Reliability of Power System in Slovenia – Comparison of Scenarios

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ABSTRACT

Due to the complexity of the power system, its reliability cannot be assessed by one method and cannot be represented by one parameter. Several methods exist and each can contribute to the power system reliability from its own viewpoint. The objective is to analyse the reliability of the Slovenian power system. The method of loss of load expectation is selected as a subject of the analysis. The loss of load expectation is used together with its upgrade with the recursive algorithm and with its upgrade related to the time-dependent modelling and analysis. The loss of load expectation is a method that gives us an estimate for the power system that is important for system planning and which gives a time interval in which the power generation cannot cover consumption in a probabilistic way in a certain period. The results specify the number of hours in a year when the power generation cannot cover consumption: the smaller the loss of load expectation, the better the power system reliability.

Reliability analysis of power system in Slovenia is performed through the application of loss of load expectation for several the most applicable scenarios. The current configuration scenario, the scenarios with renewable sources of energy, which replace some thermal power and the scenarios, where renewable sources are combined mostly with nuclear power, include the years 2018, 2019, 2020, 2028, 2030 and 2040.

The results show that the current power system in Slovenia is reliable, with relatively small average loss of load expectation. The winter months show notably reduced reliability, partly due to a larger electric energy consumption and partly due to a smaller power generation from solar power plants, which in winter months operate with significantly smaller power compared to summer months. The reliability of the Slovenian power system improves significantly after the inclusion of JEK2.

The results show that scenarios of power system where a significant number of new solar and wind power will be installed in addition to some other renewable source cannot guarantee a reliable power system. The variability of power of wind and solar is large and a reliable power system needs a powerful source of energy even when those sources are not available or not available in required amount. This problem can be can be fixed by import of power or by new nuclear power plant. Regarding the energy independence, which is mentioned in strategic documents, the import of electric energy in an extend, which is needed to insure reliable power system, cannot be considered. Therefore, the power system in Slovenia for its reliable operation needs nuclear power in addition to renewable sources.

1 INTRODUCTION

Due to the complexity of the power system, its reliability cannot be assessed by one method and cannot be represented by one parameter. Several methods exist and each can contribute to the power system reliability from its own viewpoint.

The objective is to analyse the reliability of the Slovenian power system. The method of loss of load expectation is selected as a subject of the analysis.

The method was developed decades ago [1]. Later it was upgraded several times. The most important upgrade considering evaluation of large systems was a recursive algorithm, which allows consideration realistic power systems in terms of their size [2], [3], [4]. Applications were published with extension of the method. One of them considers common cause failure of various power plants [4]. The other considers assessment of reserve power in order to reach the determined level of loss of load expectation with regard to variations of the load during a day or a year [5]. Consideration of renewable sources, which change their power output according to changes of weather, required an upgrade of the method in sense to consider instantaneous power of renewable sources versus consideration of their static nominal power all the time [5], [6], [7], [8].

2 METHODS

Power system reliability is generally represented by adequacy and security. Adequacy deals with the power system as a static system consisting of its components, while security deals with evaluation of power system dynamics, its transients and its stability. This paper mostly deals with the adequacy and the loss of load expectation is used together with its upgrade with the recursive algorithm and with its upgrade related to the time-dependent modelling and analysis.

The loss of load expectation (LOLE) is a method that gives us an estimate for the power system that is important for system planning and which gives a time interval in which the power generation cannot cover consumption in a probabilistic way in a certain period. The results specify the number of hours in a year when the power generation cannot cover consumption: the smaller the loss of load expectation, the better the power system reliability. Some unique criteria in sense what is acceptable or not or what is good or what it is not does not exist. In some countries, the acceptable values of loss of load expectation are smaller than either 8 hours per year or 4 hours per year or 3 hours per year which depends on a specific country. The majority of countries does not have quantitative requirements about loss of load expectation.

The mathematical model of loss of load expectation is presented in literature and it is not repeated here due to the reasons of space [1] - [9].

