prilep region)
- The possibility of involvement of a large number of unemployed families, thereby reducing unemployment
- Introduction of modified varieties with higher yields
- Existence of human research potential of modified varieties with higher yield of seed

Threats

- Reduce the quantity of exports of tobacco as raw material for cigarettes
- If you use modified varieties with greater quantities of seed, the quality of the leaves may fall.

IV. The oilseed rape as a feedstock for biodiesel production

Oilseed rape is traditionally grown for animal feed and it is a relatively new crop for the production of edible oil. Oilseed rape is mainly used for edible oil production and oilcakes for feeding livestock, but also it is the leading oilseed crop for the production of biodiesel. The increase in production of sunflower and oilseed rape is not just a matter of preference of manufacturers, but also national interest.

The production of major oilseed crops (sunflower, oilseed rape and soybean) have significantly developed. Financial support should be provided for manufacturers to stimulate the cultivation of these crops, increase the use of certified seed and develop new varieties.

From one ton of oilseed rape seed are received about 350 kg of oil and about 650 kg cake. Through the prism of unit area, it means – one ton oil per hectare and two tonnes cake per hectare. These economic indicators are from the practice of Bavaria, as a positive example for the use of renewable energy. The realized average yield of two tons per hectare, with an oil content of 36 percent from one hectare of oilseed rape it real can get 712 kg of oil and approximately the same amount of biodiesel. The average sunflower yield of 1.3 tons per hectare with oil content of 40 percent, can give 520 kg of oil. Ie, 520 kg of biodiesel.

In this region there are currently over 100,000 hectares of abandoned arable land, which provide great opportunities for greater representation of oilseed plants. For five years, with an annual increase of the manufacturing areas of 4,000 hectares, the total arable land in oilseed crops can reach 20,000 hectares. There is little more if you had average yields of two tons per hectare.

According to estimates by The World Organization for Food and Agriculture – FAO, since now, for production of raw materials for fuel, there is being used only one percent of arable agricultural land globally. However, logs rapid rise in coverage of surfaces, for the production of fuel from oil crops as it is a cost-profit business with the fastest growing. So, 2020 is forecasted that agricultural areas for the production of raw materials for biofuels will increase about 3%. But in 2050 the arable land for biofuel crops will take 20 % of agricultural land globally, because the biofuel is the most reliable market for agricultural products in the world. It provides opportunities for achieving major savings, especially in poor countries with continued higher oil prices in recent years.

Fig.2 Plantings of oilseed rape

Increasing of the area under oilseed rape, despite producing cooking oil, fodder and crop rotation, is also a condition required by The European Union to reach the target 20/20/20. However, recent analyzes of the Ministers of Agriculture of The European Union show that, to prevent the rise in prices of essential items and food shortages, will have to make a balance between the areas planted with raw materials for biodiesel and areas with basic crops for food. This request is justified by data from the World Food Programme, under which the 2030 global food consumption will increase by 60 %.

SWOT analysis - oilseed rape

Strengths

- Good environmental production conditions
- High-yield seed
- A high percentage of oil extracted from the seeds
- Getting the animal feed

Weaknesses

- A relatively young culture in our region
- This culture is food for people
- Areas planted with this crop in our country are very small
- Currently, this raw material is of import origin

Opportunities

- Plantations of this crop perform decontamination of polluted environment with heavy metals
- Utilization of biomass residues as a fuel
- Introduce incentives to increase production

Threats

- The utilization of this crop as a feedstock for biodiesel, reduces the quantity of food produced

V. Results

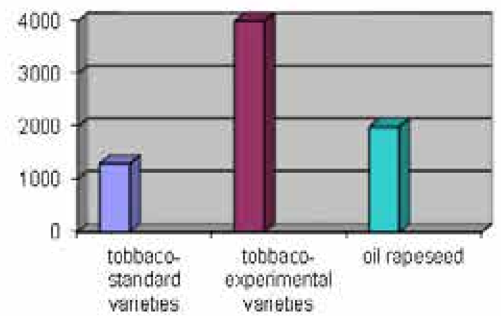

Fig.3 Yield per hectare of individual industrial crops (kg)

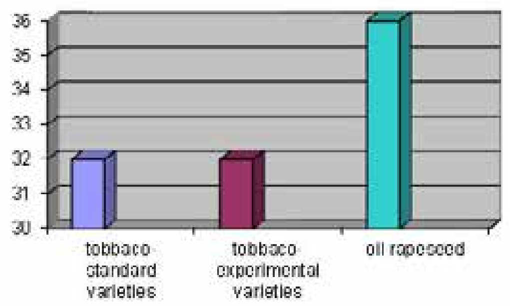

Fig.4. Quantity of biodiesel technical oil from seeds per 1ton of certain industrial crops (%)

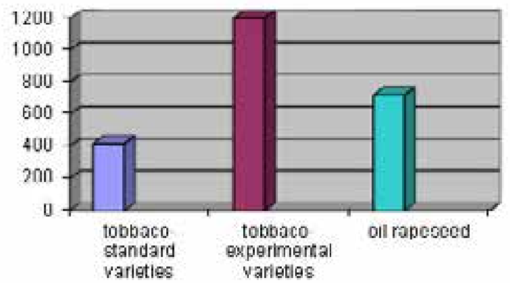

Fig.5 Amount of biodiesel produced from 1 ha of certain industrial crops (kg)

According to the previous SWOT analizes, we come to the conclusion that our region especially Pelagonian region, where there is a tradition of producing tobacco, then human resources available to the country, the amount of planted crop, the possibility of developing small businesses, reducing unemployment, large yields that this culture gives per hectare ecological farming, special and very important – " the oil obtained from the seeds of tobacco, not used as food ", as suitable feedstock for biodiesel production is tobacco. All previously will be financially viable and justified only in circumstances where we have modified varieties with higher yields of seed, appropriate machinery for treating tobacco cups and presses the seed.

The country has to play particularly important role for adopting appropriate legislation, greater incentives for tobacco (for seed varieties with higher yields), approving production of modified varieties, funding research in this area. This will reduce the import component of biodiesel production in the country and in the same time will offer the possibility for export oil from tobacco as raw material for biodiesel.

In any case we should make a proper balance between modified varieties and existing varieties that give high yields with high quality leaves, which is export-oriented component.

VI. Conclusions

Oilseed rape at this point is less suitable feedstock for biodiesel production, in comparison of tobacco for our country. It gives a high percentage of biodiesel technical oil, but it is still necessary food, so in some future conditions where will not be affected quantities of food production, oilseed rape will be suitable raw material for biodiesel production.

VII. Acknowledgements

Our country in anticipation of meeting the program targets for renewable energies 20/20/20, where one of the targets is 20% share of renewable energies in the total energy, with 10% share of renewable energies in traffic sector, should seriously start the appropriate alternative for the production of biofuel, as it can reduce import components, much more we have climate and tradition for this production.

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Harmonic Behavior of Residential Low Voltage Appliances for Load Signatures Formulation

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***Abstract*—In this paper a measurement campaign regarding the harmonic behavior of Low Voltage (LV) residential installation is presented. The measurements have been implemented under different sampling frequencies, 0.0167 Hz and 0.1 Hz, in the main feeding panel of LV residences, and the residents have been asked to keep a detailed record about their consuming behavior. The aim of this analysis is to investigate the harmonic behavior of LV appliances under aggregated measurements in order to define the most harmonic polluting LV loads. The latter could in turn contribute in identifying those appliances that embed particular features, in this case the harmonic behavior, in order to quantify those features under suitable formulations for the development of distinct load signatures. The results indicate that for specific appliances, their load signatures could depend on their harmonic behavior and thus, enhance the efficiency of Non-Intrusive Load Monitoring (NILM) techniques.**

***Index Terms*—Harmonic measurements, load signatures, NILM, residential loads.**

I. Introduction

Energy efficiency has attracted a lot of attention during the last decade mostly due to the acceptance that the constant growth of energy demand could not only be met under corresponding increase of energy production, even if this is performed by increasing the production capacity with Renewable Energy Resources (RESs). In 2007, the Expert Group on Energy Efficiency of the United Nations Foundation justified the importance of energy efficiency under the statement "World governments should exploit energy efficiency as their energy resource of first choice because it is the least expensive and most readily scalable option to support sustainable economic growth, enhance national security, and reduce further damage to the climate system" [1].

Researchers and engineers are nowadays motivated to develop innovative approaches in order to improve energy end-use and supply efficiencies. Governments provide incentives towards the improvement of both the public and private buildings' energy efficiency, while researchers investigate the effect of demand site management [2]-[3] and load shifting [4]-[6] on peak shaving and energy demand reduction. The idea of monitoring and controlling the consumption in real time is expected to be initiated via the widespread installation of smart metering devices [7] while, the online management of residential consuming behaviors will be determined by the capability for load identification in real time. The latter is expected to be implemented by NILM methodologies [8] and this is why a lot of research is being performed towards the development of unique load signatures.

NILM methodologies utilize fundamental (i.e. nominal values) features [9] along with special characteristics of LV appliances [10]-[11] (e.g. harmonic and transient behavior) in order to provide robust formations (i.e. load signature) that would describe the activation/operation of an appliance efficiently for load recognition under actual operating conditions.

In this paper, measurements regarding the harmonic content of LV residences under two sampling frequencies are presented. These aforementioned sampling frequencies, i.e. 1 sample/min for the 1st and 1/sample/10 sec for the 2nd, have been chosen since they are expected to meet the specifications of most of the available commercial smart meters [12]. The process of the measured data was based on detailed information regarding the consuming behavior of the residents. The harmonic content is expressed in this analysis only by odd current harmonics within the spectrum 0-550 Hz (i.e. up to the 11th harmonic). The paper investigates whether under aggregated measurements the harmonic content could be analyzed to its components. Thus, the harmonic contribution of some appliances to the total harmonic content could constitute a special feature of these appliances towards the development of their load signatures.

