Integration of New RES in Power System of North Macedonia

Metodija Atanasovski[1], Mitko Kostov[1], Blagoja Arapinoski[1], and Mile Spirovski[1]

Abstract – **The goal of the paper is to investigate and evaluate the impact of integration of new planned renewable energy sources (RES) on the operating parameters of the transmission networks. The paper presents methodology and algorithm for developing software module for RES impact assessment on the elements loading of the transmission networks (lines and transformers) and on network buses voltages within grid code defined limits and short circuit currents level. According to the methodology software module is developed using PYTHON platform. The integrated calculations in the module are part of standard planning mechanisms of power system and maintaining the predefined level of security of supply and reliability of power system elements and substations. The module is tested and evaluated on transmission network individual forecasted model of power system of North Macedonia for the year 2025.**

Keywords – **Renewable energy sources, power systems.**

I. INTRODUCTION

Power plants from Renewable Energy Sources (RES) have a dominant role in all new investments and constructions in power sector of the countries in the European Union in the last fifteen years. This is a result of a political decision and orientation of energy policy towards to decrease of energy generation and consumption on climate changes and it is a direct consequence of appropriate laws and regulations in EU. This kind of energy policy and regulations is stimulating investments and constructions of RES and usage of generated energy from RES by all consumers.

RES using strong political and financial support have become significant power producers of electrical energy in some EU countries. According to today level of technology development, wind power plants (WPP) and photovoltaics (PV) have a dominant role from all RES. These kind of power plants in some EU countries have reached such a level of installation that in some days with their generation total electrical energy consumption is mostly supplied.

According to EWEA (*European Wind Energy Association*), nowadays WPP share is about 16 % of total electrical energy consumption in EU+UK, and Europe installation of WPP in the next five years will be 105 GW. Dominant countries in WPP installations are Denmark, Spain, Ireland, Germany and UK [1]. Total PV installed capacity in Europe in 2019 was 131 GW, and dominant countries with PV installations are Germany, Italy and Spain (source Solar Power Europe-SPE) [2].

This paper analysis is a part of broader research project for investigating new RES future installations technical and economic impact on power systems and electricity markets in the region of South East Europe (SEE) [3].

The paper presents efficient methodology and algorithm for developing software module for RES impact assessment on the elements loading of the transmission networks (lines and transformers) and on network buses voltages within grid code defined limits and short circuit currents level. According to the methodology software module is developed using PYTHON platform. The integrated calculations in the module are part of standard planning mechanisms of power system and maintaining the predefined level of security of supply and reliability of power system elements and substations [3].

Module is tested and evaluated in the paper on transmission network individual forecasted model of power system of North Macedonia for the year 2025. Namely, the WPP and PV planned for installation and integration into power system for 2025 year are analyzed with the developed module and obtained results are depicted and discussed.

The paper is consisted of five chapters. Second chapter presents the developed methodology and algorithm for software module development and calculation. Third chapter describes the input data and performed calculation with depiction of obtained results. Fourth and fifth chapter are conclusion and references.

II. METHODOLOGY AND ALGORITHM

A. Methodology

The goal of the module is investigating and evaluating the impact of RES on the operating parameters of the transmission networks. The integrated calculations in the module are part of standard planning mechanisms of power system and maintaining the predefined level of security of supply and reliability of power system elements and substations. The basic operating parameters of the transmission networks have to be in the predefined ranges according to grid codes. Basic operating parameters of the transmission networks are loading of the network elements, network buses voltages and short circuit currents. The elements of the transmission networks (lines and transformers) have to be loaded lower than their maximum thermal limits, network buses voltages should be within grid code defined limits and short circuit currents should be lower

