MODEL OF SLOVAK POWER SYSTEM USING SIMPOWERSYSTEMS

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Introduction

Power systems are combinations of electrical circuits and electromechanical devices. Engineers working in this discipline are improving the performance of the systems. This is one of the reasons, why the modeling of the power systems is required. We've decided to built the model of the 400kV power system of Slovak republic. There is plenty of software equipment used to model and simulate power systems, for example PSLF and Modes. This model has been built using products of The MathWorks Matlab/SimPowerSystems and Matlab/Simulink. In this article we would like to describe the software equipment we used, models of the used blocks, the network topology and simulating results.

Simulink

Simulink is a graphical user interface for modeling and simulation of the block schematics. The core of the Matlab is used to compute the simulating results. Simulink is primary used for modeling dynamic systems. Simulink libraries offer a plenty of blocks useful for modeling complex systems. With help of integrating methods, we can simulate the system and analyze it in time.

SimPowerSystems

SimPowerSystems is a toolbox, which expands the simulating environment Simulink of blocks oriented on power systems. In the libraries of SimPowerSystems we could find blocks for modeling a synchronous machines, transmission lines, electronic devices and transformers. SimPowerSystem is fully integrated to the Simulink interface, so it is possible to connect the the blocks of SimPowerSystems with the other Simulink blocks, so we can use SimPowerSystems for creating complex power systems. The model can contain wide range of elements from electrical power supplies, exciting systems to higher levels of control like primary, secondary and tertiary control of power.

Once you have built your circuit with the blocks of **powerlib**, you can start the simulation just like any other Simulink model. Each time you start the simulation, a special initialization mechanism is called. This initialization process computes the state-space model of your electric circuit and builds the equivalent system that can be simulated by Simulink. The power_analyze command is part of that process. It obtains the state-space model and builds the Simulink model of your circuit. This process is done automatically, so the user needn't to interfere it.

The block description

For model of power system of Slovak republic construction we've used blocks from different libraries, but some of the used blocks must be modeled, because they couldn't be found in the libraries of SimPowerSystems.

Synchronous machine model

For modeling the synchronous machine we've used the block from SimPowerSystems library. This model has two input ports for Simulink interface blocks P_m, V_f, one output port m for Simulink interface blocks and three ports A,B,C for interface with modeled power system, like is shown on Figure 1.
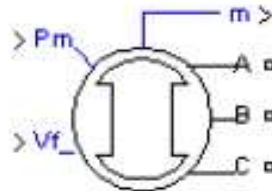

Fig. 1. Synchronous machine block of SimPowerSystems

This model could be for some conditions equivalent with Park sixth degree model. The machine is not modeled by electromotoric forces, but with electromagnetic torques. In some kinds of experiments we can observe an effect of higher harmonic frequencies, because of the machine model. We've used this model, when we were modeling domestic machines. When we were modeling transits of power through the power system of Slovak republic we've used simplified models. The simplified model could be for some conditions equivalent with Park third degree model.

Exciting system

The exciting system is used for control of exciting of synchronous machine. The model of the exciting system, shown on figure 2, consists of PI controller and simplified model of exciter.
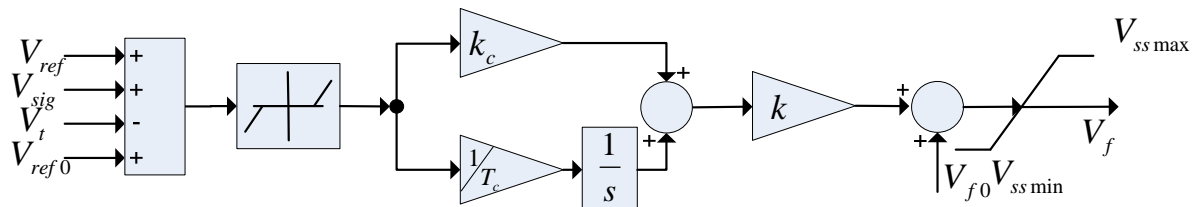

Fig. 2. The exciting system model

Description of the parameters of the exciting system:

V_{ref} - Reference value of voltage

V_t - Synchronous machine voltage

V_{sig} - Correction input (PSS, derivation feedback)

V_{ref0} - Initial reference voltage value, usually $V_{ref0} = 1$

V_{f0} - Initial exciting voltage value

k_c - Proportional gain of PI –controller

T_c - Integration time constant of PI - controller

k - Exciter gain

$V_{ss\,max}, V_{ss\,min}$ - saturation of exciter voltage

For simplified modeling and computing we've modeled the exciter just like the gain k. Model can be expanded of another controlling blocks with the input V_{sig}.

