



Exploitation of renewable power sources for local consumers' reservation

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Abstract — Rapid growth of Latvian economy resulted in rapid growth of electricity demand in cities and rural regions. Consumers' reliability requirements are increasing, but improvement of reliability is directly related to electricity supply reservation possibilities in case of one or more network components failure. This article describes conditions for independent operation of decentralized renewable power supply sources, evaluates its exploitation possibilities and feasibility for local consumers' reservation. JSC "Latvenergo" distribution network has used this work for network long-term development planning.

Keywords - renewable power sources; reservation; reliability

I. INTRODUCTION

We can divide renewable power supply sources in Latvia in two groups: first are all small power stations, second are big hydro power plants, which transmit electricity through high voltage network (110 kV and 330 kV). Analysing Latvian big hydro power plants connection schemes, we came to conclusion, that using such renewable power supply sources, for local consumers' reservation is not possible because of large investments which are needed to build system, that allow direct energy transmission in distribution (20 kV) network.

We can consider all small power stations as decentralized power supply sources: hydro energy plants, wind energy plants, and combined heat and power plants. In all of these energy plants, energy sources can be renewable. Exception is combined heat and power plants if renewable natural resources are not used for energy production.

Current connection terms for decentralized power plants to JSC "Latvenergo" public electricity network imply immediate separation of decentralized power plant from the system in case

of any system failure. Such strategy allows to minimize probability of significant damage to electrical equipment in case of repeatedly connected voltage to damaged network sector due to relay protection misdoing or staff misdoing. However, this scheme does not allow to employ full potential of renewable power supply sources for increasing reliability of electricity supply. Drawbacks of current system are especially vital when supply disruption lasts for extended periods of time, for example, storm in 2005, which caused power supply disturbances for almost half of JSC "Latvenergo" consumers' – disruption periods were especially long in rural territories. For employing maximum potential of decentralized power supply sources, it is necessary to separate these power sources from parallel work with the system with fixed amount of connected consumers', thereby retaining electricity supply for these consumers.

II. KEY FACTORS FOR RENEWABLE POWER SOURCES USE IN RESERVATION

In using decentralized power sources for local consumers' reservation, the following regulations exist:

- a) renewable energy plant for electricity production must use synchronous generator;
- b) network separation automatics must be managed separate from local consumers' systems portion in case of system failure;
- c) for system stability - decentralized energy plant rated generated power must be at least 30% higher than demanded power for consumers', which are supplied from decentralized energy plant separate from system.

Demand for the synchronous generator from possible available alternative energy plants list make to withdraw small hydro energy plants, where in most cases (in Latvia) asynchronous generators are used. In most cases small hydro energy plants rated generated electric power are not enough for reservation of significant number of consumers.

Wind energy plants rated power can be enough for part of local consumers' reservation, but this makes usage highly dependent on meteorological conditions, which in case of major system failures is not suitable for wind energy plant operation (for example storm conditions).

The above-mentioned fact allows to conclude, that, when exploitation of decentralized power sources for local consumers' reservation is analyzed, the focus must be on combined heat and power plants, which are less dependent on meteorological conditions.

To make exploitation of decentralized power sources for local consumers' reservation – feasibility analysis, it is necessary to know power station generated electric rated power and local consumers' maximum demanded load. For analysis, reliability parameters must be calculated to compare changes of energy supply interruption costs in case of using decentralized power sources for reservation.

III. EXAMPLE OF ANALYSIS FOR A SPECIFIC RENEWABLE POWER PLANT

To perform feasibility analysis of using decentralized power source for local consumers' reservation, we will make calculation for a real 110/20 kV substation and real combined heat and power plant (that uses renewable resources) where 6 generators with rated power of 1.2 MW are mounted (see Fig.1).

Reservation of all substation summary load is not possible using surveyed combined heat and power plant. However summary load at busbar KS2 – 20 is $P_1 = 3,5\text{MW}$ and such load, if necessary, is possible to reserve from neighbored combined heat and power plant.