3 ANALYSIS AND RESULTS

3.1 Models and scenarios

Reliability analysis of power system in Slovenia is performed through the application of loss of load expectation for several the most applicable scenarios, namely the current configuration scenario, the scenarios with renewable sources of energy which replace some thermal power and the scenarios, where renewable sources are combined mostly with nuclear power. The scenarios with renewable sources and the mixed scenarios with renewable sources and nuclear power are further divided into several subgroups of scenarios. The periods, which are considered and analysed, include the years 2018, 2019, 2020, 2028, 2030 and 2040. The recent years are selected for analysis of the power system current state. The years 2028, 2030, 2040 are selected, because they are important milestones in strategic documents in Slovenia.

Every scenario in a specific year includes all specific inputs related to all the features of the power system:

- the number of power plants, which are operational in specific year, and their identification,
- nominal power of the power plants and instantaneous power of the power plants, which depend on the weather parameters; for future sun and wind power plants, their power was scaled according to the weather parameters from year 2019; uncertainties can be considered,
- reliability parameters of all the power plants, which are specific for all the power plants for which specific data exists about the history of their unplanned shutdowns,
- generic reliability parameters for some plants, which are projected for future years, where no plant history exists,
- yearly load diagram, which every hour changes its load due to variability of needs of electric power consumers.

All the inputs are specific to the power system in Slovenia for a specific scenario for a specific year.

3.2 Results for recent years

Reliability analysis of power system in Slovenia through the application of loss of load expectation for the current configuration scenario in the year 2019 is presented. Figure 1 shows loss of load expectation for power system in Slovenia in the year 2019. Instantaneous value renewing every hour is shown together with yearly and monthly average. Figure 1 shows that notable differences in loss of load expectation exist between day and night due to unavailable solar power during the night. This can be seen looking to blue curve LOLE(t), which vary from minimum 0,188 h/year to maximum 2,531 h /year. The difference is larger than an order of magnitude.

