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# Examination of Smart Grids in Island Operation

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**Abstract - This paper is qualified for the assessment of cooperation and interaction of smart grids (that means a micro network with about zero transfer power) and 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 the paper the model is published, used for simulating the smart grids and how to apply them for island operation assessment. With the help of a model network the results of the simulations are presented and also the conclusions can be drawn are evaluated.**

**Index Terms—Smart grid, island operation, frequency-voltage dependent loads, electro-mechanical transients.**

## I. 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, 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 about 390 GW, and the electric energy consumption 2500 TWh. This system supplies power for about 450 million people.

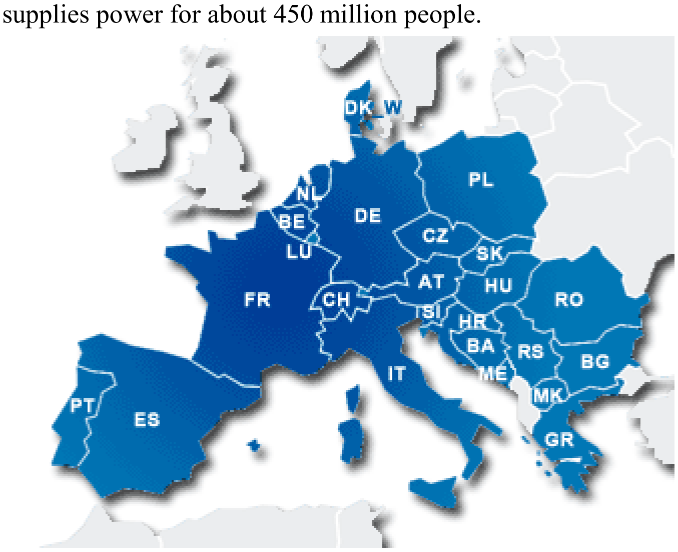


Fig. 1. The topology of the UCTE

This global energy network has many advantages however its disadvantages increasingly come 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 fact is reinforced by some events of 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 respect of control; it is able to serve its own consumers and occasionally it can connect to the large network. Analyzing of the steady state operation and transient behavior of this network is essential to set up an appropriate model.

## II. 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. With the help of the program can be analyzed steady states of networks (load-flow calculations) effects of several faults and breaker operations during transients. In addition to the steady-state analysis dynamic simulations were also calculated. The program is able to manage two synchronously operating systems with different frequency. A control simulation was calculated by Power World Power Systems Analysis Software for the steady-state simulations. The model topology is shown in Fig. 2., which was made by the Power World SAS.. 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 were involved.

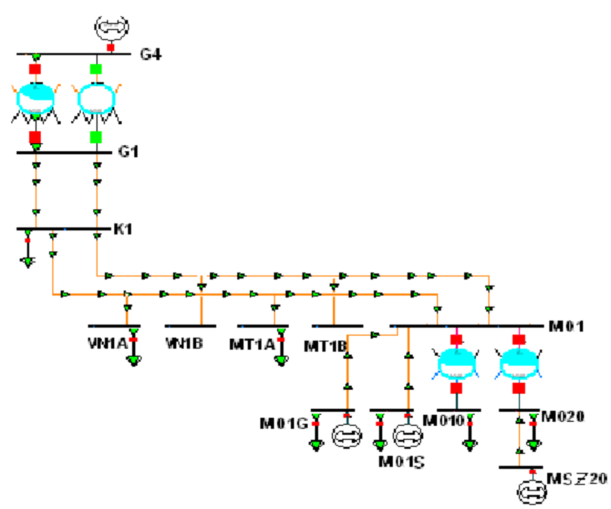


Fig. 2. The topology of the model network

The sources can have power and/or voltage control. In the model there are:

- two wind power parks 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.
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During island operation, the gas turbines constitute the system slack. In the two wind parks operate 25 x 2 MW wind turbines. The loads are frequency and voltage dependent.