Supply interruption develops in case of several system element failures, but element failures characterize:

- failure rate (average amount per year) – λ ;
- repair time (average one failure length in hours) – T_r ;
- outage probability (in relative units) – χ .

$$\chi = \frac{T_r * \lambda}{8760} \quad (1)$$

To perform economic comparison, it is necessary to calculate energy not supplied to consumers per year.

$$A_n = \chi * P_{max} * T_{max} \quad (2)$$

where,

- A_n – energy not supplied per year;
- P_{max} – maximum consumers' load (devised maximal load on busbar KS2 – 20 $P_{max} = 3,5\text{ MW}$);
- T_{max} – peak load length.

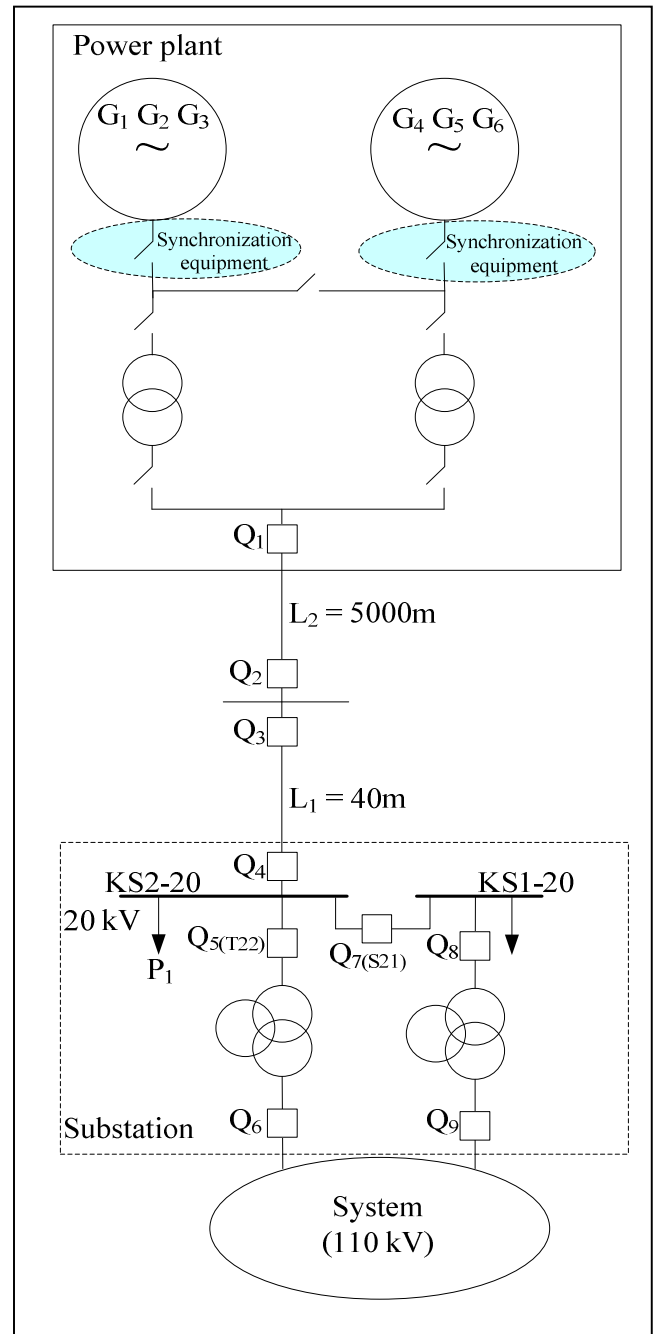


Figure 1. Simplified combined heat and power plant connection chart

where,

- $G_1, - G_6$ – generators,
- $Q_1, - Q_9$ – circuit-breakers,
- T_{22} – 110/20 kV transformer circuit-breaker,
- S_{21} – switched busbar circuit-breaker,
- $L_1, \text{ and } L_2$ – cable lines length,
- $KS1-20$ and $KS2-20$ – 20 kV busbars,
- P_1 – summary load at busbar KS2 – 20 (3,5 MW).

Knowing energy amount which is not supplied to consumers' per year, we can calculate supply interruption costs that arise in the case of failures.

$$C_R = c_r * A_n, \quad (3)$$

where,

C_R – supply interruption costs per year;
 c_r – cost of kWh not supplied.