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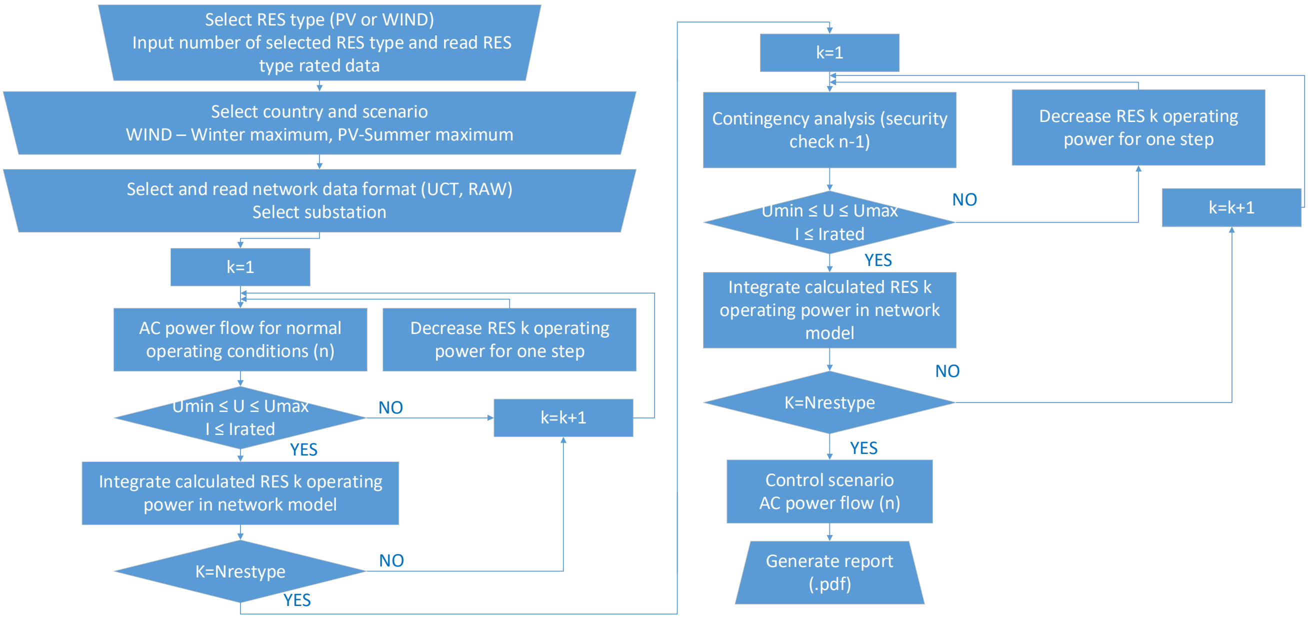

Fig. 1. Algorithm of the developed module for calculations

than breaking power of circuit breakers in substations. Additionally, when one element is out of service, power system has to remain its stability and respectively there should be no cascade out of service of other elements in the transmission network and/or loss of consumers supply and/or loss of generation.

The planning phase for RES integration in power system and calculation of hosting capacity of substations for RES integration is based on following calculations: Load flow calculations, security check based on n-1 contingency analysis and, short circuit calculations.

Several different important scenarios should be considered, when RES are integrated in power system [6], [7], [8]: 1. Maximum RES generation and maximum load conditions in the system; 2. Maximum RES generation and maximum summer load conditions in the network; 3. Average RES generation and average load conditions in the network.

Maximum RES generation and maximum winter load conditions in the network is relevant for calculation of wind power plants integration in power system. Maximum winter load time appearance in power systems of SEE is usually in cold winter afternoon or night hours when wind farms can have maximum generation and PV generation is zero. This scenario is calculated with 100% WPP and 0% PV.

Maximum RES generation and maximum summer load conditions in the network is relevant for calculation of PV plants integration in power system. Time of maximum summer load appearance in the power system of SEE is usually in hot summer afternoon when usually there is no wind and PV generation is maximum. This scenario is calculated with 0% WPP and 100 % PV.

Control scenario can be created for average load conditions in the network with both types of RES generation integration with 50% wind 50% PV of calculated operating power in previous two main scenarios. Average load in the network can be considered as 60% - 65% of winter maximum load.

B. Algorithm

The developed software module programming is mainly based on PYTHON. The module is called RES congestion and overload calculations. The algorithm block diagram is depicted on Figure 1. It is consisted of five main parts: 1. Reading input data. RES selection and input data, country and scenario selection according to RES type, data format selection and reading network model. The module calculate network integration capacity of two types of RES PV and WPP. Acceptable data formats for transmission networks are (*.raw) format from PSS/E software and (*.uct) data format. 2.AC power flow solution for normal operating conditions (n) with integrated RES types (Nrestype number of RES from the same type for integration in the selected country and selected substations). Checking buses voltages limits and branches loading. If necessary decrease RES k operating power for one-step. 3. Contingency analysis (security check n-1) Successive outages of each branch in the selected country and AC power flow solution with integrated RES types. Checking buses voltages limits and branches loading. If necessary, decrease RES k operating power for one-step; 4.Control scenario with average load and 50% PV and 50%WIND; 5. Generation of report.

The power flow calculations in the module are performed with Newton Raphson method. According to power flow calculations for normal operating conditions (all n elements in service) in the network and contingency analysis (security check n-1 when one element is out of service), loading of each element (line or transformer) should be within the limits (equal or less than rated current of the element). The level of thermal loading of lines and transformers is related to acceptable current loading of lines Irated (A) and thermal apparent power Srated (MVA) of transformers.

Buses voltage is another constraint that should be considered for RES integration capacity calculation.