## III. SIMULATIONS

### *A. Examination of the short-circuit power and voltage level*

The first examination is the effect of wind power sources on the three phase short circuit (in the following 3Φ sc.) power of the MO1 120 kV bus. (In island operation the wind park is part of the smart grid). The simulation result shows how influenced of the 3Φ sc. power of the MO1 bus by an electrically far, big power plant and an electrically near, small (wind) power plant.

Interesting results can be expected if in the network the 'wind does not blow', i.e. the power from the wind power plants is zero. In this case the missing capacity has to be given by the G4 system slack bus and the sc. capacity changes accordingly.

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.

### *B. Island operation examinations*

The island operation was established with a switch on MT1A-VN1A and MT1B-VN1B lines, and so the two system frequencies were developed. The following examination consisted of several steps: the network operates as an island i.e. the MO1 bus and geographically close loads and sources form an island (yellow area in Fig. 3.). The feasibility of island operation was examined. Different operation situations and faults were simulated; and the scale of voltage change was examined.

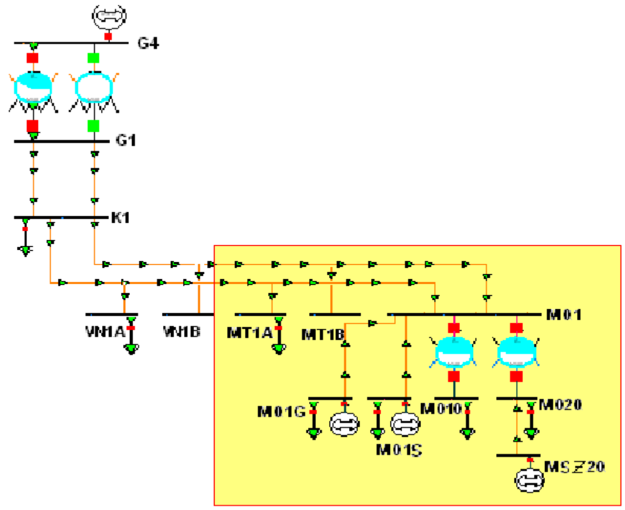


Fig. 3. Topology of the island

#### *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 as compared to the other system – and compared to the 50 Hz as well – exceeded +/- 2.0 Hz. A greater deviation would have such effect on the load that may cause failures. This way however, operating 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.

#### *2) Load changes*

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

#### 3) Shunt faults

In the third trial group the grid was subject to extreme utilization. Firstly one phase to ground short circuit (in the following 1 Φ -G sc.) and then 3 Φ sc. was simulated on connection bus of 120 kV wind power plant and 3 Φ sc. on the 20 kV wind power plant.

From these simulation examinations a conclusion was wanted to be drawn down regarding the island operation conditions of a smart grid. The conclusion should include the survey both of stability and voltage conditions.

### *C. Reclosing the grid to the large network*

During these simulations it was examined, how it is possible to switch back the in-island operating grid to the large network, and how the frequency of steady-state level could be find First the grid was reclosed in normal, stead-state power balance, and after it 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 it back switch was attempted.

## IV. SIMULATION RESULTS AND EVALUATION

Here will be reported the simulation results in the same order like in chapter III.

### *A. Examination of the short-circuit power and voltage level*

The 3 Φ sc. power was examined to find out, how the network is influenced by the wind power plant park. Diagram 1. and 2. show two important things: first of all it can been seen, that the gas turbine connected to the MO1G bus suffers larger oscillation, in case of no wind power. This means that it can operate more stable with the wind power plant park, than without.

The simulation process was the following: the system operates at steady-state. At t = 1 sec 3 Φ short circuit was simulated on the given bus. The clearing time is 0,2 sec.

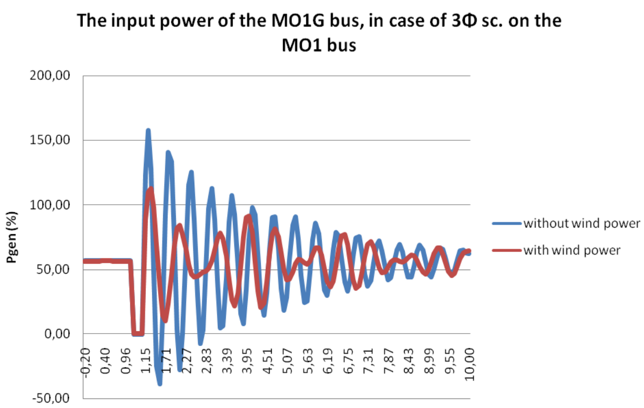


Diagram 1.