This paper is organized as follows: in section II the measurement device along with some information about the measured residences are presented. In section III, the measured data about the harmonic content and its decomposition to each component are discussed. Finally, section IV is devoted to conclusions.

II. Harmonic Measurements

A. Measurement Device

All measurements have been implemented with the "*HT Italia GSC57 Electrical Tester and Analysis of Single and Three Phase Systems*" measurement device. As logger meter, GSC57 can recording all values of electrical parameters (Voltages, Currents, Powers, Power Factory, Energies, etc.), performing harmonic analysis of Voltages and Currents (up to 49-th order) and consents a supply voltages quality analysis (sags, spikes, breaks) according to EN50160 standards reference. With optional probes GSC57 can also performing measures and recordings of environmental parameters as Temperature, Humidity, Illumination (Lux) and Leakage currents very important for troubleshooting problem of RCDs wrong tripping. Each measure can be stored inside instrument memory, recalled on instrument display and transferred to PC using the management standard software in way to create a professional relation which will improve the quality of work.

B. Measurement Parameters

All measured residences refer to single phase installations, and each residence was measured twice for approximately 24 h under two different sampling frequencies. The 1st measurement set was implemented under a sampling frequency of 0.0167 Hz (1 sample/min) while the 2nd under a sampling frequency of 0.1 Hz (1sample/10 sec). The former sampling frequency is expected to meet the specifications of commercially smart meters while the latter was chosen in order to examine whether the increased density of extracted information from the measurements about the harmonic order, could provide more robust load signatures. For each installation the odd harmonics up to the 11th were only measured since the odd harmonics are negligible [13]. The information about the activation/deactivation of each appliance could contribute in assigning harmonic variations to the corresponding appliances that have produced them. By that sense, it could be feasible to formulate harmonic fingerprints that would in turn constitute a part of the load's signature for efficient identification. In Table I the list of the utilized appliances for the two residences that are analyzed in this work are presented.

Table I
Utilized Appliances During Measurements

Residence	
1	2
TV	TV
Oven	Oven
Laptop	Washing machine
Washing machine	Desctop
Hair dryer	Laptop
Electric iron	Electric water-heater

III. Measurement Results

A. Residence 1

In Fig. 1 the measured 3rd harmonic for the residence #1 is presented for a time period of 26.5 hours (starting measurements at 15:05 and ending at 17:38 the next day).

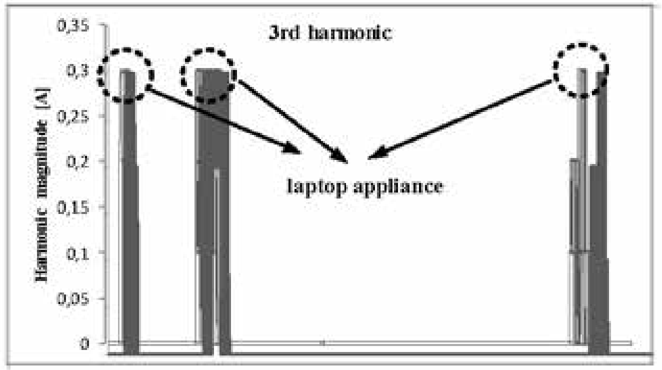

Figure 1. 3rd harmonic for residence #1 with a sampling frequency at 0.0167 Hz.

Based on the activation/deactivation record of the residences, for the first two time periods of Fig. 1 that the 3rd harmonic was present, the combinations of appliances that were operating are as presented in Fig. 2.

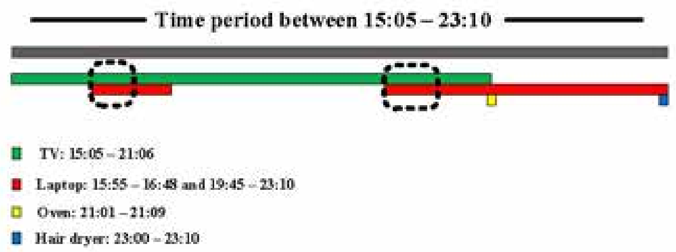

Figure 2. Operating appliances during the presence of the 3rd harmonic

In Fig.2 the dotted frames refer to the time periods during which the 3rd harmonic was present. It is easily observed that for these aforementioned time periods the operating appliances were the laptop and the TV. Therefore, so far the measurements indicate that both appliances could be considered to produce the measured magnitudes for the 3rd harmonic. On the other hand, in Fig. 2 it is clear that the 3rd harmonic is present only after the activation of the laptop appliance since during the operation of the TV only, no values regarding the 3rd harmonic were recorded. Finally, during both the operation of the oven and the hair dryer no harmonics were measured. It has to be mentioned that for this residence and under the specific sampling frequency higher harmonic orders were not measured.

In Fig. 3 the 2nd measurement set (different day) for residence #1 regarding the 3rd harmonic under the sampling frequency of 0.1 Hz is presented.

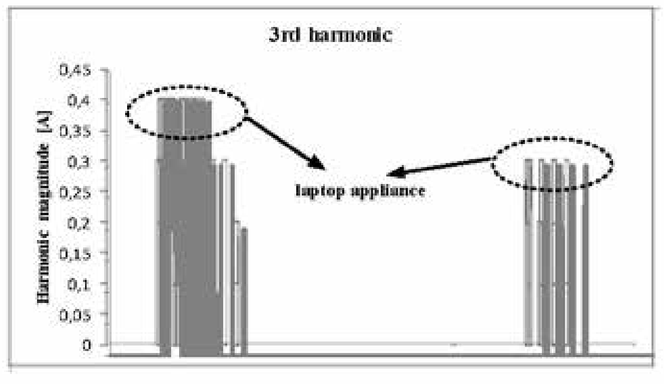

Figure 3. 3rd harmonic for residence #1 with a sampling frequency at 0.1 Hz.

Based on the residences' record about the activation/deactivation of the utilized loads, Fig. 4 illustrates the combination of appliances operating during the measurement set. The dotted frames in Fig. 4 denote time periods with recorded values for the 3rd harmonic. It has to be clarified that no higher harmonics were recorded for the 2nd measurement set with lower sampling frequency.

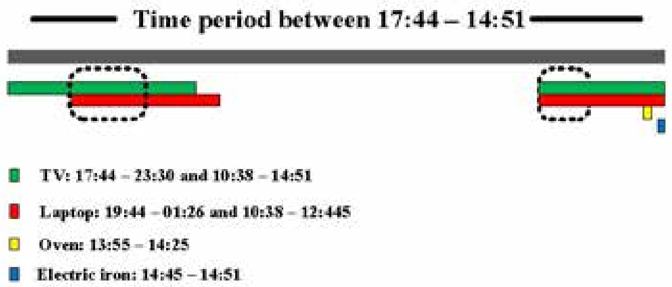

Figure 4. Operating appliances during the measurement with sampling frequency at 0.1 Hz.

By Fig.4 it is concluded that the laptop appliance was the source of the 3rd harmonic since the recording of 3rd harmonic values coincides with the activation of the laptop. Moreover, it is observed that when the TV was operating alone no harmonics were measured. Therefore, the harmonic fingerprint of the laptop appliance could be utilized as a special feature towards the development of a robust and distinct load signature.

B. Residence 2

In Fig. 5 the 3rd harmonic for the 1st measurement set under a sampling frequency of 0.0167 Hz is presented. The conclusion about the origin of these recorded values is deduced by the combination of operating appliances during the measurements presented in Fig. 6. The PC and electric water-heater appliances were activating almost simultaneously but the 3rd harmonic was still present even after the deactivation of the oven.

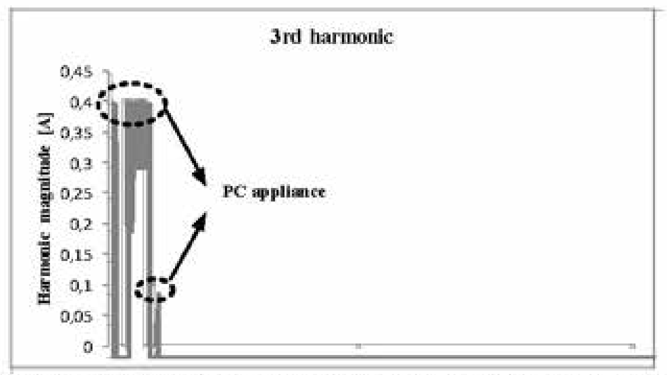

Figure 5. 3rd harmonic for residence #2 with a sampling frequency at 0.0167 Hz.

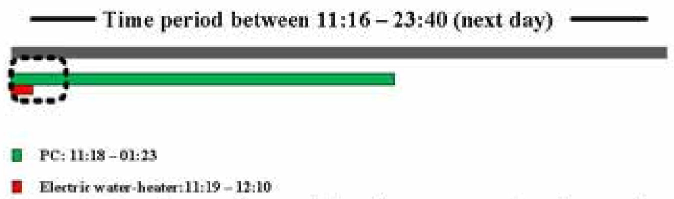

Figure 6. Operating appliances during the measurement with sampling frequency at 0.0167 Hz.

In Fig. 7, the combination of appliances operating during the 2nd measurement set (sampling frequency at 0.1 Hz) is presented. The dotted frames in Fig. 7 denote time periods with recorded values for the 3rd harmonic. The basic problem for this measurement set refers to the determination regarding the origin of the recorded 3rd harmonic values. Based on the 1st measurement set, it could be concluded that the 3rd harmonic values for Fig. 7 were produced by the PC appliance again. The problem relies on the difficulty in determining whether the washing machine appliance participates in the production of the harmonic values. The measurements showed that only the TV produced 3rd harmonic values at the magnitude of 0.2-0.4 A, while the simultaneous operation of the TV and the washing machine produced 3rd harmonic values at the magnitude of 0.2-0.5 A. Still, it is not clear the contribution of each appliance to the harmonic content (regarding the 3rd harmonic) formulation.

