Examination of Micro Grid Operation in Island Condition, Focusing on Voltage Control

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Abstract

This paper presents the assessment of cooperation and interaction of smart grids (with about zero transfer power) and a power system. Primarily, it examines the effect of the continuously increasing integration of the intelligent energy distribution networks concerning the stability of the power system. In this paper, the model that is used for simulating the smart grids is introduced, and is it also shown, how to apply them for island operation assessment, as well as the simulation results and the conclusions, that also can be drawn, are evaluated.

Keywords: MG (micro grid), island operation, voltage stability.

1. INTRODUCTION

The main phases of the electric network development were similar periods everywhere: the early local supply was followed by short-distance transfers and, nowadays, strongly meshed national or international networks are in operation.

The UCTE coordinates the operation and development of the electricity transmission grid of 24 European countries.

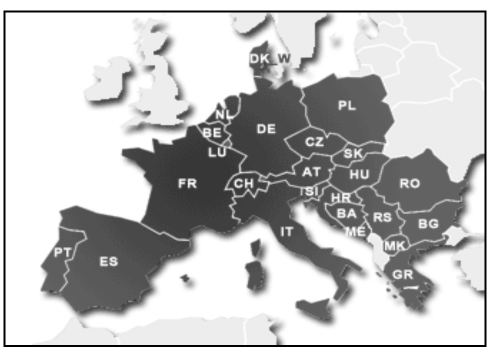

Figure 1. The topology of the UCTE

It provides a reliable market platform to all participants of the Internal Electricity Market (IEM) and beyond.The peak load of the UCTE, in 2007, was nearly 390 GW, and the electric energy consumption reached 2500 TWh. This system supplies power for around 450 million people.

This global energy network has many advantages. However, its disadvantages come increasingly to the light, because of the expectations of the current market conditions. As a consequence of extreme utilization: the safety of supply may be dragged into danger, which it was been confirmed by some events in the near past. There is a need to develop small and simple system-structures with easier control and design. The micro grid may be a solution for these questions. It simplifies the network in aspect of control; it is able to serve its own consumers and, occasionally, it can connect to the large network. Analyzing the steady state operation and transient behavior of this network is essential to set up an appropriate model.

2. MODEL DESCRIPTION

For set-up and examination purposes, a network analyzer software package (developed by the Department of Electric Power Engineering, TU Budapest) was used. By the help of the program, steady states of networks (load-flow calculations) effects of several faults and breaker operations during transients can be analyzed. In addition to the steady-state analysis, dynamic simulations were also calculated. The program is able to manage two synchronous systems operating with different frequency. A control simulation was calculated by Power World Power Systems Analysis Software for the steady-state simulations. The reason, why we used Power World is that the simulation software – made by

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the Department of Electric Power Engineering, TU Budapest – is not so known. On the other hand, the system topology cannot be drawn by that software. The model topology is shown in figure 2, which was made by the Power World SAS.

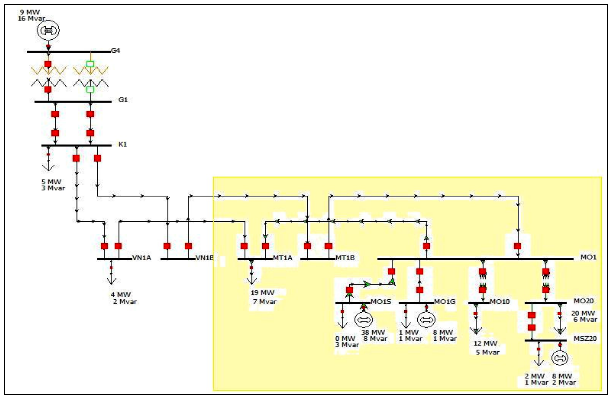

Figure 2. The topology of the model network

The network model consists of:

- high and middle voltage lines and buses (400-120-20 and 10-kV)
- transformers
- lines, parallel-lines
- generators and loads.

The sources may be power and/or voltage controlled. In the model, there are:

- two wind power plants connected to MO1S and MSZ20 buses,
- three 5 MW gas turbines (connected to the MO1G bus),
- and a large machine (connected to the G4 bus), as a system slack bus, in case of parallel operation with large network.

During the island operation, the gas turbines are the system slack. In the two wind plants 25 MW × 2 MW wind turbines are in operation. The loads are frequency and voltage dependent.