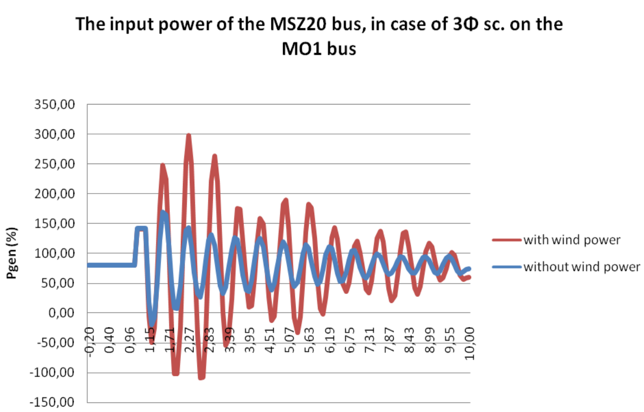


Diagram 2.

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. This is interesting, that the MSZ20's wind turbines supply own consumers in this area, while power is provided from the MO1S wind power plant park. If it is out of operation, the interconnected system supplies the whole network, so the MSZ20 bus's generators have smaller tension. (Diagram 3. and 4.)

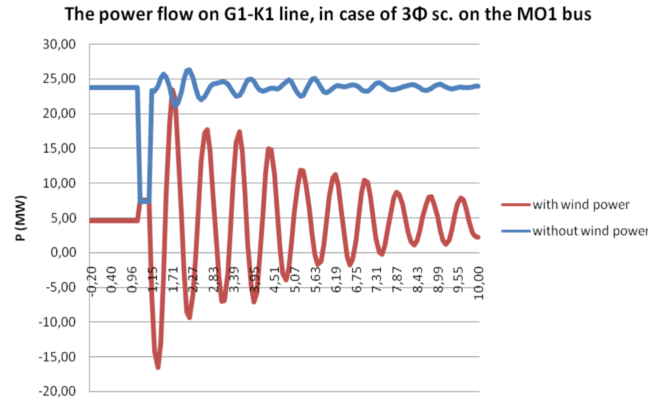


Diagram 3.

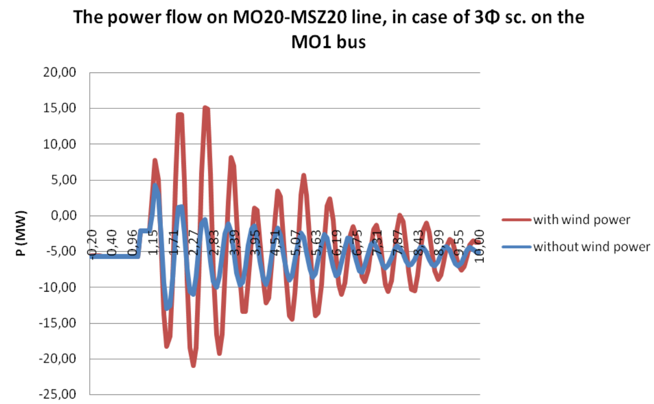


Diagram 4.

It is possible to hold 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 cooperation operation. (Diagram 5.) And 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.

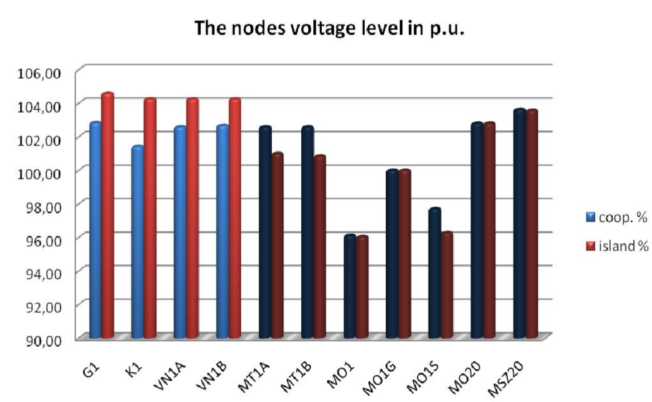


Diagram 5.