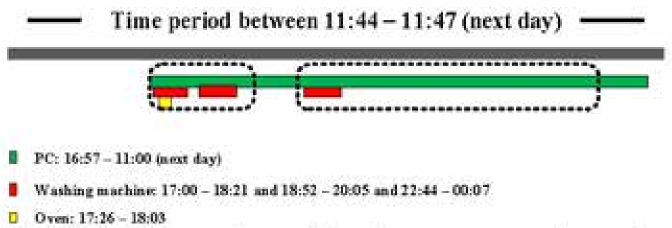

Figure 7. Operating appliances during the measurement with sampling frequency at 0.1 Hz.

On the other hand, the results of the measurements showed that for this residence, higher harmonics were also recorded. In Fig. 8 the magnitude of the higher harmonics is presented.

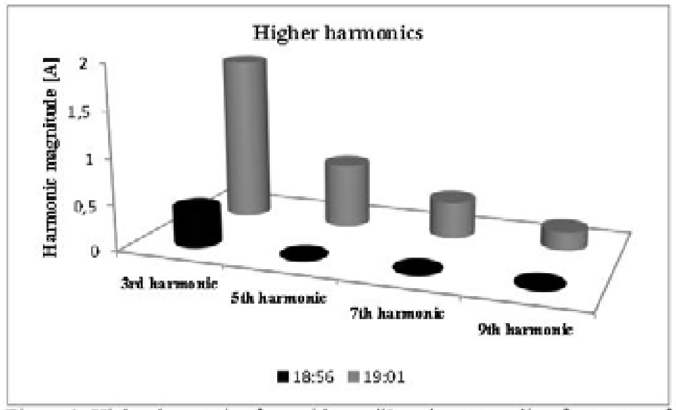

Figure 8. Higher harmonics for residence #2 under a sampling frequency of 0.1 Hz.

In Fig. 8 it is shown that higher harmonics were recorded during the simultaneous operation of the PC and the washing machine. Based on the observation that during the stand alone operation of the PC no higher harmonics have been recorded for both measurement sets, it is rational to conclude that these higher harmonics were produced by the washing machine. Although it is not clear which of the various operational modes of the washing machine actually caused these aforementioned harmonics, their presence could potentially contribute in developing appropriate harmonic fingerprints for efficient load signatures.

IV. Cocnlusions

In this paper the early results regarding LV residence power quality measurements are presented. The implemented measurements are focused on recording odd current harmonics with sampling frequencies that meet the specifications of commercially available smart meters. The aim is to investigate whether suitable harmonic fingerprints could be formed towards the development of distinct load signatures in order to improve the efficiency of NILM methodologies.

Two residences have been measured for two time periods of approximately 24 hours each, under different sampling frequencies. The residences were asked to keep a detailed record about the activation/deactivation of each appliance. Based on the latter, the odd harmonic magnitudes were processed in order to investigate whether specific harmonic fingerprints could be assigned to respective appliances. The results proved that for some appliances, their harmonic content could be utilized for the enhancement of their signatures' robustness.

The results presented in this work, show that nonlinear LV loads could be mapped based on their harmonic content. The latter could be in turn utilized in order to enhance load signatures with unique load characteristics and develop distinct load signatures. More measurements with combinations and stand-alone operations of various LV appliances are expected to validate these early results.

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A.Q.M.E.I.S.: Air Quality Meteorological and Enviromental Information System in Western Macedonia, Hellas.

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***Abstract*—An operational monitoring, as well as high resolution local-scale meteorological and air quality forecasting information system for Western Macedonia, Hellas, has been developed and is operated by the Laboratory of Atmospheric Pollution and Environmental Physics / TEI Western Macedonia since 2002, continuously improved. In this paper the novelty of information system is presented, in a dynamic, easily accessible and user-friendly manner. It consists of a structured system that users have access to and they can manipulate thoroughly, as well as of a system for accessing and managing results of measurements in a direct and dynamic way. It provides updates about the weather and pollution forecast for the next few days (based on current day information) in Western Macedonia. These forecasts are displayed through dynamic-interactive web charts and the visual illustration of the atmospheric pollution of the region in a map using images and animation images.**

I. Introduction

Web applications constitute valuable up-to-date tools in a number of different cases. One such case is their use in the management of environmental problems so as to protect civilians from any unfortunate consequences that these problems can cause. Their evolution, therefore, has been especially important in many cases, one of them being in the development of systems of administration of the air quality [1].The right of accessing environmental information has been enacted in European level through appropriate legislation, which are incorporated in the relevant Greek legislation see [2]- [6].

Nowadays, the combination of telecommunications and new technologies create a framework for developing such systems increasingly sophisticated [7]- [10] . That is just diffusion of environmental information and public access which was attempted effectively through the system codenamed EAP (Laboratory of Atmospheric Pollution and Environmental Physics) in Western Macedonia. It is developed for the first time in 2002 [11], providing the possibility for direct information to the public about the air quality, as it was recorded in the four atmospheric measurement stations established in the capitals of Countries Kozani, Florina, Kastoria and Grevena though an appropriate web-site, as well as SMS, with the possibility for extension of stations and also the historical measurements privilege [12]. For every station a previous and current index of pollution appears (in a scale 1-10) with an appropriate colour scale [13]. The system was expanded and upgraded in May 2010, which consists in transferring data, the way of presentation as well as the amount of information provided. Specifically it is recommended: a) the combine use of different methods of transportation in real or almost real time data of terminal stations measurements to a central base station b) the environmental information is promoted to the internet, with a properly designed dynamic website with enabled navigating of Google map [14], [15], [16].

In this paper the novelty of information system EAP is presented, in a dynamic, easily accessible and user-friendly manner. It consists of a structured system that users have access to and they can manipulate thoroughly, as well as of a system for accessing and managing results of measurements in a direct and dynamic way. It provides updates about the weather and pollution forecast for the next few days (based on current day information) in Western Macedonia. These forecasts are displayed through dynamic-interactive web charts and the visual illustration of the atmospheric pollution of the region in a map using images and animation images. Moreover, there is the option to view historical elements. An additional new function is the use of online reports to monitor, analyze, control and processing measurements, historical data and statistics of each station in real time over the Internet. This function focuses on designing an effective and user-friendly process. Finally, the management system of measurement stations, the administrator has the ability to dynamically create, modify and delete objects, points and information of each station on the GoogleMap. In this way the processing (update, delete, add) of points is easier.

The A.Q.M.E.I.S. application has been developed using open source software tools like HTML, Javascript, PHP and MySQL. HTML is the language for the Internet Interface design. The goal for HTML was to create a platform-independent language for constructing hypertext documents to communicate multimedia information easily over the Internet [17]. Javascript is a client-side scripting language that provides powerful extensions to the HTML used to compose web pages and is mainly utilised for checking and validating web form input values to make sure that no invalid data are submitted to the server [21]. PHP is the most popular server-side programming language for use on Web servers. Any PHP code in a requested file is executed by the PHP runtime, usually to create dynamic web page content. It can also be used for command-line scripting and client-side GUI applications. PHP is a cross platform programming language and can be used with many relational database management systems (RDBMS)[18]. MySql is a high-performance, multi-thread, multi-user RDBMS and is built around a client-server architecture. Also MySQL uses the Structured Query Language standard giving a great deal of control over this relational database system [19]. Finally, Apache server is responsible for expecting requests from various programs - users and then serve the pages, according to the standards set by the protocol HTTP (Hypertext Transfer Protocol) [20].

II. User Interface

In this section the user interface and functions of this application are described. There are three (3) levels of user access (groups of users). On the first level the user has the ability to be informed in real time about the weather conditions, the air pollution and air pollution indices in an area of interest using Google Map.The second level is for authorized users only, who can be informed analytically through reports about measurements of a specific time period. The third level is for the administrator, who has access to all information and who also inserts, updates or deletes data from the database. The administrator can also interfere dynamically and manage all the information of the GoogleMap.

A. Online Web Station Reports

The 'Online Web Station Reports' is a new online web feature which offers to the approved members of the application to monitor, analyze, check and process the measurements using statistics of each station in real time. Furthermore, the ability of pumping previous measurements is given; a function that did not exist in the web application until a short time ago. The login is achieved through the use of a special personal password that is given to the members by the support group of the web application. The users input the password and after validation, they can perform a number of available functions in a safe and user-friendly online web environment. More specifically the feature offers the following functions to its members: Presentation of daily, weekly, monthly and according to the user's choice values either for a chosen station of all its measured data or for specifically chosen measured parameters (sensors), with simultaneous calculation

Fig. 1.

and presentation of maximum, minimum, average values, sum, number and percentage of measurements in a table or the ability of output of data in MS Excel. The functions of the new web features are described in detail . There are four categories of Online Web station reports, i.e. daily, weekly, monthly and custom. Each report is displayed in three parts (forms). In the first form, by choosing a station the image is displayed as well as various information about the specific station (Fig. 1).

If the user does not choose a station, an error report appears. By clicking on 'Next', the second form of the report appears in which the user can choose which measure fields to be shown,as well as the measure time interval (5min or 60min) and the specific date that those measurements were taken (Fig. 2).

The dates differentiate according to the report category that the user will choose; more specifically, there are: a) Daily report: the current date appears. b) Weekly: the first day of the current week is set as the starting date. c) Monthly: the first day of the current month is set as the starting date. d) Periodical: the current dates are set as the dates (From - To) with the ability of changing the spaces (From - To) by the user

If the user does not choose any measure fields or chooses date in which there are no figures reported, then the system will display an error message. By clicking on 'Report' the algorithm moves to the last tab of the report where a table of contents appears in a dynamic way with information about the hour, the measure fields, measurement results as well as other statistical data (Fig. 3).

Also, the algorithm calculates and displays the number of measurements (e.g. '100 measurements were found'), the current page and the total number of pages (e.g. 'page 1 from 12'). Depending on the number of records, an equal number of pages is created. The application can display 25 measurements per page. Also the users can move to any page they wish so

Fig. 2.