The experiment shown on Figure 3., displays the result of step change of reference voltage value on synchronous machine EMO11. We can see that in voltage control is a 0.05% non-sensitivity of control error. At the frequency time response we could see the high harmonic oscillations. These oscillations are also acting in the change of power.
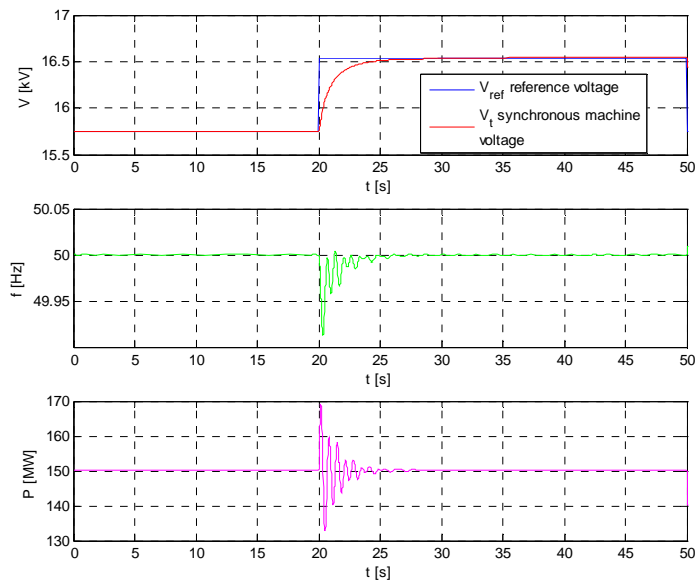

Fig. 3. Step change of voltage on synchronous machine EMO11 of 5% at time t=20s, with PSS off

Power system stabilizer

The structure of the power system stabilizer PSS3b is shown on figure 4. The stabilizer has three feedbacks of:

- Active power
- Electrical frequency
- Field current

All feedbacks in stabilizer have the same structure. The feedback contains: lowpass filter, highpass filter and feedback gain.
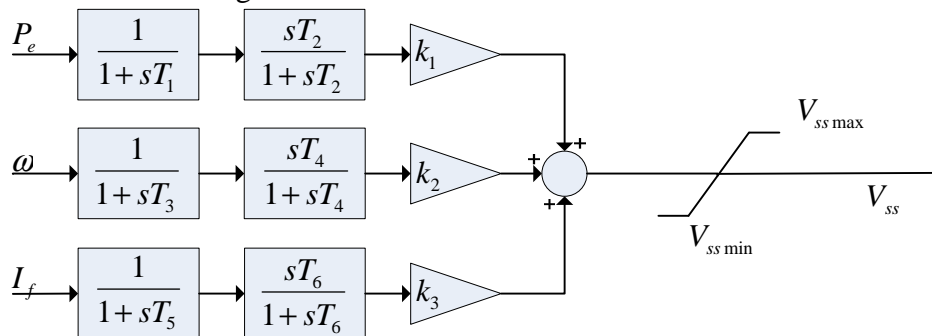

Fig. 4 schematic of power system stabilizer PSS3B

Description of the parameters of the power system stabilizer PSS3b:

T_1, T_3, T_5 - Time constants of lowpass filters

T_2, T_4, T_6 - Time constants of highpass filters

k_1, k_2, k_3 - Gains of feedbacks

$V_{ss\,max}, V_{ss\,min}$ - saturation of power system stabilizer output

P_e - Synchronous machine active power

ω - Synchronous machine electrical frequency

I_f - Synchronous machine field current

V_{ss} - Output of power system stabilizer

The experiment shown on Figure 5, displays the result of step change of reference value of voltage on synchronous machine EMO11, with PSS on.
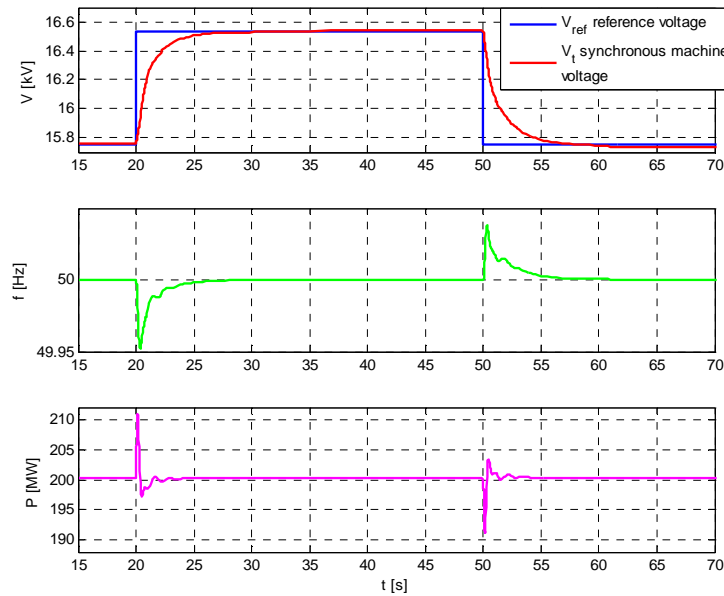

Fig. 5. Step change of voltage on synchronous machine EMO11 of 5% at time t=20s, with PSS on

Power controller

The power controller, shown on figure 6, consists of PI controller and the frequency corrector. Increasing rate of reference value of power P_{ref} is limited by ramp. To the sum block of controller is plugged signal form frequency corrector. Controller output is then limited.
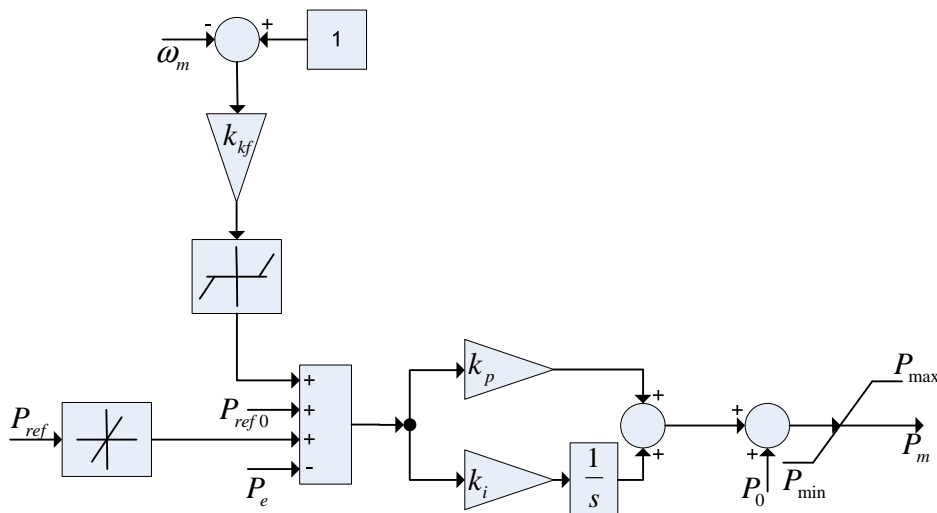

Fig. 6 Power controller model

Description of the parameters of the power controller:

P_e - Electric power

k_{kf} - Gain of the frequency corrector

P_{ref} - Reference value of power

$P_{ref\,0}$ - Initial value of reference power

k_p - Proportional gain of PI-controller

k_i - Integration gain of PI –controller

P_0 - Initial value of power

P_{max} - Maximum value of power

P_{min} - Minimum value of power

P_m - Power of turbine

ω_m - Voltage frequency

For verification of the power controller we choose the following experiment. Step change of load in node Krizovany of 13 MW at 30 s and step change of reference value of power on synchronous machine EMO11. The figure 7 shows the result of the experiment.
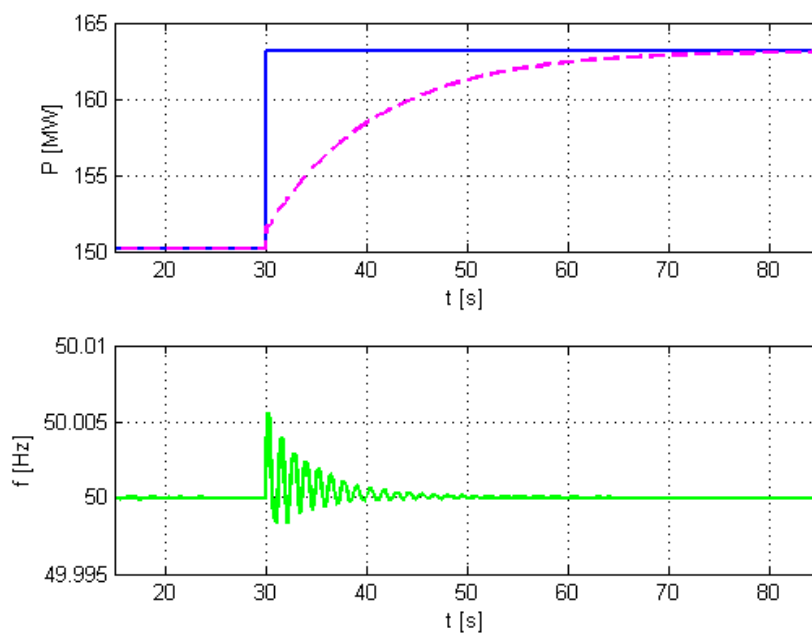
Fig. 7. Step change of load in node Križovany