The dark color nodes are together in the grid.

## *B. Island operation examinations*

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.

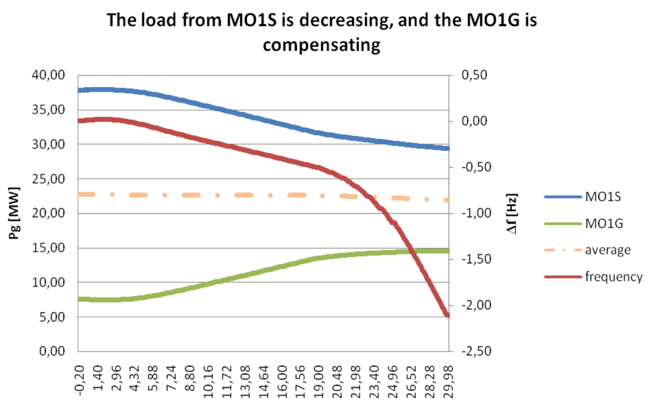


Diagram 6.

Diagram 6. shows how the MO1G tries to compensate the lack of source power as a consequence of power generation decrease of MO1S wind turbine park. 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 8MW 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.

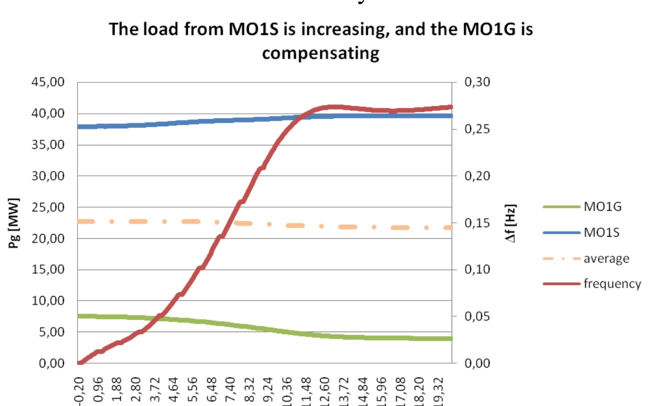


Diagram 7.

In diagram 7. as a consequence of increasing wind power generation, the frequency is rising. In case of 2 MW generated power increase (up to 100% load of machines) the frequency will change by +281 mHz.

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.

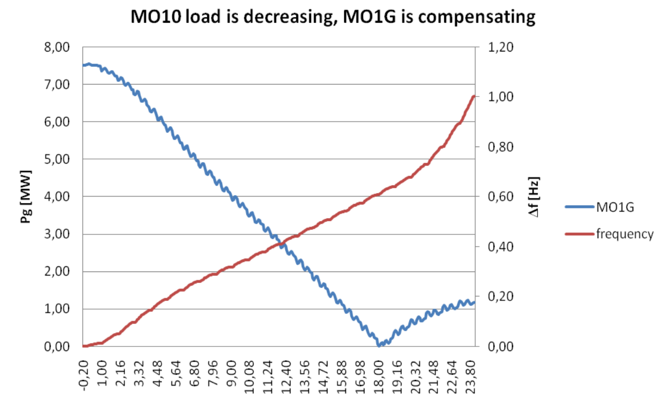


Diagram 8.