Fig. 3.

as to have access to any measurement of interest. Every form of measurement also has a status field (numbers 0, 1 or 2). This table is used to check the validity of the measurements of a field. In this way, if there are no results for a specific date in one field, then the indication 'NO DATA' is displayed. All checks are made based on the status field. If, however the measurements in a field are wrong for a specific date due to various factors, then the indication 'Offscan' is displayed. In a similar manner, checks rely on the status field. For every measure field in a specific moment the following statistics are taken into account a) average, b) minimum value, c) date and time that minimum value was found, d) the number of records of the minimum value, e) maximum value ,g) the date and time of record of the maximum value, h) the total number of measurements, i) the % percentage. By pressing 'Excel' the measurements of the station can be displayed on Excel form, which the user is able to open or save it for later use (Fig. 4).

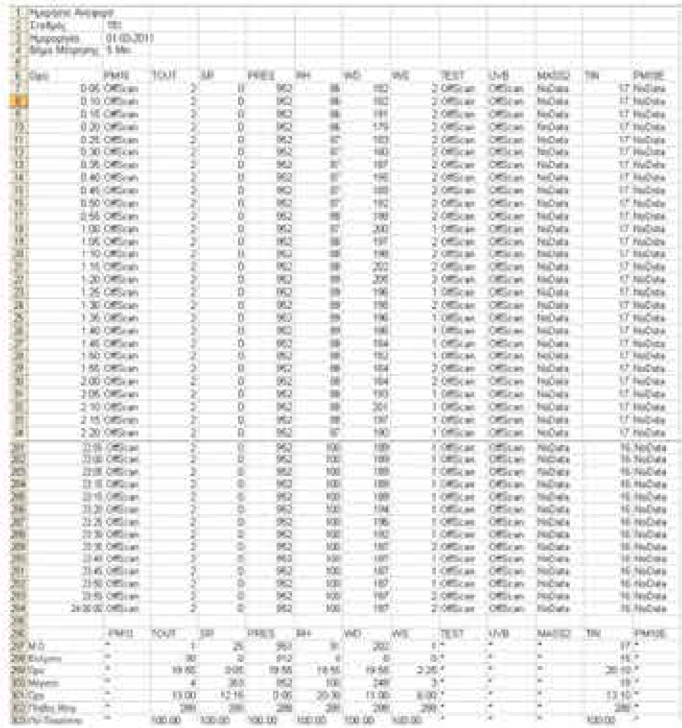

Fig. 4.

B. Manage Stations using GoogleMaps

Another innovation of the web application is the dynamic management of the measurements from each station in a simple way using an online geographical web interface. The administrator using this specific feature (Management of the Measurement Stations using GoogleMaps) can insert, delete and modify easily and simply data having as a purpose the dynamic renewal on the GoogleMap. This gives the advantage to the administrator to use the specific feature as a platform of visualization of information without having to write on their own not even a line of code for this purpose. Moreover, an important element of the feature is the easy expansion and integration N (N = count) measurement stations on the interactive GoogleMap.

Station management is made through the interactive interface of GoogleMap; the administrator of this application can insert, delete and modify dynamically a certain point (station) in an area (according to geographical latitude and longitude). To insert a certain station in the map, the following actions are required: a) the insertion of Municipality of choice: the user chooses through a list the one which the station belongs to; b) the insertion of the type of station of measurement: the user chooses if the station is meteorological or one that measures pollution or both. All the data is stored in the application MySQL database. As a last step, the administrator sets the name of the station, the longitude and latitude, municipality, address, description, type of station and the image of the station. (Fig. 5). Next, all information are stored into the database and are retrieved from there to be displayed dynamically (both the points and information) on the GoogleMap.

On the map users can see meteorological information as well as information about pollution from various stations and areas. For every station a previous and current index of pollution appears (in a scale 1-10) with an appropriate corresponding colour scale. By clicking on each point of the station the information (i.e. Online measurements, air pollution indices for the previous and current day, general information about the station) is displayed. The user may also activate or deactivate one or more points on the map [14].

To achieve the dynamic update of the measurement stations on the GoogleMap, the file airlab_markers.php is called. It is responsible for the creation and update of the XML file. More specifically, the data of the application, i.e. the name and the measurements of the station, their geographical position where they belong, the general information with the representative photograph of each station, even the representation symbol, are retrieved in XML structure, submitting the appropriate preset SQL question to the database, via the corresponding code of the php page. The XML file has an element (root-top level element) and especially the '¡markers¿ ¡/markers¿'. The remaining elements are nested to this. For the appropriate structure of the XML file, there is an additional code in the airlab_markers.php file. All necessary checks about the validity of the data then take place. The algorithm was realized by PHP scripts and the specific feature that was developed, is supported by the Internet Explorer, Firefox, Opera and Google Chrome browsers.

C. Weather Forecast in West Macedonia with Dynamic Web Charts

An additional new feature is the weather forecast with the aid of dynamic web charts, is committed to deliver the most reliable, accurate weather information possible. It provides free, real-time and online weather information for the web users with the state-of-the-art technology monitors conditions and forecasts in the area of Western Macedonia in the next few days (Fig. 6).

The information is produced in a high-end server in EAP / WMAQIS [22] and is read and stored in a database and it appears in the internet with the form of dynamic web graphs (Fig.7).

Meteorological parameters are temperature, humidity, wind speed, wind direction, accumulated precipitation, mixing height and total solar radiation. PHP scripts retrieves from the MySQL database the 24 average hourly values for each meteorological parameter (except for the accumulated precipitation, for which a total of 6 hours is taken into account) on each location in Western Macedonia. Next, the information is

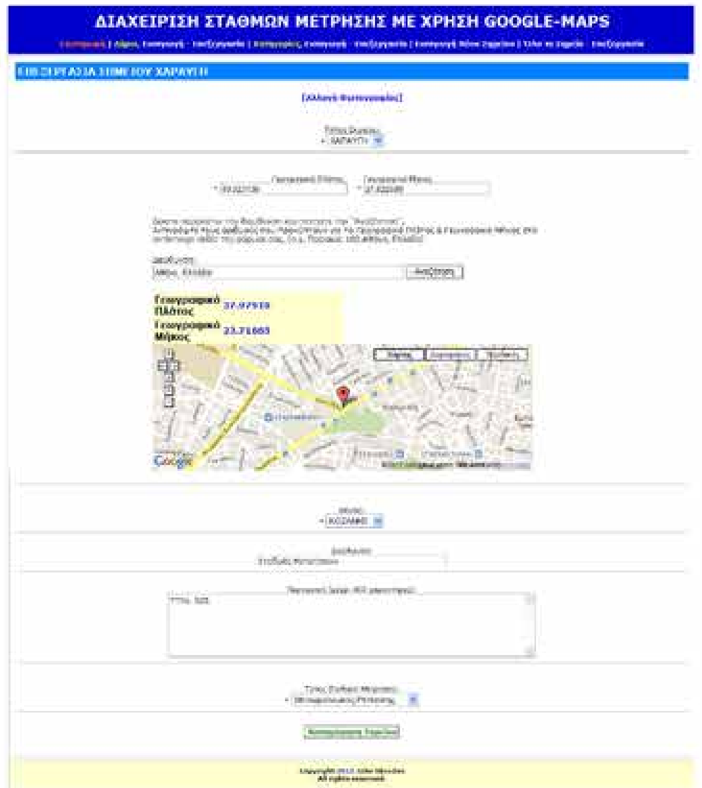

Fig. 5.

displayed with a graph. The user then can choose a location to see the weather forecast. By choosing 'History', the previous meteorological measurements and figures are displayed using graphs.

D. Air Pollution Forecast in West Macedonia

Another important part of the A.Q.M.E.I.S. application is the atmospheric pollution forecast of the pm10 (particulate matter) concerning the next few days in Western Macedonia. (Fig. 8). Our application displays dynamically these regions in a map using images; according to pollution percentages in a certain region, the corresponding colour scale is represented denoting the levels of pollution. Choosing 'region', 'pollutant agent', 'source of emission' and 'date', pollution for the previous and current dates, as well as the ones of the next three days are displayed . This part of the application uses javascript, while a very small part of the code was written in PHP (dates management).

The air pollution model produces image files (xxx.jpg) in the hard disc of the server in which javascript searches and then displays. In cases where not enough environmental data exist for a certain date, an image appears entitled 'Pollution Image Display Unavailable'. The necessary validation integrity checks of the dates are also made (from-to). Finally choosing 'history' the user can see older images of pollution rates in a certain region of Western Macedonia.

Choosing 'movement', a javascript algorithm is executed animating the pollution illustrations in the area of interest.

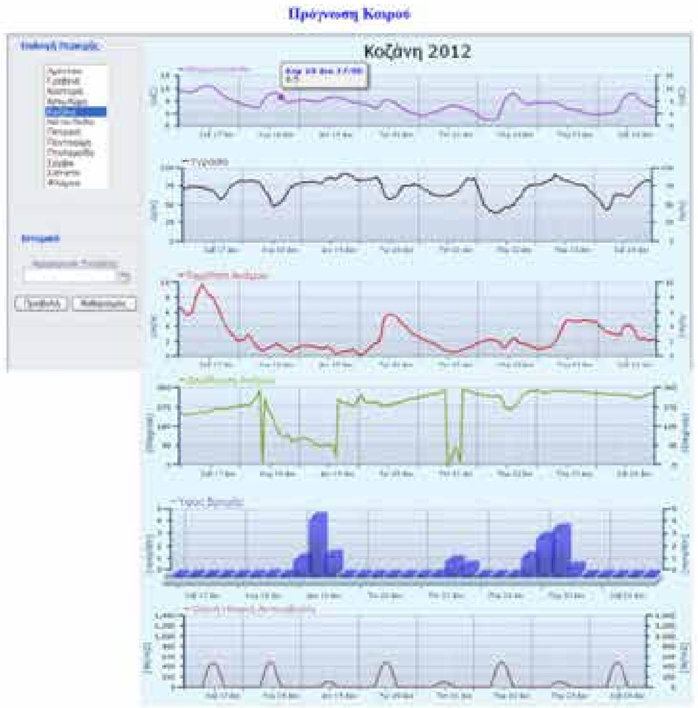

Fig. 6.