The power system diagram

The diagram of 400kV power system of Slovak republic has been made by plan with co-operation with SEPS. First we've made the topology of the system; location of loads, blocks and their connection through the transmission lines. We've modeled these synchronous machines: Mochovce, Bohunice V2, Gabčíkovo, Vojany and Liptovská Mara. The modeled nodes are: Stupava, Podunajské Biskupice, Gabčíkovo, Krizovany, Bošáca, Varín, Sučany, Spišská Nová Ves, Lemešany, Moldava, R. Sobota, Levice and Horná Žďaňa. This model contains all of the important elements of 400 kV power system. Part of the model is shown on Figure 8.
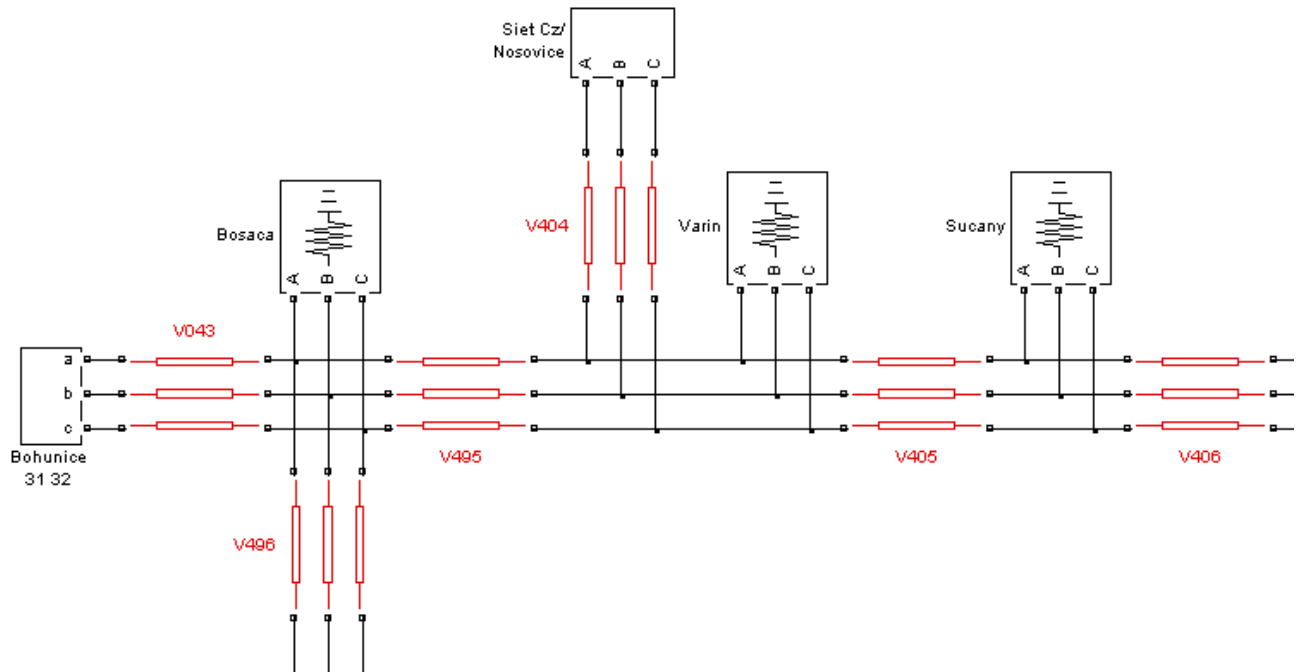
Fig. 8. Connection of nuclear power plant EBO31, EBO32 to the power system

