Island Russkiy - test field for the research of emergency control in microgrids

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Introduction

Russian power system doesn't have any test fields for study and development of scientific, technological and economic solutions in microgrids and virtual power plants (VPP). This fact stops the work on implementing modern technologies on electricity generation, distribution and consumption. However, this topic is one of the prioritized in Europe and US. Taking into account convenient geographical position of Island Russkiy and recently renewed energy infrastructure, as well as potential for solar and wind energy, one can find the island very perceptive, unique test field for experiments and research in microgrids.

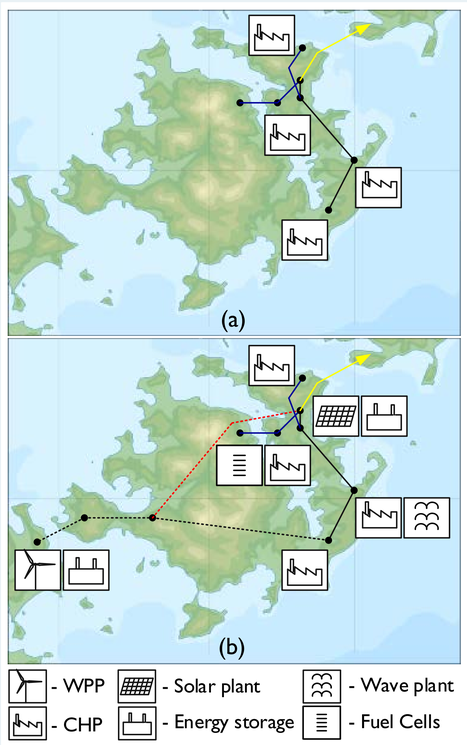

Figure 1 – Possible stages of power system development on the Island.
Solid lines – existing power lines, dashed lines – possible lines.
Voltage levels: yellow color – 220 kV, red – 100 kV, black – 35 kV, blue – 10 kV.

Methods

The purpose of the work is to test possible smart grid components, such us energy storage devices, for emergency control in the microgrid power system. To do this an adequate mathematical model of Island Russkiy's power system is required.

Thus the first stage was focused on model creation and validation. The base regime is designed so there is a power flow from the main grid to the Island. Then, the following test was set:

Trip of the 220 kV overhead line that connects the Island to Primorskaya power system. The microgrid will operate in islanded mode.

The intent is to show the frequency control possibilities of an energy storage device as well as power oscillations damping during lack of generation.

Model description

Island Russkiy's power system consists of four combined heat and power plants (CHPs) that have rated capacity from 2.8 to 28.4 MWe (see [1-3] for details) with total rated capacity on the island of 45 MWe.

Generation voltage level is 10 kV and all power plants are connected by 35kV radial cable lines. The microgrid has connection to the mainland by 220 kV marine cable and overhead line, through substation (SS) Russkaya.

Centralnaya CHP is the biggest one with 6 installed gas turbines (28.4 MWe). The highest consumption is Far East Federal University (35 MWe) and is located at the same node.

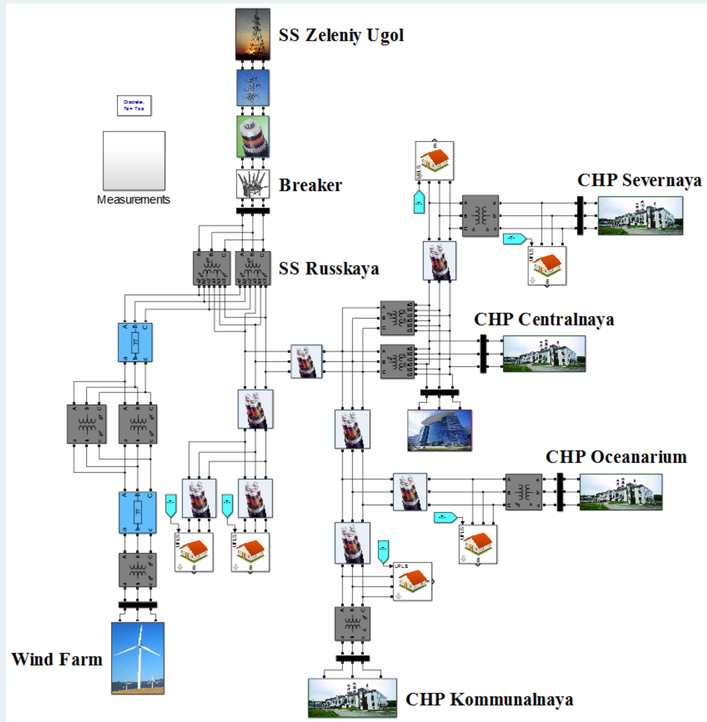

Figure 2 – MATLAB/Simulink model of the power system.