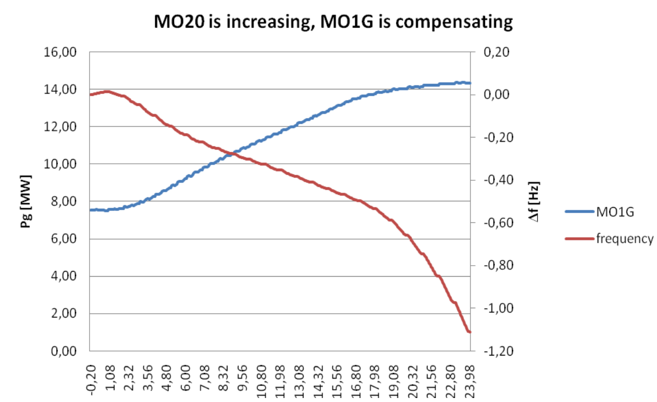


Diagram 9.

The third type of simulations in this chapter is fault analysis. 1Φ-G sc. and 3Φ sc were simulated. The 1Φ-G sc.'s clearing time is 0,3 sec., afterwards the failure phase is switched off till 1 sec, and the normal operation is back. The 3Φ sc.'s clearing time is 0,2 sec. Three parameters were observed: generator frequency, system frequency and bus voltages. These diagrams are in the Appendix (Diagram 10-15., 18., 19.)

## *C. 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 cooperation operation. Firstly both systems were in steady-state operation. As next step it was attempted to find out the maximum amount of generation change, 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. (Diagram 17.) In island operation the power was increased in the grid by 10 MW, so the frequency falls down to 48,25 Hz. After this, it was possible to make the back-switch.

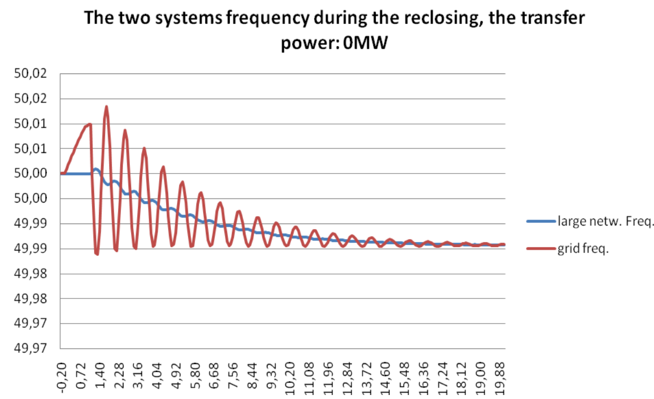


Diagram 16.

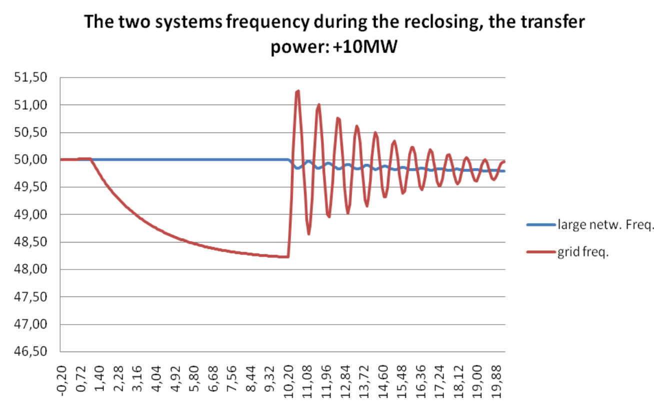


Diagram 17.

## V. SUMMARY

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

1. island operation vs. cooperating operation
2. voltage conditions
3. frequency limits of island operation

Conclusion:

- the wind power plant in the model increases the stability of the system
- if the grid operates synchronously with the interconnected system the voltage conditions of the concerned busses are not worse
- the modelled smart grid has great tolerance limit in respect of generation change, consumption change and network faults.

## VI. REFERENCES

[1] Technical And Economic Feasibility of Microgrid-Based Power Systems
Phil Barker, Doug Herman. Seventh EPRI Distributed Resources Conference and Exhibition Dallas, TX March 20-22, 2002

[2] Daniel Kirschen: Towards Decentralised Power Systems. ECCE meeting in Bruxels, oct. 2003

[3] Khaled A. Nigim, Wei-Jen Lee: Micro Grid Integration Opportunities and Challenges. IEEE 2007 General Meeting, Tampa, USA, 24-28 June 2007

[4] A. Faludi, L. Szabo: Power System Operation and Control (Hungarian) Lecture notes on vet.bme.hu/okt/foszak/ver/veri/index.htm, Budapest 2002.