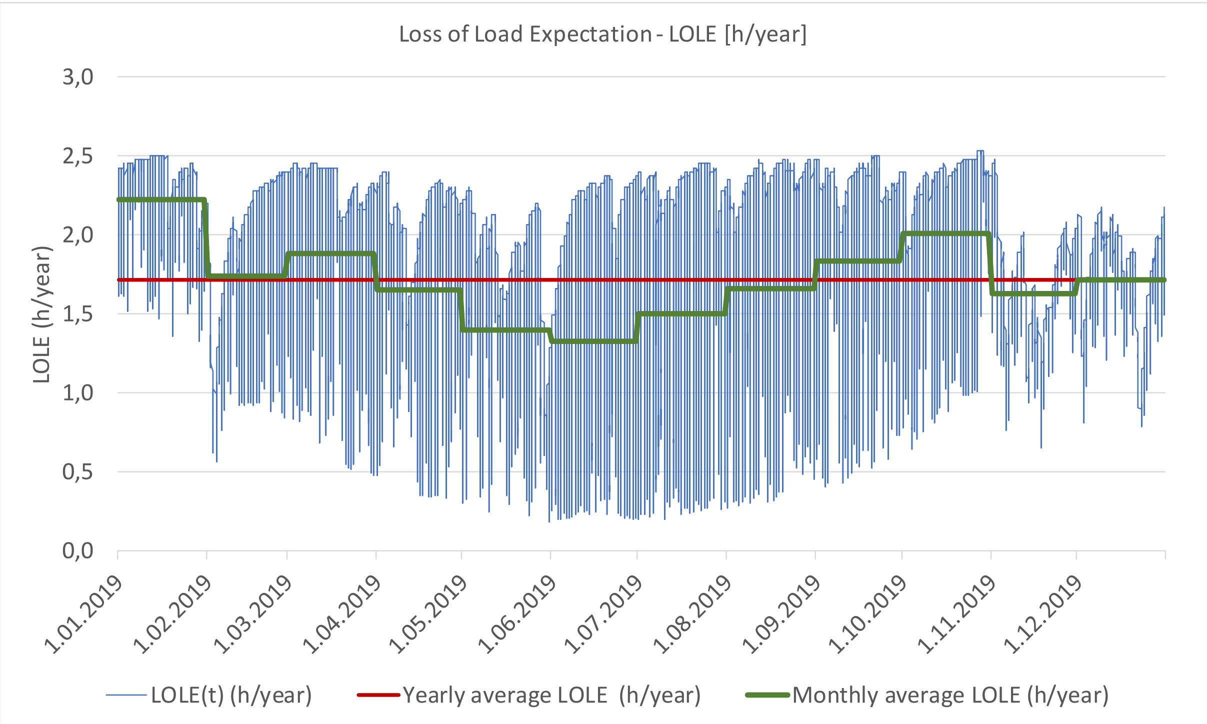

Figure 1: Loss of load expectation for power system in Slovenia in the year 2019

The differences due to the changing wind speed are not observed, because the amount of wind power in Slovenia is nearly negligible.

The consequence of larger power consumption in winter and smaller solar power production are shown comparing the monthly averages in winter and in summer months. Figure 1 shows notably larger loss of load expectation and consequently notably lower power system reliability for the winter months.

Figure 2 shows daily average of loss of load expectation for power system in Slovenia in the year 2019 compared to monthly and yearly average. Daily average varies from minimal loss of load expectation 0,731 h/year to maximal 2,432 h/year.

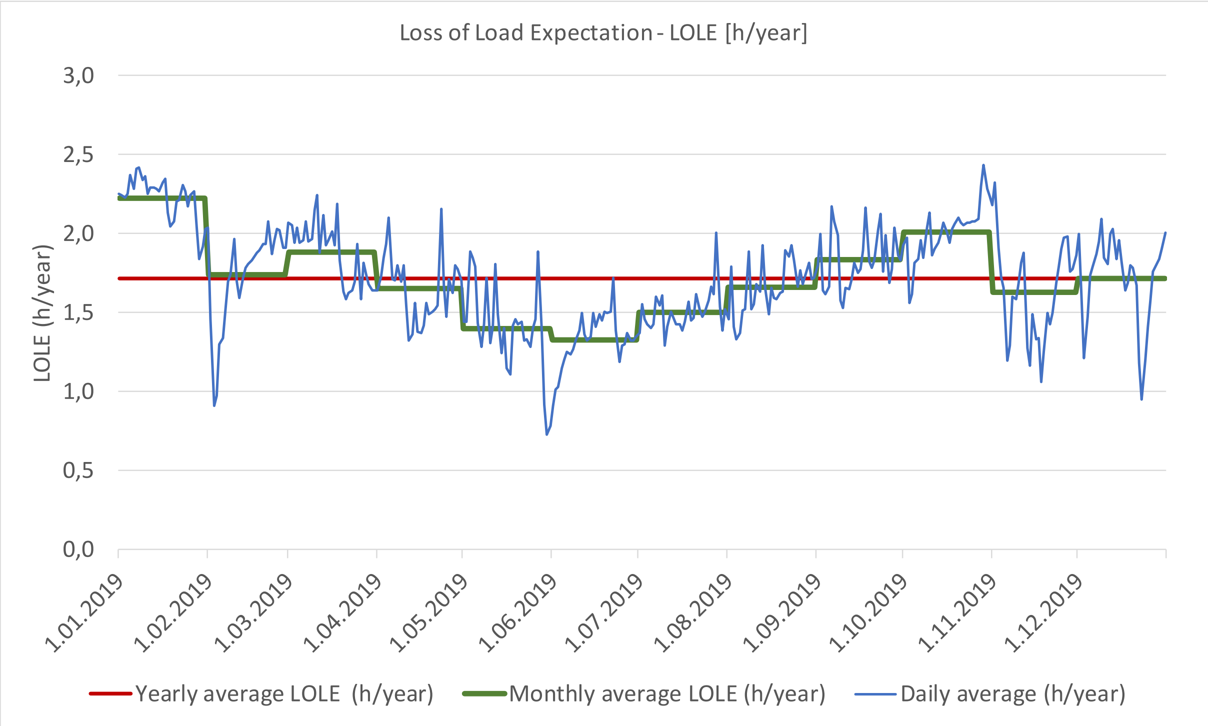

Figure 2: Average loss of load expectation for power system in Slovenia in the year 2019