The model of the power system was created in EUROSTAG 5.1 as well as in MATLAB/Simulink. The first software was used for fast modelling of only electromechanical processes in the network. The second one was used for electromagnetic and electromechanical transients in more detailed model – it consists of full models of synchronous machines, Rowen's models for gas turbines [4] and energy storage device (ES) with on converter (figure 3). It was assumed that energy storage has rated capacity of 5 MWe and located on the Far East Federal University campus.

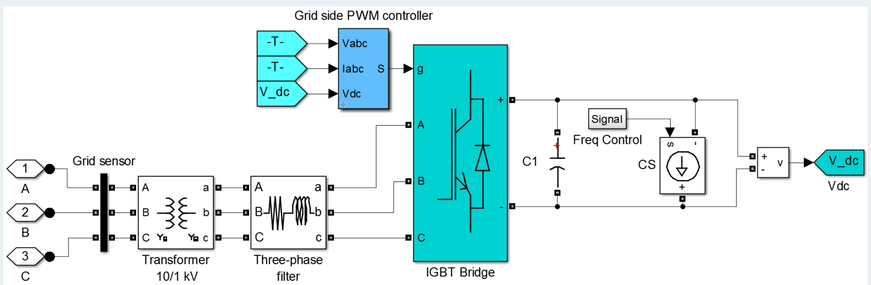

Figure 3 – MATLAB/Simulink model of the energy storage with AC/DC converter.

Results

For both models disconnection from the grid was simulated. One can see the results for EUROSTAG on figure 4 and for MATLAB/Simulink on figure 5. in both cases under frequency load shedding (UFLS) was modelled as a standard tool for emergency control [5]. Then a joint operation of UFLS and ES was studied.

It is clear that energy storage device can significantly improve the quality of transients. For example, there were no load shedding during operation, after the disturbance. Also the resulting low-frequency oscillations of gas turbines' power due to speed controller characteristics were quickly dumped.

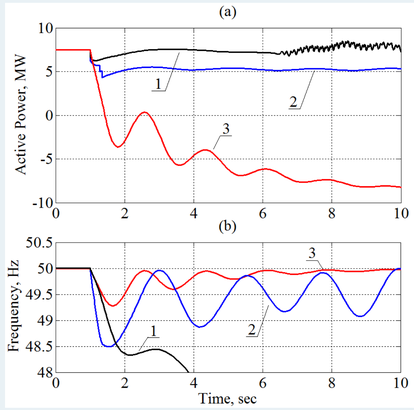

Figure 4 – Energy storage device active power (a) and frequency at the Centralnaya CHP node for EUROSTAG 5.1:
1) no control actions, 2) UFLS, 3) UFLS and ES

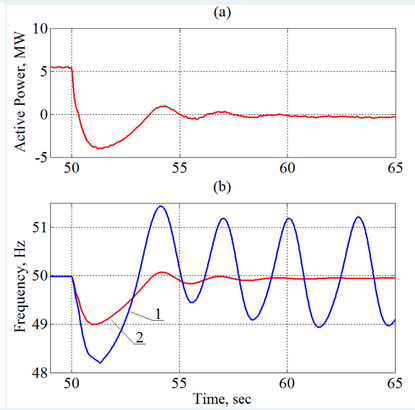

Figure 5 – Energy storage device active power (a) and frequency at the Centralnaya CHP node for MATLAB/Simulink:
1) UFLS, 2) UFLS and ES

Conclusions

The Russkiy Island may become one of the most convenient places for testing new technologies in Russian power system. This work presents one of the most probable network topologies. Two models were designed based on this network configuration – simplified EUROSTAG 5.1 model and relatively detailed MATLAB/Simulink.

The study was focused on application of energy storage device for frequency control in the system. The results for both models showed that with proper control ES can be highly effective for microgrid stability.

Recently, detailed information on the current structure on Island Russkiy power system was obtained, so future work will be dedicated to model detalization and validation.

References

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