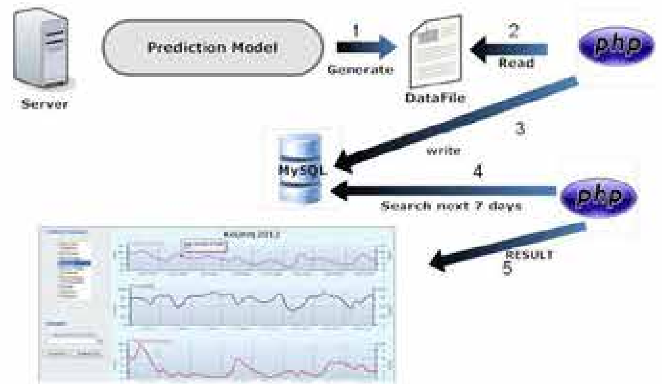

Fig. 7.

(Fig 9).

III. MySQL and Database Architecture

MySql is a very fast and powerful database management system. Allows the user to store, search, sort and recall data efficiently. This application stores all information in the MySQL database, so that they can be retrieved dynamically every time they are needed. The architecture of this database consists of a total of 23 tables. 8 tables (s001t05, s001t60, s002t05, s002t60, s003t05, s003t60, s004t05, s004t60) include measurements collected from the stations; they are used in reports and in the dynamic system for monitoring the air pollution, via an interactive chart. 's00x' refers to station x and t05 or t60 refer to a measure time interval (i.e. an average 5 or 60 minute measurement). The primary key is Date_Time, while the rest

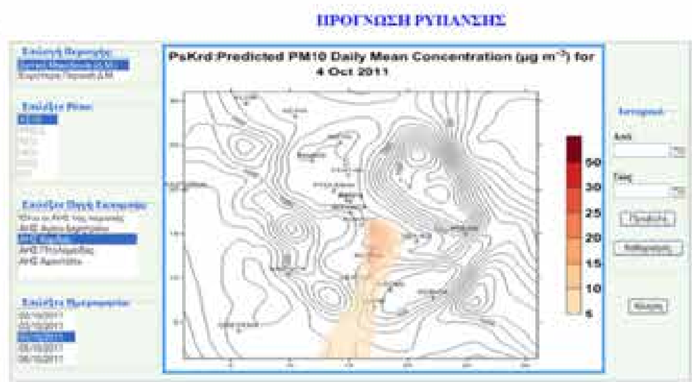

Fig. 8.

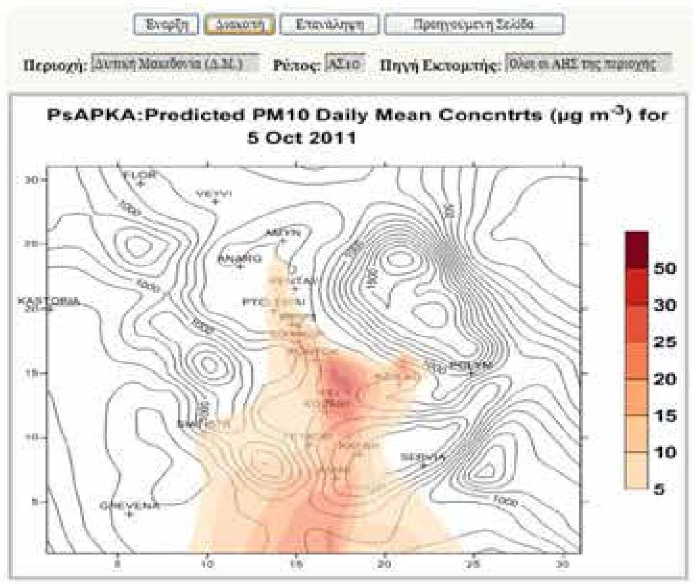

Fig. 9.

of the fields (value1 up to value32) store meteorological and environmental data. Tables 'city_info', 'points_categories' and 'points' are used for the management of stations that use Google Map. In particular, 'city_info' stores the town in which each point (station) is located, along with additional information. Fields include 'id' (main key), title, en_title, lat, log . Table 'points_categories' stores the station's category (fields: 'id' is the primary key, 'title' and 'en_title') . On the table 'points' points are set up, along with additional information. These fields are 'id' (primary key), 'category', 'city', 'en_city', 'address', 'title', 'description', 'lat', 'log', 'thumb', 'image' . Finally 12 tables (mamyntaio, mflorina, mgrevena, mkastoria, mkkomi, mkozani, mnpedio, mpetrana, mpontokomi, mptl, mservia, msiatista) which store weather forecast information are used. Every table represents a certain location in Western Macedonia. Fields DATE , HOUR have been set up as primary key denoting solely each record. The rest (WDIR, TEMP, RHUM, TEMPSCR, RHUMSCR, TSR, NETR, SENS, EVAP, WSTAR, ZMIX, USTAR, LSTAR, RAIN and SNOW) are meteorological parameters . Tables about pollution forecasts do not exist, all measurements are stored in the hard disc of the server as image files. A sample table of weather forecast has the following form : mkozani (DATE, HOUR, WDIR, TEMP, RHUM, TEMPSCR, RHUMSCR, TSR, NETR, SENS, EVAP, WSTAR, ZMIX, USTAR, LSTAR, RAIN and SNOW.)

The proposed A.Q.M.E.I.S. application is part of a system - air quality monitoring network, which was developed in the Laboratory of Atmospheric Pollution and Environmental Physics of Technological Education Institute of Western Macedonia, to monitor the air quality in Western Macedonia area, with industrial focus on the region of Prolemais - Kozani basin. This system was co-financed by the TEIWM, Regional Operational Programm 2000 - 2006 Western Macedonia and recently by the municipality of Kozani. The architecture of this system is constituted by five terminal stations, which collect environmental information, the central station and a web server. Different technologies (ADSL, GPRS, ETHERNET) are used to transfer the data to the central station. The data are sent every half an hour to the main station which collects the complete set of data and transfers them to the web server every sixty minutes, where under the application proposed in this paper provides meteorological, environmental, weather and air pollution forecast data in West Macedonia area. Further details on the design of the above mentioned air quality monitoring network can be obtained from [1],[14], [15].

IV. Conclusion

An operational monitoring, as well as high resolution local-scale meteorological and air quality forecasting information system(A.Q.M.E.I.S.) for Western Macedonia, Hellas, has been developed and is operated by the Laboratory of Atmospheric Pollution and Environmental Physics / TEI Western Macedonia. In this paper the novelty of information system is presented, in a dynamic, easily accessible and user-friendly manner. The application is developed using state of the art web technologies (Ajax, Google maps etc) and under the philosophy of the open source software that gives the ability to users/authors to update/enrich the code so that their augmentative needs are met.

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Control algorithm and infrastructure for smart grid topologies

Dimitrios Tsiamitros, Dimitrios Stimoniaris, T. Kottas, V. Zacharaki, and Evangelos Dialynas, *Senior Member,IEEE*

***Abstract*— The control infrastructure and algorithm of a smart distribution grid topology are described. They are applied to a typical microgrid with increased renewable energy sources penetration and experimental results are presented. The results show clearly the contribution of the topology towards a smarter grid with increased reliability performance and power quality.**

***Index Terms* – Demand-Side management, Distributed Generation, Smart Grids, Microgrids, Renewable Energy Sources.**

I. Introduction

The increased penetration of renewable energy sources and energy storage technologies into the grid require the determination of the proper grid topology and the respective control infrastructure [1]-[3]. The new distribution grid should be divided into smaller interconnected grids that operate in parallel. Each smaller grid contains nested sub-grids and should have the ability to be disconnected from the remaining grid and operate in an islanded mode [2]-[4]. This means that it must be self-controlled. The autonomous intelligent control being conducted by all the sub-grids in parallel makes the new distribution grid smart.

The experimental investigation of interconnected microgrids of such topologies could facilitate the transformation from the traditional to the smart electric grid [2], [3], [5]. The purpose of the paper is to analytically present a smart grid topology and more specifically the control infrastructure and algorithm. The proposed topology is implemented on a microgrid scale and experimental results are presented. The results show the contribution of the proposed topology towards a smart grid and its worth of expandability to the entire distribution grid.

II. The Smart Distribution Grid Topology

The proposed topology is shown in Fig. 1. Every dc load, generator or energy storage device is equipped with its dc-ac inverter and connected to the ac grid via a smart device called special control unit (SCU). SCUs are also necessary for the ac loads (or group of loads) and generators.

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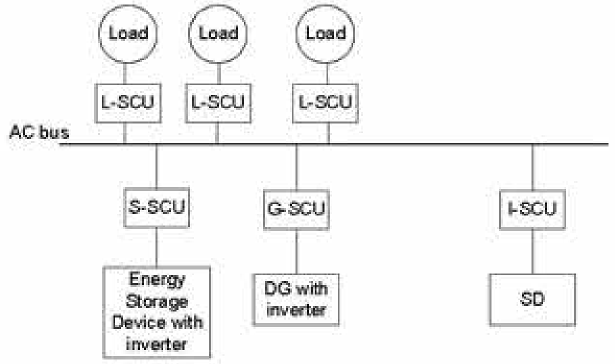

Figure 1: Smart Distribution Grid Topology.

The special control units (SCUs) are categorized in load SCUs (L-SCUs), storage SCUs (S-SCUs), generators SCUs (G-SCUs) and interconnection SCUs (I-SCUs), for connecting the small grid of the ac-bus to the remaining grid (SD). All SCUs consist of a simple metering module, a communication module, an activation module (actuator) and a "smart" module that is responsible for the decision making of each SCU. This module is integrated into software that runs on a microgrid-dedicated PC.