To simplify calculation, the model was prepared on the following assumption:

- a) generators G_1 ; G_2 ; G_3 and accordingly G_4 ; G_5 ; G_6 operate in interrelated two blocks;
- b) busbar disconnector at generator bus is not used in normal conditions, therefore it is not considered in calculation;
- c) substation 110 kV transfer busbar is not used in normal conditions, therefore it is not consider in calculation;
- d) substation supply from 110 kV side regard as faultless ($\chi = 0$);
- e) calculation is required for busbar KS2 – 20 reliability characteristic comparisons, therefore calculation for every option realized from power supply point till busbar KS2 – 20, without regard to busbar itself and its adding's effect to reliability parameters.

Busbar KS2 – 20 reliability estimate considering each supply element availability [1] (see Fig. 2). Availability describes object ability be ready realize marketable function. Availability is easy to calculate knowing outage probability.

$$R = 1 - \chi, \quad (4)$$

where,

R – availability (in relative units).

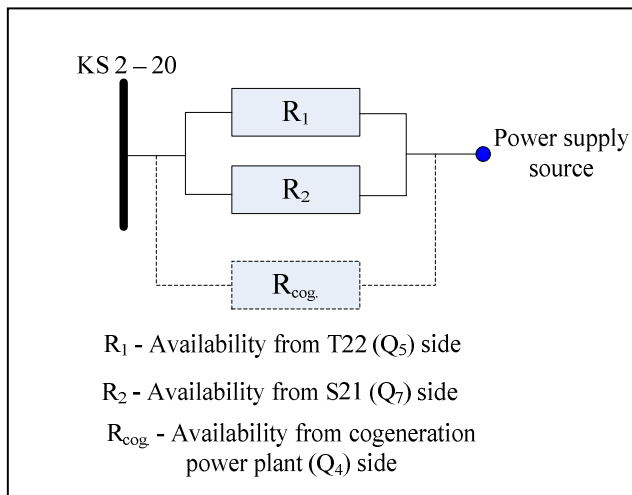


Figure 2. KS2 – 20 reliability calculation model

Considering failure rate of several elements and thus elements average repair time, and using simplified combined heat and power plant connection chart (see Fig. 1), main reliability parameters can be calculated: outage probability, availability and summary non-supplied energy per year.

Institute of Physical Energetics, Latvian Academy of Sciences scientists had developed program (LDMSG) for distribution network technical – economical analysis (ordering organization – JSC “Latvenergo”), that allow to evaluate different distribution network development variations considering network reliability factor too. For example, in Fig.3 is simulated situation, when local consumers' energy supply is reserved from combined heat and power plant.