3. SIMULATIONS

3.1. Examination of the short-circuit power and voltage level

The subject of the first examination is the effect of wind power sources on the three phase short-circuit (in the following 3Φ short-circuit) power of the MO 1120 kV bus. (In island operation, the wind power plant is part of the smart grid). The simulation result shows how the 3Φ short-circuit power of the MO1 bus is influenced by an electrically far, big power plant and an electrically near, small (wind) power plant. Interesting results can be expected, if the 'wind does not blow' in the network, i.e. the power from the wind power plants is zero. In this case, the missing capacity is to be supplied by the G4 system slack bus and the short-circuit capacity changes in connection with this. The model was used for voltage stability examinations. To verify this fact the voltage conditions of the network have to be compared when the grid is in island operation and when the grid is connected to the network.

3.2. Island operation examinations

The island operation was established with a switch on MT1A-VN1A and MT1B-VN1B lines, so the two system frequencies were developed. The following examination consisted of several steps: the network operated as an island i.e. the MO1 bus and geographically close loads and sources form an island (the yellow area, see figure 2). The feasibility of island operation was examined. Different operation situations and faults were simulated, and size of voltage change was examined.

3.2.1. Power changes

The power generation of the wind power plant, connected to the MO1S bus, was reduced or increased by 0.5 MW steps, until the frequency deviation was compared to the other system, and to 50 Hz, as well as it exceeded by +/-2.0 Hz. A greater deviation should have such effect on the load that may cause failures. However, within the range of the limit (e.g. in case of an interconnected system collapse), the grid can become detached and stay operable by itself.

3.2.2. Load changes

Similar examinations were performed in relation to 10 and 20 kV load connected to the MO1 bus. In this case, the consumption was changed and not the power. The robustness of the grid was observed (how large consumption changes would not result +/- 2 Hz frequency limit override).

3.2.3. Shunt faults

In the third trial group, the grid has been put under extreme utilization. Firstly, one phase to ground short-circuit (in the following 1 Φ-G short-circuit) was simulated. And then a 3 Φ short-circuit was simulated on connection bus of 120 kV wind power plant and 3 Φ short-circuit on 20 kV wind power plant. From these simulation examinations, a conclusion was aimed to be drawn regarding the island operation conditions of a smart grid. The conclusion should include the survey both of stability and voltage conditions.

3.3. Reclosing the grid to the large network

During these simulations, the possibility to switch back the in-island operating grid to the large network was examined, and the frequency of steady-state level that could be found. At first, the grid was reclosed in normal steady-state power balance, and, after that, different situations were simulated. The power was reduced and increased in 2 MW steps – which is the size of one wind turbine – in the grid, so the frequency changed, and after that, the back switch was attempted.

4. SIMULATION RESULTS AND EVALUATION

The simulation results are reported in the same order like in chapter 3.

4.1. Examination of the short-circuit power and voltage level

The 3 Φ short-circuit power was examined to find out, how the network is influenced by the wind power plant. Figures. 3 and 4 show two important things: first of all, it can been seen, so the gas turbine connected to the MO1G bus suffers larger oscillation; in case of lack of wind power, it can be stable with the wind power plant, than without it.

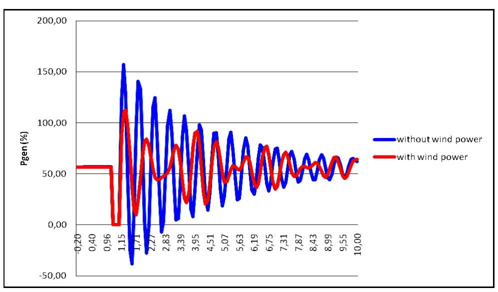

Figure 3. The input power ofthe MO1G bus, in case of 3Φ sc. on the MO1 bus

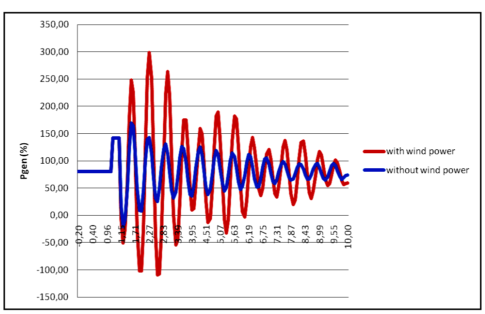

Figure 4. The input power of the MSZ20 bus, in case of 3Φ sc. on the MO1 bus

The simulation process was the following: the system operated at steady-state. At t = 1 sec, a 3 Φ short-circuit was simulated on the given bus. The clearing time was 0.2 sec.