The results show that the current power system in Slovenia is reliable, with relatively small average loss of load expectation. Table 1 shows the results from last three years compared. Year 2020 gives the smallest loss of load expectation, because a new gas power plant in Brestanica went in operation (53 MW) and the average power consumption compared to previous year was smaller for 6,6 % (the reason lays in pandemic situation in the year 2020).

Table 1: Loss of load expectation (h/year)

Year	Loss of load expectation - LOLE (h/year)			
	Yearly average	Monthly average – minimum - maximum	Daily average – minimum - maximum	Instantaneous value - minimum - maximum
2018	2,11	1,631 - 2,718	0,955 - 2,946	0,221 - 3,072
2019	1,72	1,331 - 2,226	0,731 - 2,432	0,188 - 2,531
2020	0,44	0,339 - 0,568	0,196 - 0,620	0,055 - 0,646

3.3 Results for future scenarios

Future scenarios base on strategic documents related to future power plants and projection of electric energy consumption in future years. The focus is placed to future years as defined in strategic documents: year 2028, year 2030 and year 2040.

Strategic documents are the following.

- Transmission system operator issued projection of new power plants including projected amounts of different renewable energy sources (RES) and projection of electric energy consumption in the year 2028; abbreviation ELES is used for identification of all related features.
- Ministry for infrastructure issued action plan for renewable sources of energy, which specifies the newly installed power from different renewable energy sources and projection of electric energy consumption in the future years up to the year 2030; term Action Plan is used for identification of all related features.
- Government of Republic of Slovenia issued an Integrated National Energy & Climate Plan of the Republic of Slovenia, which specifies the newly installed power from different renewable energy sources and projection of electric energy consumption in the future years up to the year 2040, abbreviation NEPC (National Energy & Climate Plan) is used for identification of all related features.

Future scenarios differ in general in the number of power plants of certain type and their power in the future years, where some amounts are given in the range of values: higher limit and lower limit: in terms of more or less MW obtained from specific power source. Additionally, the future scenarios differ in projections of electric energy consumption in Slovenia, where the last 24 years of data show that yearly average increase of power consumption is 1,8 % (our assessment). Projections of electric energy consumption consider increase between this 1,8 % yearly increase and half of it in the future years.

Table 2 shows collected results of selected scenarios. First three scenarios are for realistic power system as it was in a specific year. The columns of lower or higher limit of newly installed renewable sources of energy are not applicable, because all the power plants are considered in the system as they are.

The next four rows show four future scenarios with large increase of renewable sources. Each row includes information regarding the range of new solar and new wind power. Exception is scenario named RES 40 % (2040) NECP, where new solar and wind power are given as exact values (without range). Consequently, the results of lower, higher and average loss of load expectation would be the same. Only the last column of the results is given for the sake of transparency.

The next four rows show future scenarios with large increase of renewable sources and a new nuclear power plant named JEK2. The last scenario represents the same scenario as the one before it with only one change: a gas plant is there instead of nuclear plant of the same power.

Table 2 in the left column gives the details of newly installed solar and wind power in the future years. Other renewable sources such as hydro power plants, biomass power plants, biogas power plants are not given in the table due to reasons of space.

In addition, some other scenarios were evaluated, e.g. with and without existing nuclear power plant.