## VII. BIOGRAPHY

**Istvan Vokony** was born in Mosonmagyarovar in Hungary on October 19, 1983. He graduated at Revai Miklos grammar-school in Gyor, and studied at the Budapest University of Technology and Economics Faculty of Electrical Engineering and Informatics Department of Electric Power Engineering.
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**Andras Dan, Dr**. is Professor with the Department of Electric Power Engineering, Budapest University of Technology and Economics. He received M.Sc. degree from Budapest Technical University in 1966, Ph.D. and D.Sc. degrees in Electrical Engineering from the Academy of Sciences in 1983 and 2005 respectively. His expertise is in power electronics, power quality and reactive power compensation especially associated with power system harmonics.

## VIII. Appendix

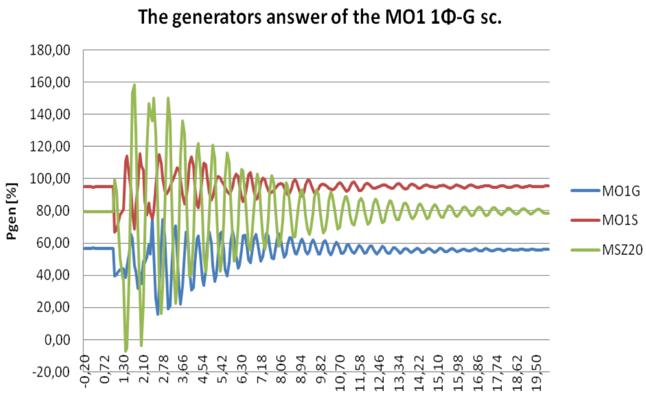



Diagram 10.

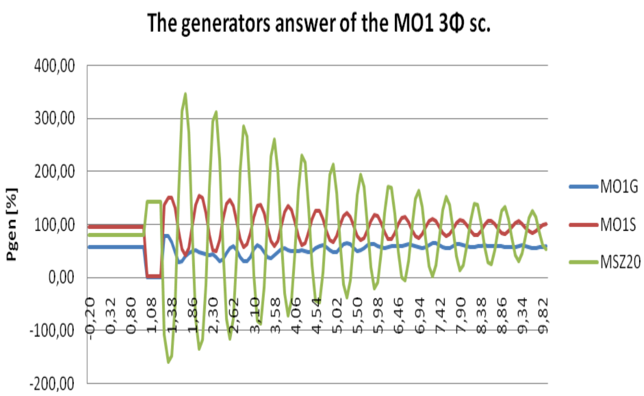



Diagram 11.

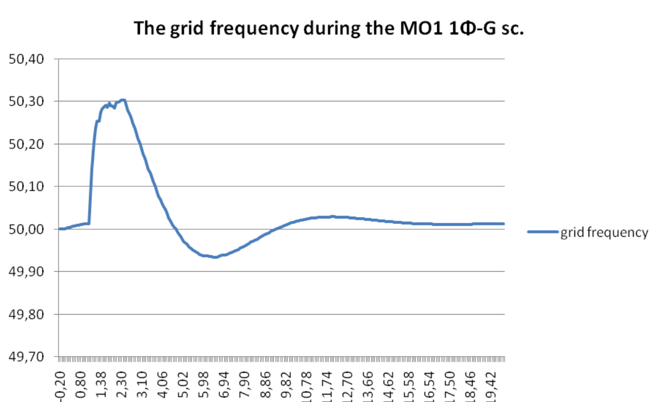



Diagram 12.