On the other hand, the oscillations of the wind generators, connected to the MSZ20 bus, are smaller in amplitude and in periodic time, when there is no power input from the MO1S wind power plant. It is interesting, because the MSZ20's wind turbines supply the consumers in this area, while the power is provided from the MO1S wind power plant. When the inter-connected system is out of operation, it supplies the whole network, so the MSZ20 bus's generators have smaller tension. (see figures 5 and 6)

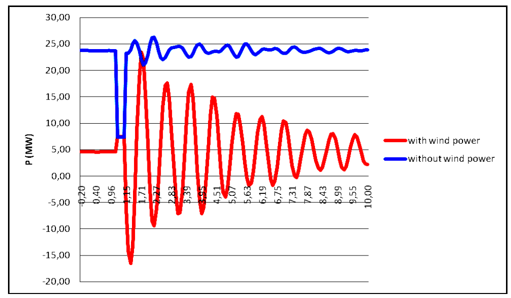

Figure 5. The power flow on G1-K1 line, in case of 3Φ sc. on the MO1 bus

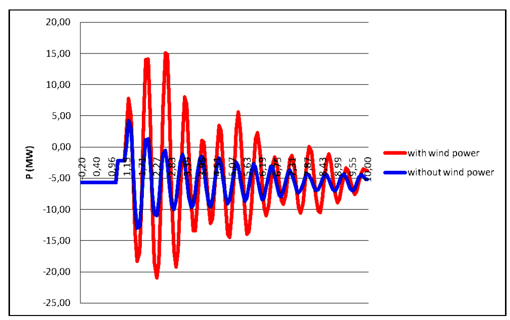

Figure 6. The power flow on MO20-MSZ20 line, in case of 3Φ sc. on the MO1 bus

It is possible maintaining the voltage-level in the grid in island operation as well. Those nodes, which are not voltage-holder points, have lower voltage level in the island, than in the synchronous operation. (see figures 7, 8 and 9).

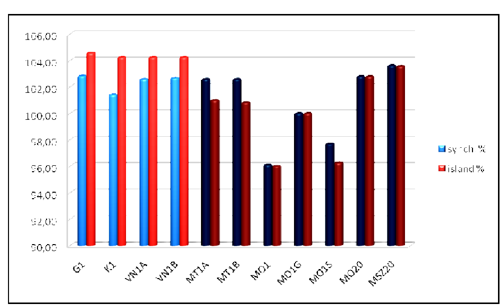

Figure 7. The nodes voltage level in p.u.

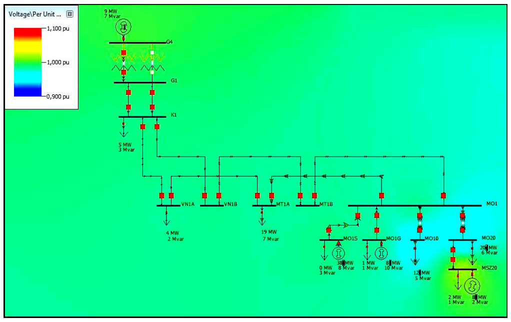

Figure 8. Voltage conditions in synchronous operation

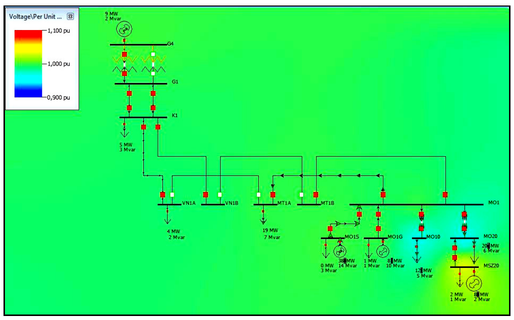

Figure 9. Voltage conditions in island operation

The remaining part of the network has a bit larger voltage level, when the grid is in the island. So, the island operation does not mean a voltage level problem. The dark color nodes are together in the grid.

4.2. Examinations in island operation

The main goal of this examination was to find out, how flexible the system is. Load was changed until the frequency-change remains between +/-2 Hz. Most of the consumers can tolerate this change of frequency, but larger frequency deviation may cause system failures.

Figure 10 shows how the MO1G tries to compensate the lack of power as a consequence of power generation decrease of MO1S wind turbine.

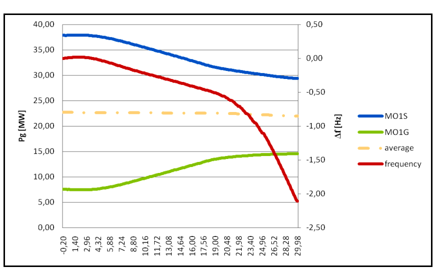

Figure 10. The load from MO1S is decreasing, and the MO1G is compensating

The whole primary reserve of MO1G is 7 MW, which is fully activated at 0.5 Hz frequency deviation. The primary control effect is not instantaneously limited by the gas turbine control dynamics. After reaching the primary control MW limit, the frequency of the island collapsed. Because of frequency sensitivity of loads about 8 MW wind power generation decrease is possible to correspond to the frequency criteria. The built-in power of the grid is 56 MW, so the grid is able to compensate almost 15 % of the full built-in power.