III. Description of the Metering, Communication and Activation Modules of the SCUs

At the Technological Educational Institute of Western Macedonia (TEIWM) in Greece, the installed microgrid incorporates renewable energy sources and energy storage devices. It contains two inverters that are used to integrate 12 PV panels into the microgrid, a battery bank of 24 FLA batteries and 600 Ah capacity, five (5) ac loads of 2634 W peak and a wind generator of 1 kWp. Ten (10) SCUs are totally installed, exploiting ten Current Transformers (CTs), two Voltage Transformers (VTs), one voltage divider (13 sensors) and ten activation modules (relays). The topology including the 10 SCUs is shown in Fig. 2 while the laboratory installation is shown in Fig. 3.

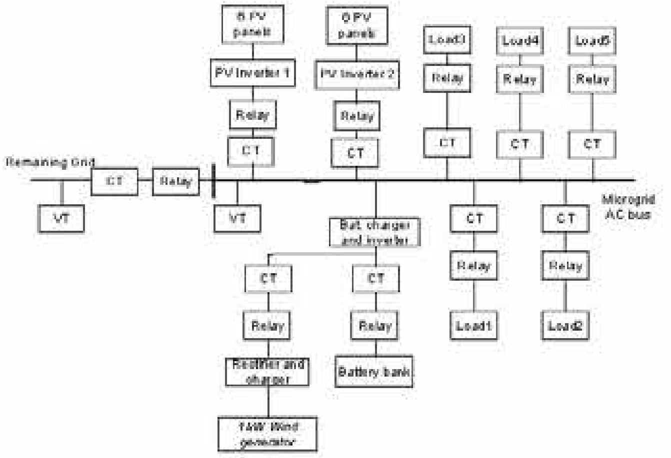

Figure 2: The microgrid topology

The thirteen (13) current and voltage sensors are connected to the analog inputs of two Data Acquisition (DAQ) cards (NI-USB-6008), whereas the ten (10) activation modules are activated or deactivated by the digital outputs of one of the DAQ cards. The two DAQ cards are connected via USB cables to a PC where a software application in Labview processes the input data, incorporates the control algorithm and derives the proper output commands. In this case the transmission cables, the two DAQ cards and the Labview application represent the communication modules of the SCUs.

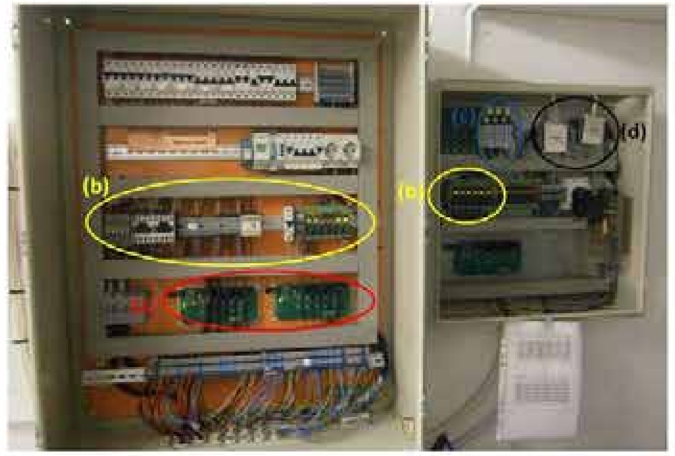

Figure 3: The laboratory installation of the microgrid: (a) The ten CTs, (b) the relays, (c) the ac voltage sensors, (d) the DAQ cards.

IV. Description of the Topology's Control Algorithm

The developed Labview application is responsible for the following tasks:

• Data sampling (12-bit resolution, 1kS/sec sampling rate) and calculation of the RMS values.

• Calculation of other electrical parameters (active and reactive power, frequency, etc).

• Incorporation of the control algorithm written in MatLab code.

• Data recording.

• Transmission of the commands derived by the control algorithm back to the digital output of the DAQ card.

A part of the Labview application including the MatLab control algorithm into a math script node is shown in Fig. 4.

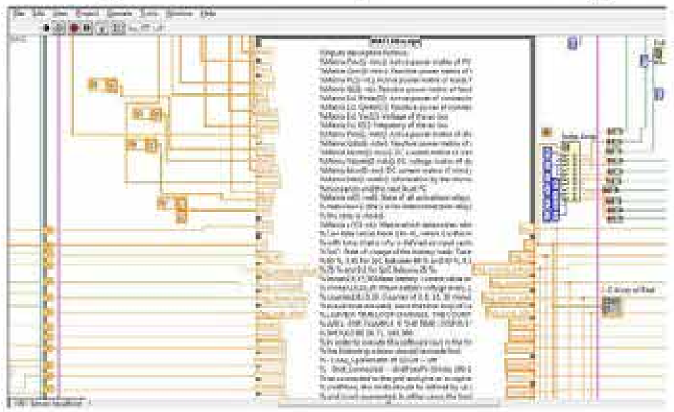

Figure 4: Part of the Labview application and the MatLab control algorithm.

The inputs of the control algorithm are the real-time measurements inputs that are updated every second and the output variables that are fed back into the algorithm at the end of its execution period. Some of the real-time measurements inputs of the algorithm include the array of the AC active power produced by the PV inverters, the ac voltage of the microgrid AC bus and the DC current of the batteries. Some of the output variables are the ten activation modules array that is transmitted to the digital output of one DAQ card every second, the previous State of Charge of the batteries (SoC) and a group of flags that helps fault diagnosis of the system. The execution time of the algorithm is less than 10 msecs and it is executed every second.

The control algorithm consists of two major steps:

1. The real-time voltage and frequency surveillance and correction, as well as the interoperability with the remaining grid.

2. The storage units' State of Charge (SoC) and the load shedding policy determination.

First Major Step of the Algorithm

Eight routines are executed in this step and will be described analytically in the full paper. Some of them are the following:

1) If excess active power production by the Renewable Energy Sources (RES) increases the microgrid voltage, the interconnection relay is set to be on in order to supply the excess power to the remaining grid. If the interconnection relay is already set to be on, the biggest RES supplier is switched off.

2) If the battery discharge current is larger than a predefined value, the relative flag is activated while the loads that do not consume energy are disabled together with the less critical load that consumes energy.

3) If the produced active power is less than that needed to supply the loads and the voltage decreases, the interconnection relay is set to be on in order to permit the remaining grid to supply excess power to the microgrid. If the interconnection relay is already set to be on, all or part of the loads can be rejected, depending on the storage unit capability to supply all or part of the loads. The relative flag is activated.

Second Major Step of the Algorithm

In this step, the storage units' State of Charge (SoC) and the load shedding policy are determined and implemented. The SoC of the battery bank is determined by a technique similar to the one applied in [6]. The mean batteries voltage per cell and the mean batteries current per 100 Ah are calculated for 2, 6, 15 and 30 minutes periods independently. The current-voltage characteristic curves of lead-acid batteries that correspond to SoC equal to 60 %, 40 % and 25 % are reproduced. Every 2, 6, 15 and 30 minutes four routines are executed and will be described analytically in the full paper. One of them is the 2-minutes routine, which is executed only if the batteries are discharging for two minutes with a mean current above 2 A/100 Ah (12 A here). Then, the 2-minutes mean batteries voltage per cell and mean batteries current per 100 Ah are compared to the characteristic curves.

1) If these values lie above the 60 % SoC curve, no action is taken.

2) If they lie between the 60 % and the 40 % curves and the battery charging possibility by the RES or by the remaining grid is small (night hours) all the loads are deactivated except of the most critical load (load No1). On the other hand, if the battery charging possibility by the RES or by the remaining grid is high (daytime hours) the loads that do not consume energy are disabled together with the less critical load that consumes energy.

3) If they lie between the 40 % and the 25 % curves, the previous SoC is checked. The first tests indicated that the microgrid may fall in this situation when large loads are switched on at the same time, leading to great discharging current that does not correspond to the real SoC. Thus, if the previous SoC is above 60 %, the actions in subsection (2) above are taken and a new SoC between 60 % and 40 % is assigned on purpose. If the previous SoC is below 60 %, the new SoC is defined correctly and only the critical load is supplied.

4) If they lie below the 25 % curve, the previous SoC is checked and the procedure in (3) is followed. If the previous SoC is below 40 %, the new SoC is defined correctly and no loads are supplied.

V. Experimental Results

The real-time voltage and frequency surveillance and correction step of the control algorithm (sub-Section IV.A) had an excellent response. For example, the maximum discharge current was deliberately set to 80 A. When all the loads were switched on and the microgrid was forced to supply all the loads by the batteries, the less critical loads were deactivated gradually every second. The load shedding policy (sub-Section IV.B) was implemented successfully and resulted in increased reliability operation. For example, in the case of islanded operation mode, the most critical load together with two less critical loads are always supplied, in opposite to the constant load switching and quick batteries charging and discharging of another topology [2], [3], as shown in Fig. 5.

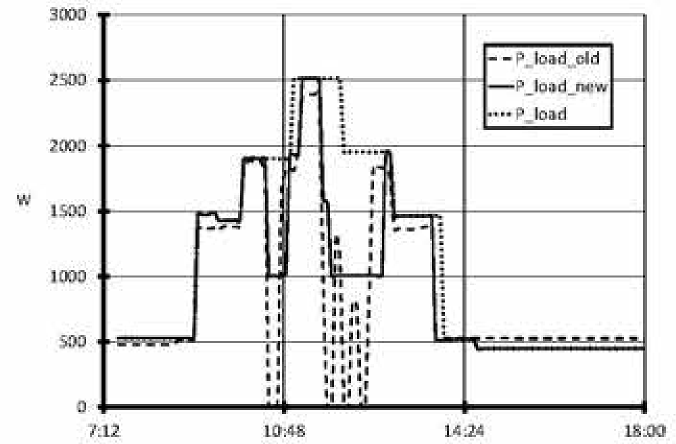

Figure 5: Loads profiles of an old, the new topology and desired load profile. Island operation: 9.30 until 10.30, 11.30 until 12.30, 13.30 until next morning.

