ELECTRIC LOAD MODELLING OF THE POWER TRANSMISSION LINES AND COMPARISON WITH SCADA MEASUREMENTS

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Abstract

Due to the growing need for a global scale minimization of the greenhouse gasses in recent years, there is a high tendency for the renewable energy sources implementation. These circumstances allude to a different organization and optimization of existing power grids through inclusion of the new energy sources. Using the existing trends as the input parameters of the electric load from particular geographical area, detailed white box model of an electric consumption has been created. The simulation data from the model of the electric consumption have been analysed and compared with the SCADA measurements from the transmission grid. Through detailed analysis, the reliability indicators have been introduced for the future predictions of the important parameters in the transmission grid.

Keywords: energy sources; modelling; electric consumption; transmission grid; loadflow

1. Introduction

Energy efficiency is known as one of the most important and critical problems that scientific and research community needs to address in future years. Energy plays an important role in life of the ordinary people since it enables economies to expand, mobility and communication for the whole world and also enables basic needs such as lighting and heating application. Despite the potential benefits and uses of the energy in improving the quality of life for the whole planet, there are various negative impacts related with the extensive and inefficient energy use such as the increase of the greenhouse gasses and air pollution. In order to address these issues, large amount of effort has been invested to new technologies that should improve energy efficiency and reduce the amount of energy needed for the operation of the whole economies with the main goal of saving money and protecting the environment.

Transmission lines can be seen as the most important part of the electric power grids. Metaphorically, they are the arteries of electrical power systems. The system of well optimized, developed and high capacitance transmission line is able to easily move large quantities of electrical energy over long distances. In electrical power systems, the energy is moved from the plants or generating stations through transmission lines in to the distribution grid. The flow of active and reactive power is usually called load flow or power flow.

Various grid analysis tools are available to future investors who, using data from the grid, can model the connection of a new production unit or consumption in the form of a new industry [2] [3]. Both production and consumption, depending on the type and performance and accessories, affect the condition of the grid. E.g. consumption can be capacitive or inductive and, depending on that, can additionally load the grid with reactive power, which requires additional investment in the form of reactive power compensators. And if, for example, it is a solar or wind power plant, the connection of which can lead to asymmetry of voltage and current, as well as increased load in the grid and increased losses. These are all things that the designer will take into account, study and design in detail, but one can initially do the calculation of power flows in the model using real SCADA data, which will greatly reduce the time spent in choosing the optimal grid connection.

2. Case study radial transmission grid

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It consists of the following, interconnected 110 kV transmission lines:

- switchyard WMOST15 - SS (substation) WMOST45,
- SS WMOST45 – HPP (hydro power plant) WHMBLA5,
- HPP WHMBLA5 - SS WMOST55,
- SS WMOST55 - SS WMOST75,
- SS WMOST75 - SS WMOST65 and SS WMOST65 – switchyard WMOST15.

As a case for observing the maximum load on this radial transmission system, SCADA data is used for the so-called winter peak which occurred on January 15, 2020. The exchange between hubs i.e. substations as well as transmission line loads for a given period is shown. Also, it is necessary to check the availability of this system when it comes to maximum loads. In this way, we come to predict future scenarios that include an increase in consumption caused by any event, and gain knowledge about the necessary future investments in the security and reliability of transmission systems in a particular area. So, we can detect the weak points of the grid, whether it is the power of transformation or the need to relieve the transmission system with new transmission lines.

SUBSTATION	WMOST15	WMOST45	WMBLA5	WMOST55	WMOST65	WMOST75	LOAD FLOW (MW)
WMOST15	•	-14.8					
WMOST45	14.8	•	8.9				
WMBLA5		-8.9	•	38.8			
WMOST55				•		29.9	
WMOST65	-16.8				•	-14.1	
WMOST75					14.1	•	

Table 1. Load flow during winter peak on January 15th 2020

Given that during January the maximum consumption of electricity occurs on the case study grid, where it can be witnessed the maximum production of electricity in nearby hydropower plants, it is necessary to take into account the data on the availability of elements of the observed radial grid. During January, the maximum loads of transmission lines and associated equipment occur, so it is necessary to review the availability of elements of the observed grid during that period. Given that the entire radial case study 110 kV grid is under significant load, it is necessary to read the reports of the competent dispatch centre and see if there are any failures that could be prevented in the future. This is important if the observed area plans to build new consumption objects, as well as plants producing electricity from renewable energy sources which in a special way affect the grid. In addition, this case study includes a hydroelectric power plant in the system, which may be out of operation due to regular annual maintenance. The competent dispatch centre records the number and duration of active and transient failures as well as the number and duration of forced, planned and unplanned failures. For the three of the six case study transmission lines, in January 2020, unavailability was recorded only due to planned disconnections due to overhaul or maintenance of equipment.

TRANSMISSION LINE	Voltage [kV]	Number of planned disconnections	Duration of planned disconnections [min]
WMOST15- WMOST45	110	4	1117
WMOST45- WHMBLA5	110	5	1685
WMBLA5- WMOST55	110	2	637
WMOST55- WMOST75	110	-	-
WMOST75-WMOST65	110	-	-
WMOST75- WMOST15	110	-	-

Table 2. Transmission line downtime statistics (January 2020)

As it can be seen from statistics, the only unavailability of the observed transmission lines occurred during the planned outages related to regular maintenance, so we can conclude that the observed grid withstands peak loads well during the winter.

3. Electric load modelling

The aim of this paper is to make a model of the existing part of the grid whose characteristics were recorded at a specific occasion on the screen of the dispatch centre or SCADA service. In this case it is the maximum grid load in January 2020 during the winter increase in consumption. The model done in NEPLAN [5] simulation tool should be compared with real circumstances and point out possible modifications of the case study grid.