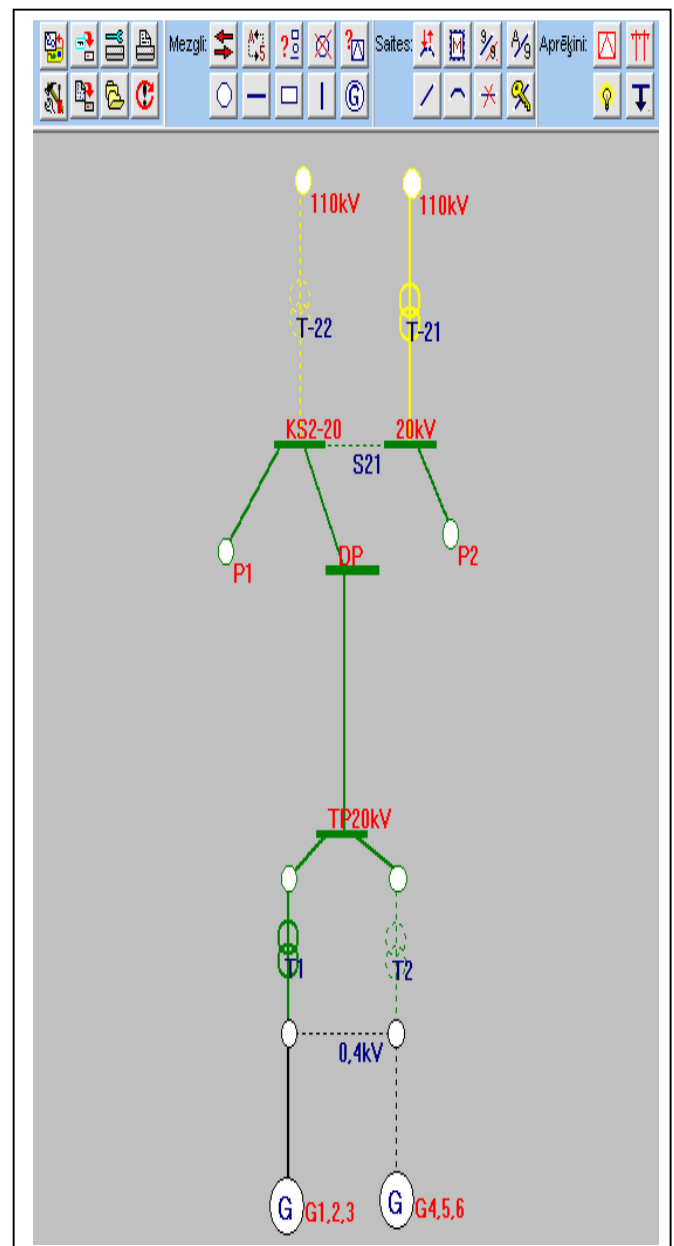


Figure 3. Combined heat and power plant connection chart model in program LDM-SG07

Calculation was managed for two cases – with and without using reservation combined heat and power plant.

1) Calculated power supply reliability technical – economical feasibility characterized parameters without using combined heat and power plant for reservation:

$$\lambda_1 = 1,063 * 10^{-3}$$

$$\chi_1 = 1,757 * 10^{-6}$$

$$R_1 = 0,999998$$

$$A_{n1} = 54 \text{ kWh.}$$

2) Calculated power supply reliability technical – economical feasibility characterized parameters using for reservation combined heat and power plant:

$$\lambda_2 = 1,605 * 10^{-6}$$

$$\chi_2 = 1,626 * 10^{-9}$$

$$R_2 = 0,999999998$$

$$A_{n2} = 0,05 \text{ kWh}$$

$$\Delta A_n = 53,95 \text{ kWh.}$$

If $c_r = 3 * 0,073 \text{ €}$ (accordingly to Latvian legislation compensation for consumer energy not supplied are triple cost of one kWh cost for each not supplied kWh),

$$\text{then } \Delta C_R = 11,80 \text{ €.}$$

If $c_r = 4 \text{ €}$ till 60 € (real costs of outages for service sector, if outage length don't exceed one hour accordingly to [2]),

then $\Delta C_R = 216,66 \text{ €}$ till $3249,94 \text{ €}$,

where,

ΔC_R –energy not supplied to consumer amount decrease per year.

Admittedly, in this example reliability parameters are not calculated in absolute values, because 110 kV system outage probability is not considered, that would increase A_{n1} (especially considering reliability problems that came to light after storm in 2005) and consequently would increase ΔA_n and ΔC_R , too. The purpose of example is only to show value decrease of energy not supplied, if decentralized power source is used for local consumers' electricity supply reservation. True busbar KS2 – 20 availability relative value will be smaller, because of busbar itself and its adding's effect to outage probability.

CONCLUSIONS

As shown in calculation, supply for existing substation busbar KS2 – 20 is reliable enough, therefore the gain from combined heat and power plant using in reservation is not so significant to invest resources in such reservation establishment for this specific example. Situation could change at the moment, when Latvian distribution network will pay compensation for consumers' energy not supplied considering actual incurred losses, which is not possible considering present legislative regulations.

To implement power supply reservation from combined heat and power plants as shown in example, there is no need for capital investments. Only requested investments are investments for digital rely programming and testing, but even these costs will not pay off, because of small benefit from this reservation.

The main conclusion is that exploitation of decentralized power sources for local consumers' reservation does not pay off if alternative power source can reserved load that is connected directly to 110/20 kV substation 20 kV busbar, where availability level is high. Such reservation will pay off only if compensations for energy not supplied will significant increase. Renewable power sources using for local consumers' reservation can pay of if network outage probability is relatively high e.g. if alternative power source can be connect in distribution network circuit comparatively far from 110 kV substations.

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