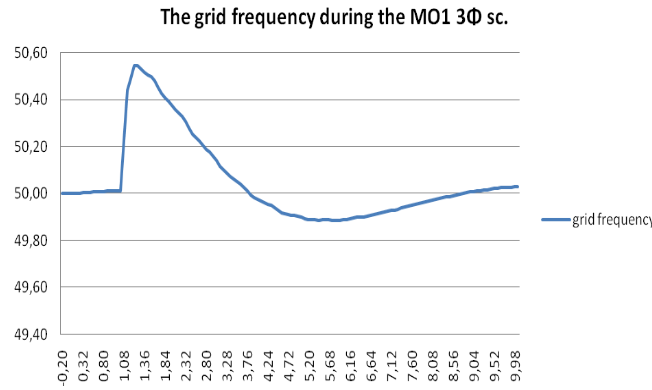



Diagram 13.

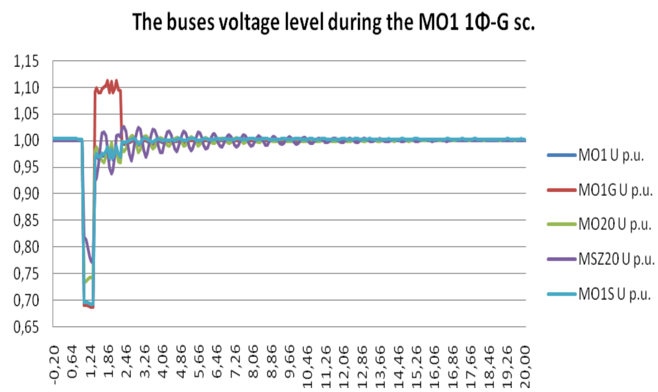
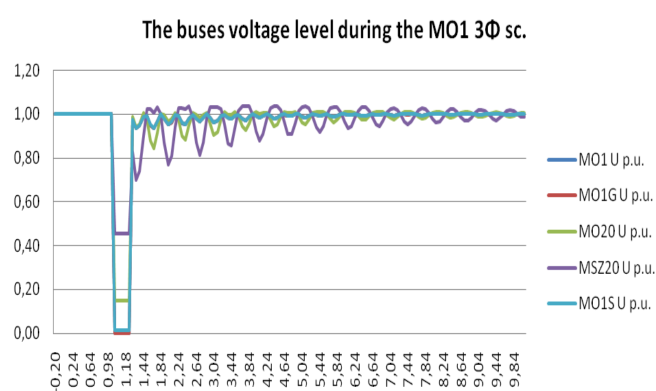



Diagram 14.

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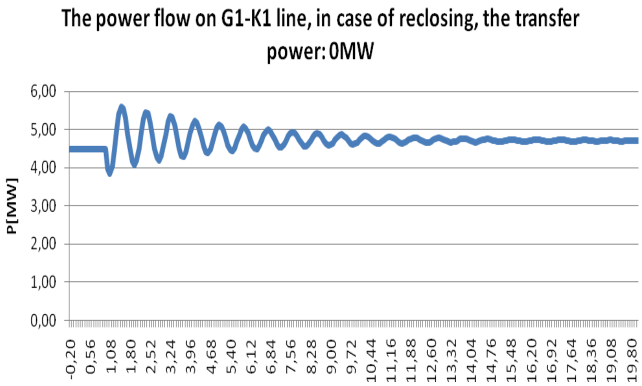


Diagram 18.

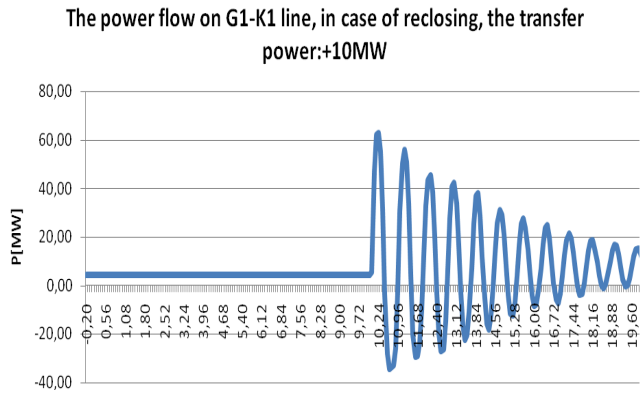


Diagram 19.