3.1 Case study

The model calculation requires data on the observed transmission lines such as conductor type, transmission line length, line constants, voltage level, etc. [6][7]. When designing transmission lines, catalogue values of line constants are used, which change during the service life and must be regularly measured and checked to adjust protective devices.

Conductor type	In [A]	R1 [ohm/km]	X1 [ohm/km]	L1 [mH/km]	R0 [ohm/km]	X0 [ohm/km]	L0 [mH/km]
AlFe 1 240 40	645	0,1190	0,4050	1,2890	0,3297	1,2648	4,0260
AlFe 2 240 40	1290	0,0483	0,3159	1,0055	0,1700	1,0400	3,3104
AlFe 1 150 25	470	0,1941	0,4217	1,3423	0,5823	1,4740	4,6919
Cu 1 150	510	0,1229	0,4610	1,4674	0,3687	1,5600	4,9656
AlFe 1 120	410	0,2370	0,4100	1,3051	0,7100	1,6400	5,2203

Table 3. Line constants catalogue values for the type of conductor

Through the known inductance of the line it is possible to calculate the line capacity. According to the theory of electricity transmission, the product of the driving capacity C_1 and the driving inductance L_1 per unit length of the line is equal to the reciprocal of the square of the speed of light [8]:

$$C_1 L_1 = \frac{1}{c^2} \quad (1)$$

Where $c = 3 \cdot 10^8 [m/s]$.

Fig. 2. Line parameters of the WMOST15-WMOST45 110 kV line [5]

4. Results overview and discussion

Because the observed grid is only a small part of a large national transmission system, ie the data is a micro-fragment that is not without other grid influences, feeders (F1-F4) that simulate the surrounding grid outside the case study transmission system are inserted.

Fig. 3. Case study radial 110 kV transmission grid in NEPLAN [5]

What needs to be analyzed are the voltage conditions on the busbars (nodes) as well as the loadflow. Given the results, some future improvements can be given in the form of a new 110 kV connection, which would further relieve the existing grid. The possibility of connecting some larger additional industrial consumption can be considered, as well as the possibility of supplying this part of the grid with some renewable form of energy.

NODE NAME	U [kV]	u [%]	U [angle °]
WHMBLA5	113,17	102,88	-0,1
WMOST15	112,20	102,00	0
WMOST45	113,19	102,90	0
WMOST55	112,31	102,10	0
WMOST65	112,53	102,30	0
WMOST75	114,76	104,32	-0,4

Table 4. Model nodes voltages

NODE NAME	ELEMENT NAME	P [MW]	I [kA]	I angle [°]	P loss [MW]
WHMBLA5	WMOST45-WHMBLA5	-8,537	0,721	91,7	0,0029
WHMBLA5	WHMBLA5-WMOTST55	4,357	0,721	-88,3	0,1168
WMOST15	WMOST15-WMOST45	-14,722	9,342	89,7	16,1217
WMOST15	WMOST15-WMOST65	16,212	9,15	89,5	14,4062
WMOST45	WMOST45-WHMBLA5	8,729	2,742	88,5	0,469
WMOST45	WMOST15-WMOST45	14,722	9,342	89,7	16,1217
WMOST55	WMOST55-WMOST75	48,561	9,158	88,4	12,3999
WMOST55	WHMBLA5-WMOST55	29,951	2,748	86,2	0,3909
WMOST65	WMOST15-WMOST65	-14,468	2,241	-92,7	4,1385
WMOST65	WMOST75-WMOST65	14,468	2,241	87,3	0,1195
WMOST75	WMOST55-WMOST75	-29,907	3,789	-90,9	5,3541
WMOST75	WMOST75-WMOST65	29,907	3,789	89,1	1,1557

Table 5. Model loadflow data

4.1 Model comparison with SCADA

The tool used has built-in functions related to the types of protection of the power system and the option of entering electrical parameters to adjust the remote and differential protection of lines and transformers. The differences between the values of SCADA downloaded data and the model are most obvious in the relationship between node voltage and transmission line power. The actual grid is largely complex and balanced, as part of a national and international transmission system, so it is realistic to expect certain deviations of a model that observes only a small fragment of a large system. Compared to the bus voltage, we witness slightly higher voltage values. As for power flows, it can be seen that the model values (Table 5.) are almost equal to the SCADA data for January 15, 2020 (Table 1.) with some additional flows. Comparison charts are shown in Fig.4. and Fig.5.

Fig.4. Load flow comparison

Fig.5. Node (busbar) voltages comparison

5. Conclusion

A comparison of the model and the real-time state of the radial grid showed that with the basic grid parameters a very good model can be obtained which can then be used for grid model changes in the form of adding new elements such as power plants, new transmission lines, substations and additional grid load. The aim of the study was to show that the grid can be simulated using data on transmission lines such as conductor type, transmission line constants, transmission line length, load and voltage level. In addition to these basic parameters, the substance and analysis of this paper can be expanded by entering data on the type of transformers in substations, by inserting the types of protection of transmission lines and transformers and their adjustment. In addition to the catalogue values of line constants, some future research may use measured values that change over time and need to be constantly monitored.

This paper also showed that there is a good response from the competent grid monitoring and management services that can provide real-time data on the part of the grid in which one wants to invest or which needs to be improved for infrastructure needs. A very simple way is to come up with a model that can then be modified according to the needs of investors and local infrastructure projects to get some initial information on the impact of the investment on the grid and to get an introduction on the additional cost of removing any negative impacts.

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