VI. Conclusions

The infrastructure and the control algorithm of a simple and expandable to large scale smart grid topology are described. The infrastructure comprises of simple metering, communication and activation modules. The control algorithm handles important grid operation features such as real-time voltage and frequency surveillance and correction, real-time estimation of the state of charge (SoC) for the energy storage apparatus, determination and implementation of load shedding policies, transition to island operation and maximum and optimal renewable energy sources exploitation. The modules and the control algorithm are applied at a typical microgrid and were tested successfully, increasing reliability performance of a microgrid with increased RES penetration.

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Adaptive Control for Sun Tracking Devices

Tsiakalos Anastasios, Thodoris Kottas*,

***Abstract*— - Finding energy sources to satisfy the world's growing demand is one of society's foremost challenges for the next half-century. The challenge in converting sunlight to electricity via photovoltaic solar cells is dramatically reducing €/watt of delivered solar electricity. In this context the sun trackers are such devices for efficiency improvement. The diurnaland seasonal movement of earth affects the radiation intensity on the solar systems. Sun-trackers move the solar systems to compensate for these motions, keeping the best orientation relative to the sun. Although using sun-tracker is not essential, its use can boost the collected energy 10–100% indifferent periods of time and geographical conditions. However, it is not recommended to use tracking system for small solar panels because of high energy losses in the driving systems. It is found that the power consumption by tracking device is 2–3% of the increased energy. In this paper a novel adaptive system is presented in order to drive the sun trackers to collect over 7% energy of the usual types of astronomic algorithms.**

***Index Terms* – Sun Tracking, Adaptive Control.**

I. Introduction

Finding sufficient supplies of clean energy for the future is one of society's most daunting challenges. Alternative renewable energy sources such as sun energy can be substituted for exceeding human energy needs. Covering 0.16% of the land on earth with 10% efficient solar conversion systems would provide 20 TW of power, nearly twice the world's consumption rate of fossil energy. Directly converting sunlight to electricity is accomplished via PV solar cells. The birth of the modern era of PV solar cells occurred in 1954, when D. Chapin, C. Fuller, and G. Pearson at Bell Labs demonstrated solar cells based on p–n junctions in single Si crystals with efficiencies of 5–6%. Peak watt (W_p) rating is the power produced by a solar module illuminated under the standard conditions: 1000W/m2 solar intensity, 25 degrees Celcius ambient temperature, and a spectrum related to sunlight passing through the atmosphere when the sun is at a 42 degrees elevation from the horizon (defined as air mass 1.5; i.e., when the path through the atmosphere is 1.5 times than that when the sun is at high noon). Because of day/night and time-of-day variations in insolation and cloud cover, the average electrical power produced by a solar cell over a year is about 20% of its Wp rating.

A part of the incident energy is reduced by scattering or absorption by air molecules. The radiation that is not reflected or scattered and reaches the surface directly is called direct or beam radiation. The scattered radiation reaching the ground is called diffuse radiation. The albedo is the fraction of radiation reaching the ground that is reflected back to the atmosphere from which a part is absorbed by the receiver.

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II. Energy Gain in Tracking Systems

Solar tracking can be implemented by using one-axis, and for higher accuracy, two-axis sun-tracking systems. For a two-axis sun-tracking system, two types are known as: polar (equatorial) tracking and azimuth/elevation (altitude–azimuth) tracking. The solar tracker, a device that keeps PV or photo-thermal panels in an optimum position perpendicular to the solar radiation during daylight hours, increases the collected energy. The first tracker introduced by Finster in 1962, was completely mechanical.

One year later, Saavedra presented a mechanism with an automatic electronic control, which was used to orient an Eppley pyrheliometer [1]. Trackers need not point directly at the sun to be effective. If the aim is off by 108, the output is still 98.5% of that of the full-tracking maximum. In the cloudiest, haziest locations the gain in annual output from trackers can be in the low 20% range. In a generally good area, annual gains between 30 and 40% are typical. The gain in any given day may vary from almost zero to nearly 100% [2].

Bione et al. compared the pumping systems driven by fixed, tracking and tracking with concentration PVs. The PV–V-trough system, consisted of four cavities and two PV modules to track the sun along its N–S axis, tilted at an angle of 208towards the north. A theoretical simulation as well as experimental comparison between three cases was performed. By analyzing the daily characteristic curve for three given modes, the results showed that for a given irradiance, the pumped water flow rate was significantly different from one another. They proved that the benefit ratios obtained for water volume were higher than that for collected solar energy. The fixed PV, the PV with tracker and the concentrating-tracking systems pumped 4.9, 7.4 and 12.6 m3 /day, respectively [3].

Tomson analyzed the performance of the two-positional control of single stand-alone flat plate concentrator. The collector was rotated around its single tilted axis twice per day with predefined deflections. The effect of different tilt angles, initial tilt angle, initial azimuth, and azimuth angle of the deflected plane were evaluated on the daily and seasonal gain. The comparison of simulation and experimental results indicated that using a simple tracking drive with low energy input for a brief daily movement, increased the seasonal energy yield by 10–20% comparing to that of a fixed south facing collector tilted at an optimal angle [4].

Michaelides et al. investigated and compared the performance and cost effectiveness of a solar water heater with collector surface in four situations: fixed at 40 degrees from the horizontal, the single-axis tracking with vertical axis, fixed slope and variable azimuth and the seasonal tracking mode where the collector slope is changed twice per year. To analyze the system, they used computer simulations using the TRNSYS simulation program for a thermosyphon system. The simulation results showed that the best thermal performance was obtained with the single-axis tracking. In Nicosia, the annual solar fraction (fraction of load that is provided by solar radiation) with this mode was 87.6% compared to 81.6% with the seasonal mode and to 79.7% with the fixed surface mode, while the corresponding figures for Athens were 81.4%, 76.2% and 74.4%, respectively. From the economic point of view, the fixed surface mode was found to be the most cost effective [5].

Helwa et al. studied the solar energy captured by different solar tracking systems. They calculated the solar energy collected by using measured global, beam and diffused radiations on a horizontal surface. Four systems were used in their experiments: fixed system with tilt angle of 408 due south, one-axis azimuthally tracking with tilt angle of 338, one-axis tracking oriented in the N–S direction with 68tilt angle and two-axis tracking system, one axis vertical and the other horizontal. They developed formulas for three modes of radiation that come in contact with the surfaces and wrote a computer program in BASIC to calculate and store daily radiation for each system. The comparison between calculated and measured data showed the annual average for the hourly root mean square difference (RMSD) values of 5.36, 9.07, 7.92 and 5.98 for the fixed, vertical axis tracker, tilted axis tracker and two-axis tracker systems, respectively. All values were in the acceptable range [6].

Grass et al. compared non-tracking compound parabolic concentrator collectors with two novel tracking collectors: a parabolic trough and an evacuated tube collector with an integrated tracking reflector. Tracking was performed by the use of a magnetic one-axis tracking system. For ray-tracking analysis they used the ray-tracking code ASAP (Breault Research Organization Inc., 1999). To determine the optical efficiencies for direct and diffuse radiations and incidence angle modifiers of the collectors, measurements were carried out near the ambient temperature. The results showed that optical efficiencies for direct radiation can be increased during the day by using tracking systems. However, small tracking errors can have significant effects, if the step angle is low [7].

III. Sun Tracking methods

The presence of a solar tracker is not essential for the operation of a solar panel, but without it, performance is reduced. Although solar trackers can boost energy gain of PV arrays, in their installation some problems such as cost, reliability, energy consumption, maintenance and performance must be considered.

All tracking systems have all/some of the following characteristics:

- Single column structure or of parallel console type.
- One or two moving motors.
- Light sensing device.
- Autonomous or auxiliary energy supply.
- Light following or moving according to the calendar.
- Continuous or step-wise movement.
- Tracking all year or all year except winter.
- Orientation adjustment with/without the tilt angle adjustment.

Several methods of sun following have been surveyed and evaluated to keep the solar panels, solar concentrators, telescopes or other solar systems perpendicular to the sun beam. An ideal tracker would allow the PV cell to accurately point towards the sun, compensating for both changes in the altitude angle of the sun (throughout the day), latitudinal offset of the sun (during seasonal changes) and changes in azimuth angle. Sun-tracking systems are usually classified into two categories: passive (mechanical) and active (electrical) trackers.

Passive trackers

Passive solar trackers are based on thermal expansion of a matter (usually Freon) or on shape memory alloys. Usually this kind of tracker is composed of couple of actuators working against each other which are, by equal illumination, balanced. By differential illumination of actuators, unbalanced forces are used for orientation of the apparatus in such direction where equal illumination of actuators and balance of forces is restored. Passive solar trackers, compared to active trackers, are less complex but work in low efficiency and at low temperatures they stop working. Tests have shown that passive trackers are comparable to electrically based systems in terms of performance. Although passive trackers are often less expensive, they have not yet been widely accepted by consumers.

Active trackers

Major active trackers can be categorized as microprocessor and electro-optical sensor based, PC controlled date and time based, auxiliary bifacial solar cell based and a combination of these three systems. Electro-optical solar trackers are usually composed of at least one pair of anti-parallel connected photo-resistors or PV solar cells which are, by equal intensity of illumination of both elements, electrically balanced so that there is either no or negligible control signal on a driving motor. In auxiliary bifacial solar cell, the bifacial solar cell senses and drives the system to the desired position and in PC controlled date and time based, a PC calculates the sun positions with respect to date and time with algorithms and create signals for the system control.

Microprocessor and electro-optical sensor based for active trackers

In this type, by differential illumination of electro-optical sensors differential control signal occurs (Fig. 1a) which is used to drive the motor and to orient the apparatus in such direction where illumination of electro-optical sensors become equal and balance. In addition, the photodiodes can be mounted on tilted planes in order to increase the photocurrent sensitivity (Fig. 1b) and, very commonly in concentrator PV applications, the shading device is presented as a collimating tube which prevents diffuse irradiation from entering the sensor and masking a precise measurement of the sun alignment position (Fig. 1c) [8].