The simulation process was the following: the system operates at steady-state. From t=1 sec, the generated power was reduced on the MO1S bus in each second by 0.5MW.

In figure 11, as a consequence of increasing wind power generation, the frequency is rising. In case of 2 MW increase in generated power (up to 100 % load of machines), the frequency will change by +281 mHz.

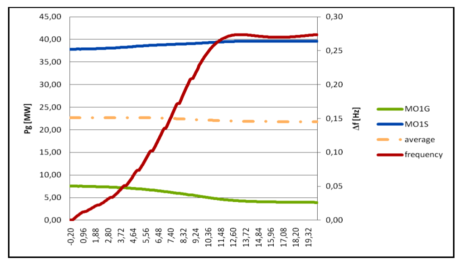

Figure 11. The load from MO1S is increasing, and the MO1G is compensating

The next examination was to reduce the consumption by 0.5 MW/sec. The full reserve capacity of MO1G was utilized (7 MW referring to initial state), and the frequency change was almost 1-1.1Hz. This indicates that our grid's robustness is good.

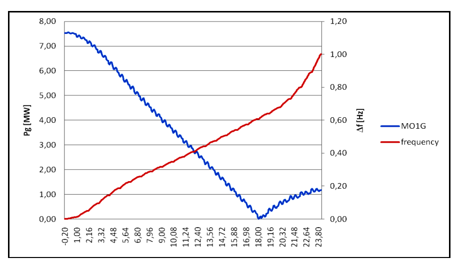

Figure 12. MO10 load is decreasing, MO1G is compensating

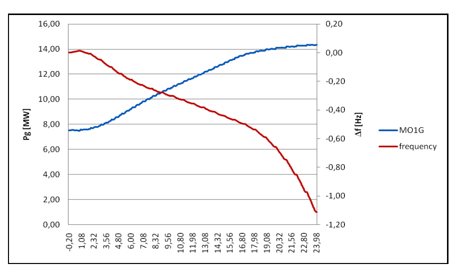

Figure 13. MO20 is increasing, MO1G is compensating

The third type of simulations in this chapter are fault analysis. 1Φ-G short-circuit and 3Φ short-circuit were simulated. The 1Φ-G short-circuit's clearing time is 0.3 sec., afterwards the failure phase is switched off for 1 sec, and the normal operation is back. The 3Φ short-circuit's clearing time is 0.2 sec. Three parameters were observed: generator frequency, system frequency and bus voltages.

4.3. Reclosing the grid to the large network

During these examinations, it was observed, how it is possible to switch back the grid to the large network, how the system frequency responds, and how it is possible to set back the synchronous state. Firstly, both systems were in steady-state operation. As next step, it was attempted to find out the maximum amount of change in generation, when it is possible to reclose the grid to the interconnected network. It is amazing, as in an extreme 10MW load-change situation it was possible to switch back (see figures 14 and 15).

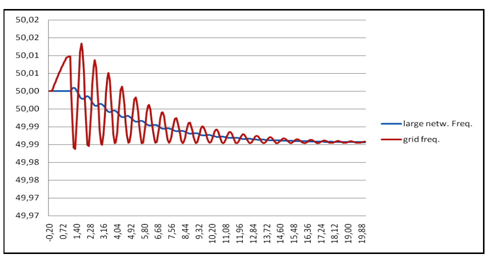

Figure 14. The two systems frequency during the reclosing, the transfer power: +10MW

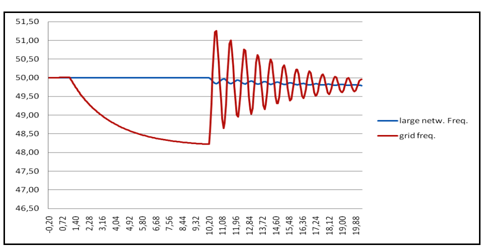

Figure 15. The two systems frequency during the reclosing, the transfer power: 0MW

In island operation, the power was increased in the grid by 10 MW, so the frequency falls down to 48.25 Hz. After that, it was possible to make the back-switch.

5. SUMMARY

Summarizing the main results: a simulation model was created, that is very similar to a part of the Hungarian power system. This area is capable for island operation, this way is convenient to be examined as a smart grid. The examinations after model creation can be divided into three main groups:

- island operation vs. synchronous operation
- voltage conditions
- frequency limits of island operation

In conclusion, we consider that:

- The wind power plant increases the stability of the system.
- If the grid synchronously operates with the interconnected system, the voltage conditions of the concerned busses do not change.
- The modeled smart grid has great tolerance limit in respect of generation change, consumption change and network faults.

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