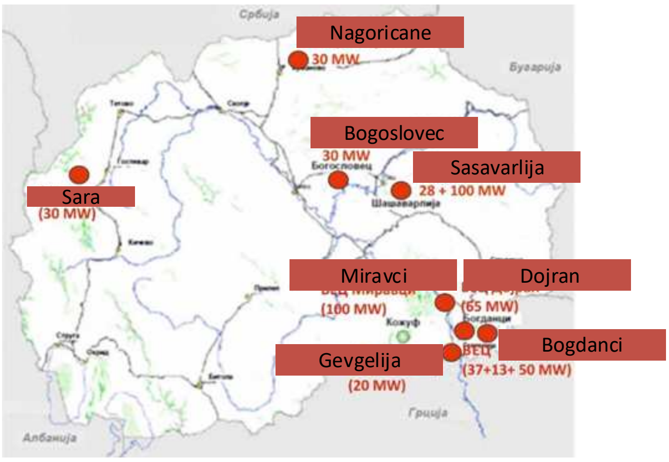

Fig. 2. Geographic position of new WPP in power system of North Macedonia [6]

According to grid codes of TSOs in the countries of SEE, voltages in the transmission network should be in the acceptable voltage limits range. Generally, for planning purposes voltage limits for HV voltage levels are defines as follows: for 400 kV voltage level, (± 5%); for 220 kV voltage level, (± 10%); for 110 kV voltage level, (± 10%). Contingency analysis or security check (n-1) is a criterion for technical security used for transmission network operation, development planning and construction. For the case when one element of the system (line or transformer) is out of service, transmission network should remain its security and further thermal overloading of branches (lines and transformers) is not allowed, since it can cause cascade outages of elements. In addition, voltages of transmission network buses should be retained in the range of acceptable limits.

The results from contingency analysis will be presented in the generated report in a form of alerts which branches are overloaded (loading over 100%) and which buses are with voltages out of the limits. The report should illustrate which branches have high loading (over 90%) as an indicator for future overloading.

III. Results and Discussion

Methodology and developed module is tested and evaluated in the paper on transmission network individual forecasted model of power system of North Macedonia for the year 2025. Namely, the WPP and PV planned for installation and integration into power system for 2025 year are analyzed with the developed module.

Table I summarizes new WPP installation (installed or planned) in the power system of North Macedonia for the time horizon 2020 – 2040 [4]. Figure 2 depicts the geographic positions of new installed and planned WPP installations. According to North Macedonia system operator planning documents [5] and [6], for the year 2025 WPP are planned with installations of WPP Bogoslovec 30 MW and WPP Sasavarlija 28 MW and in total with existing Bogdanci the total WPP installed power will be 108 MW. Total planned WPP planned capacity for the year 2040 is 503 MW [6].

Table I
Installed and planned WPP for the period 2020-2040

WPP	Installed capacity (MW)	Year of installation
Bogdanci 1A	37	2014
Bogdanci 1B	13	2020
Sasavarlija 1	28	2025
Bogoslovec	30	2025
Miravcci	100	2030
Gevgelija	20	2030
Dojran	65	2040
Sasavarlija 2	100	2040
Bogdanci 2	50	2040
Nagoricane	30	2040
Sara	30	2040
TOTAL	**503**	

New PV installation are forecasted for the year 2025 to additional 50 MW to today's situation. Table II summarizes the planned installed PV capacity per power substations.

Calculations for WPP Bogoslovec and Sasavarlija are performed on forecasted winter maximum. Power balance for 2025 winter maximum is as following domestic generation – 1280 MW; load – 1801 MW; losses – 39 MW; import – 560 MW.

Maximum WPP commitment of Bogdanci with 50 MW, Bogoslovec 30 MW and Sasavarlija 1 28 MW (without PV), with AC power flow solution on the model with for normal operating conditions (n), there is no overloaded lines and transformers and nodes voltages are within the acceptable limits. During the same operating conditions security check criteria (n-1) is also satisfied, and it can be concluded that additional installations of WPP with the analyzed power are not jeopardizing the transmission network security. Line loadings near planned WPP Bogoslovec and Sasavrlija are depected on Figure 3 and Figure 4. 110 kV lines evacuating the power of Sasavarlija in the winter maximum (n) scenario for 2025 are loaded 40 % of the maximum thermal power (maximum loaded line is 110 kV Bucom – Radovis), and maximum loaded line near Bogoslovec is the line Stip 1 – Neokazi (47 % of its maximum allowed power).

Calculations for PV are performed on forecasted summer maximum. Power balance for 2025 summer maximum is as following domestic generation – 858 MW; load – 1392 MW; losses – 24 MW; and import – 558 MW.