Table 2: Loss of load expectation (h/year) – comparison of results for all scenarios

Scenario	Loss of load expectation - LOLE (h/year)		
	Scenario (range of power of new renewable sources)		Average
	Lower limit	Higher limit	
Power system in the year 2018	/	/	2,11
Power system in the year 2019	/	/	1,72
Power system in the year 2020	/	/	0,44
RES 30 % (2028) ELES {new solar: lower 464 MW, higher 786 MW, new wind: lower 150 MW, higher 179 MW}	9,19	8,29	8,74
RES Action Plan (2030) {new solar: lower 570 MW, higher 916 MW, new wind: lower 235 MW, higher 415 MW}	119	102	110
RES 40 % (2030) NECP {new solar: lower 492 MW, higher 1650 MW, new wind: lower 10 MW, higher 150 MW}	148	106	127
RES 40 % (2040) NECP {new solar: 4400 MW, new wind: 415 MW}	/	/	478
RES 30 % + JEK2 (2028) ELES {new solar: lower 464 MW, higher 786 MW, new wind: lower 150 MW, higher 179 MW}	0,0144	0,0121	0,0132
RES Action Plan + JEK2 (2030) {new solar: lower 570 MW, higher 916 MW, new wind: lower 235 MW, higher 415 MW}	0,318	0,276	0,297
RES 40 % + JEK2 (2030) NECP {new solar: lower 492 MW, higher 1650 MW, new wind: lower 10 MW, higher 150 MW}	0,613	0,302	0,457
RES 40 % + JEK2 (2040) NECP {new solar: lower 2375 MW, higher 2497 MW, new wind: lower 224 MW, higher 236 MW}	0,27	0,0886	0,179
RES 40 % + Gas (2040) NECP {new solar: lower 2375 MW, higher 2497 MW, new wind: lower 224 MW, higher 236 MW}	1,38	0,453	0,917

The results show that reliability of power system in Slovenia decreases significantly without nuclear power plants. Due to the increased power consumption in the incoming years: the installation of new hydro power plants (nearly 1000 MW), new biomass power plants, new biogas power plants in addition to new solar and wind power, as planned in strategic documents, are foreseen. All this does not represent enough electric power for a reliable power system.

The results show that the reliability of the Slovenian power system improves significantly only after the inclusion of the new nuclear power plant JEK2 in addition to new renewable sources.

The results show that reliability of power system cannot be achieved only by adding the volatile and weather dependent renewable power sources of energy. One needs to build other power plants, too. The power plants with heavy rotation masses, e.g. nuclear power plant, which largely improves the reliability of power system as shown by the results, contribute also to better power system security (not only to better adequacy as shown in this paper).

4 CONCLUSIONS

The objective of the work to develop a method capable of considering volatile power plants in additional to classical power plants for assessment of reliability of power system was realised. The method was developed in a way that a realistic power system is modelled and analysed in terms of its reliability as a function of timely available power in power plants in the electric power system.

A collection of data related to realistic power system in terms of its configuration, its power plants, their available power as a function of time (capacity factors of different power plants differ significantly), their reliability parameters related to forced outages, was prepared. Those data served as an input to the models, which include several scenarios related to variety of power plants available and planned and related to the best estimated energy consumption in future.

Both, the method and the data represent input for the evaluations, which have been are conducted. Both the method and the data offer wide space for sensitivity evaluations and evaluations of different scenarios.

The results show in a probabilistic way, how many hours per year the electric power consumption cannot be covered by power production, which is a good indicator of the power system reliability. Smaller number of hours is an indicator of better power system in terms of its reliability.

The results show that scenarios of power system where a significant number of new solar and wind power will be installed in addition to some other renewable source cannot guarantee a reliable power system. The variability of power of wind and solar is large and a reliable power system needs a powerful source of energy even when those sources are not available or not available in required amount. This problem can be can be fixed by import of power or by new nuclear power plant. Regarding the energy independence, which is mentioned in strategic documents, the import of electric energy in an extend, which is needed to insure reliable power system, cannot be considered. Therefore, the power system in Slovenia for its reliable operation needs nuclear power in addition to renewable sources.

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