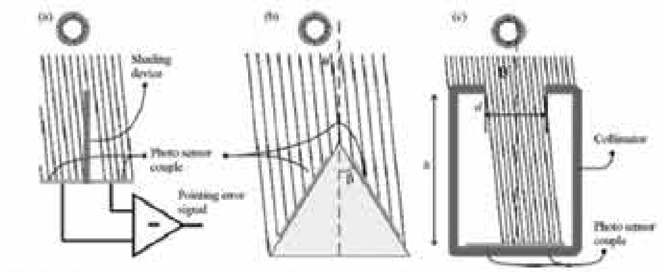

Fig. 1.: Shade balancing principal (a) sun-pointing sensors (b) tilted mount of photo sensors (c) precise sun pointing by means of a collimator [8]

IV. The presence of temperature in Photovoltaic modules

Using the equivalent circuit of a solar cell (Fig. 2) and the pertinent equations the non-linear I-V characteristics of a solar array are extracted, neglecting the series resistance:

$$I_0 = I_{ph} - I_{rs}(e^{\frac{qV_0}{kTA}} - 1) - \frac{V_0}{R_{sh}} \qquad (1)$$

where Io is the PV array output current (A); V_o is the PV array output voltage (V); q is the charge of an electron; k is Boltzmann's constant in J/K; A is the p–n junction ideality factor; T is the cell temperature (K); and Irs is the cell reverse saturation current. The factor A in Eq. (1) determines the cell deviation from the ideal p–n junction characteristics. The ideal value ranges between 1 and 5 and to a commercial available software package for PV systems PVSYST V3.1.

The photocurrent Iph depends on the solar radiation and the cell temperature as stated in the following equation:

$$I_{ph} = (I_{scr} + k_i(T - T_r))\frac{s}{100} \qquad (2)$$

where Iscr is the PV array short circuit current at reference temperature and radiation (A); k_i is the short circuit current temperature coefficient (A/K) and S is the solar radiation (mW/cm^2).

The reverse saturation current Irs varies with temperature according to the following equation:

$$I_{rs} = I_{rr}\left(\frac{T}{T_r}\right)^3 e^{\frac{1.115}{k'A}\left(\frac{1}{T_r} - \frac{1}{T}\right)} \qquad (3)$$

where T_r is the cell reference temperature, I_{rr} is the reverse saturation current applied at T_r, and k' is the Boltzmann's constant in eV/K and the band-gap energy of the semiconductor used in the cell is equal to 1.115.

Finally, Equation (4) was used in the computer simulations to obtain the open circuit voltage of the PV array:

$$V_{oc} = \frac{AkT}{q}\ln\left(\frac{I_{ph} + I_{rs}}{I_{rs}}\right) \qquad (4)$$

The required data for identifying the maximum operating point at any insolation level and temperature are the following:

- k_i,
- Open Circuit Voltage (for initial conditions),
- Short Circuit Current (for initial conditions),
- Maximum Power Voltage (for initial conditions),
- Maximum Power Current (for initial conditions)

all given by the PV array manufacturer

where initial condition are equal to: $T_r = 25°C$, $S = 100mW/cm^2$

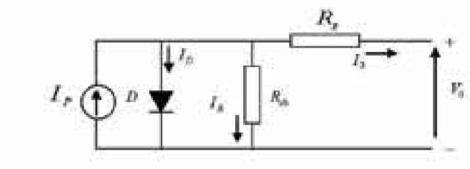

Fig. 2.: Equivalent circuit of a solar cell.

Using the software PVSYST we present to different approaches of the same photovoltaic module. In Fig. 3 one can see the maximum power produced by the module when the isolation is 1000 W/m2 and the module temperature is equal to 45 degrees. The maximum produced by the module is 210.2 Watt, while in Fig. 4 the same module when the isolation is equal to 980 W/m^2 and the temperature is equal to 40 degrees then it has a production of 210.8 Watt. One can easily see that the maximum power produced from the PV module is not in the vertically point of the sun as the active trackers reach but in the point where the power of the PV module is maximum is depended from the Temperature of the module.

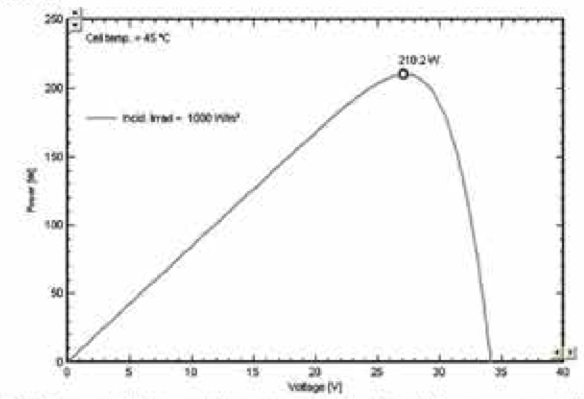

Fig. 3.: Power vs Voltage with main parameter of module temperature (T=45 degrees Celsius)

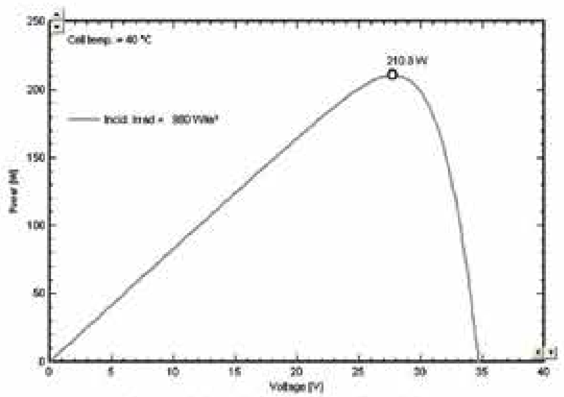

Fig. 4.: Power vs Voltage with main parameter of module temperature (T=40 degrees Celsius)

V. Adaptive Control of Active Trackers

Considering the temperature of the PV module authors designed an active tracker system. The system is taking the same with the active trackers system of Fig. 1(b) but it uses photovoltaic modules and not photo sensors. The system measures the temperature of the PV modules and controls the tracking device according to eq. 4. As a result one can have a raise in the energy produced at about 1.2% compared to active controllers.

Secondly the system taking into account the fact that the maximum power production is depended in the level of the cloudiness.

1. *Partly cloud*: In addition to the direct solar irradiation, diffused light is also used to maximize the effect of the PV module.
2. *Overcast sky*: The system catches all the diffused light by moving the tracker to horizontal position.

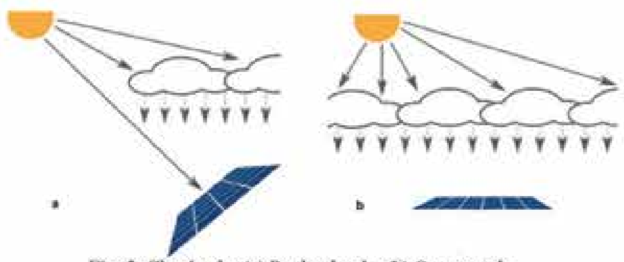

Fig. 5: Cloudy sky (a) Partly cloud – (b) Overcast sky

The total energy gain by using the presented adaptive active tracker system is calculated from 4 different plants in 7% over a year. Authors installed the experimental system in four different plants in West Greece and the results are shown in Fig. 6. The total gain calculated in 9% over a year considering the fact that the tracker has not moved from the horizontal position for 78 days because of a cloudy overcast sky. The extra energy gain came from the power that the tracker is not consumed in order to move.

In Fig. 6 one can see a comparison between the proposed adaptive algorithm and a simple sun positioning algorithm. The morning hours the sky was partly cloudy. The adaptive system was moving according to the maximum power production spot instead of the suns spot in the sky. The next hours the sky was totally clean of clouds. The gain of energy is at about 16.5 %.

In Fig. 7 one can see a comparison between the proposed adaptive algorithm and an active algorithm. The day is presented is a totally shiny day. The difference is spotted between the noon hours when the adaptive system is taking into account the temperature of the module, while the active system is only considering the sun positioning. The gain of energy is 3.7%.

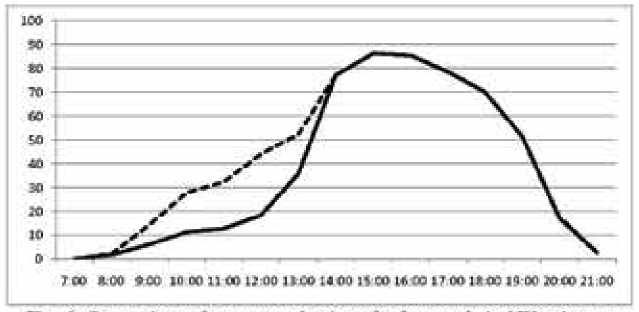

Fig. 6: Comparison of power production of solar panels in kWatt between adaptive active tracking system (slashed line) and sun position tracking system (continues line). Energy increases at 16.5%.

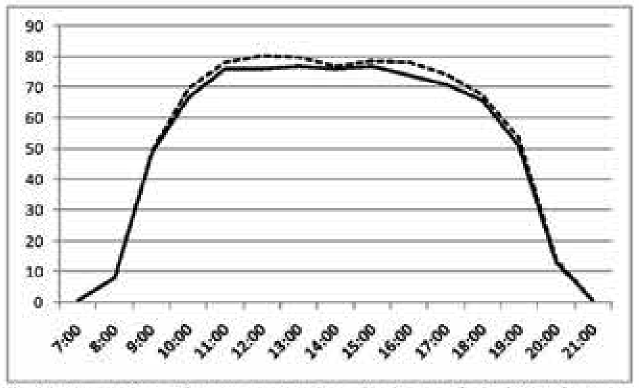

Fig. 7: Comparison of power production of solar panels in kWatt between adaptive active tracking system (slashed line) and active tracking system (continues line). Energy increases at 3.7%.

VI. Conclusions

The proposed system is a novel system based on the way the PV modules are reacting through their power to isolation and temperature. All active systems are based in the sun positioning and not in the maximum power production. The total gain calculated in 9% over a year.

VII. Acknowledgements

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