With additional installations of new 50 MW PV (0 MW WPP), with AC power flow solution on the summer maximum model with for normal operating conditions (n), there is no overloaded lines and transformers and all nodes voltages are within the acceptable limits. Security check (n-1) is also satisfied, what leads to conclusion that new PV installation with maximum power of 50 MW do not cause any potential problems in the transmission network.

TABLE II
PLANNED PV FOR THE PERIOD 2020-2040

Power substation	Installed capacity (MW)		
	2025	**2030**	**2040**
G. Petrov	2.2	6.6	11
Dracevo	1.8	5.4	9
Kumanovo 1	2.0	6.0	10
Binardzik	2.0	6.0	10
Gostivar	1.8	5.4	9
Polog	2.0	6.0	10
Tetovo 1	2.0	6.0	10
Samokov	2.2	6.6	11
Struga	3.0	9.0	15
Bitola 1	1.2	3.6	6
Bitola 3	0.8	2.4	4
Ohrid 1	3.0	9.0	15
Resen	3.0	9.0	15
Bitola 4	3.0	9.0	15
Negotino	1.4	4.2	7
Kavadarci	1.8	5.4	9
Prilep 1	1.8	5.4	9
Veles	1.0	3.0	5
Valandovo	2.0	6.0	10
Gevgelija	2.0	6.0	10
Strumica	2.0	6.0	10
Radovis	2.0	6.0	10
Kocani	2.0	6.0	10
Stip	2.0	6.0	10
TOTAL	**50**	**150**	**250**

Average load conditions scenario, with load of 62% of maximum winter load, is used as control scenario with 50% WPP power (54 MW) and 50% PV power (25 MW). Power balance for 2025 average scenario is as following domestic generation – 1280 MW; load – 1117 MW; losses – 33 MW; and export – 130 MW. Calculations for the average scenario (all n elements available) have shown that involvement of WPP and PV does not cause any potential problems with overloaded lines and transformers and nodes voltages conditions.

According to the described and discussed analysis presented above, it can be concluded that there are no technical limits for network integration of WPP of 108 MW and additional PV of 50 MW in the year 2025 in the power system of North Macedonia.

IV. CONCLUSION

RES will be dominant in the future power systems and their impact on power system planning and operation must be carefully evaluated. In this paper efficient methodology and algorithm was presented for evaluation of RES integration impact on power system. According to the methodology, software module on PYTHON platform was developed and successfully tested on forecasted individual model of power system of North Macedonia for the year 2025. It is obvious from the obtained results that there is no any limitations for integration of desired 108 MW of WPP and 50 MW of PV. According to the AC power flow results for scenario with all available elements (n) and for contingency analysis (n-1

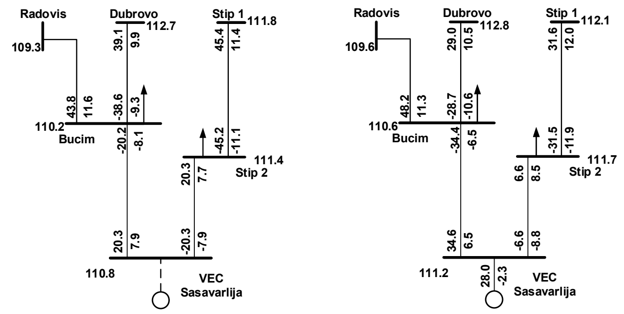

Fig. 3. Power flow of 110 kV lines near Sasavarlija

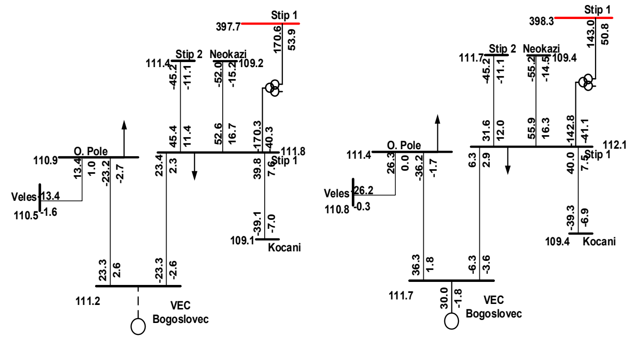

Fig. 4. Power flow of 110 kV lines near Bogoslovec

scenario), there is no overloaded lines or transformers and all nodes voltages are within the grid code limits.

ACKNOWLEDGEMENT

This research is supported by the EU H2020 project TRINITY (Grant Agreement no. 863874) This paper reflects only the author's views and neither the Agency nor the Commission are responsible for any use that may be made of the information contained therein.

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