The modeling of the power plant blocks is shown on Figure 9. There we can see the four blocks of Mochovce power plant, lines V046 and V047 and the block of measurement of active and reactive power.
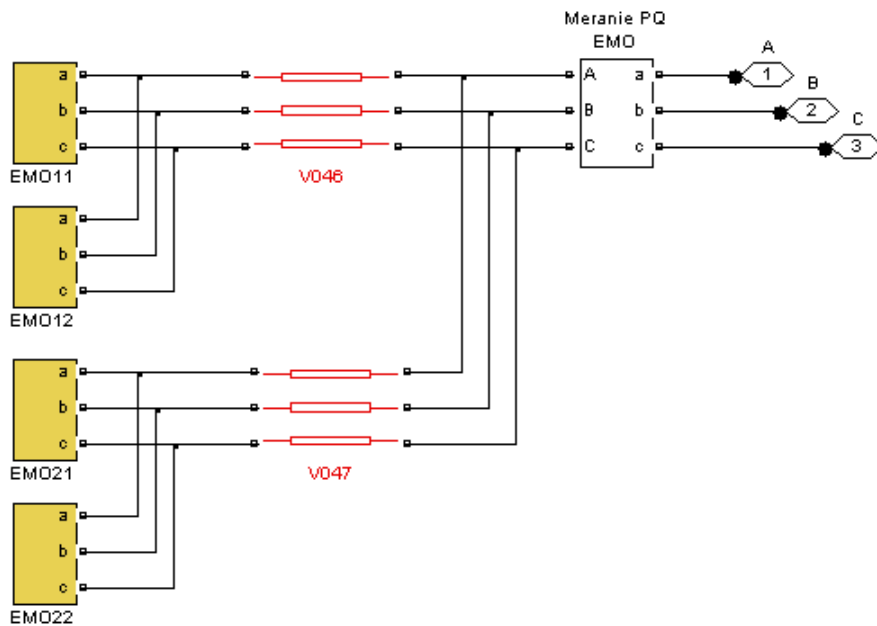

Fig. 9. Schematic of EMO power plant

Behind the blocks EMO11, EMO12, EMO21 a EMO22 are modeled: synchronous machine, block transformer, power controller, power system stabilizer and exciting controller, like is shown on Figure 10. We have used this concept to model all of the power plant blocks used in the model.
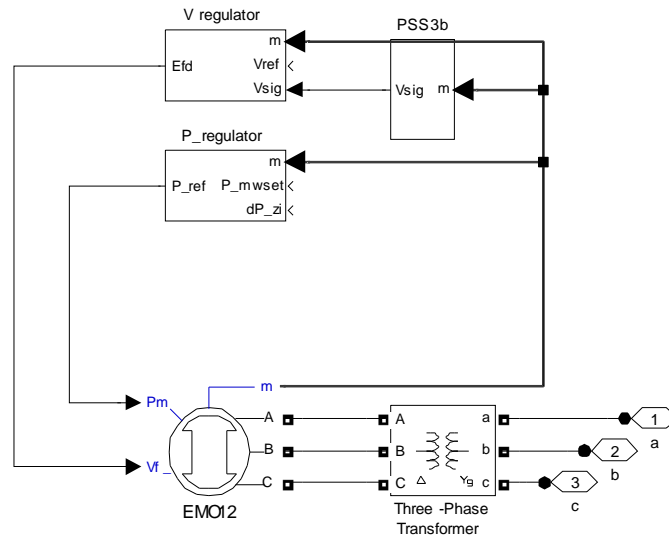
Fig. 10. Block diagram of power plant EMO12

Steady state

The computing of steady state values was divided to 2 phases. At first we've set the load in the nodes of power system. Then we've, with help of *powergui*, tool of SimPowerSystems, compute steady state for turbine power an exciting voltage and set each synchronous machine in the power system. Like a variant between power system of Slovakia and the foreign countries we used transit from Czech Republic, node Sokolnice to Hungary node Gyor. Other electrical states we've computed by running the simulation from end state of the previous one. This process we've repeat since the final value of states was equal to initial states. SimPowerSystems has a tool for computing steady states, but it is not possible to use it with own modeled blocks.

The foreign power systems we've modeled by simplified model of a synchronous machine and the load, like is shown on figure 11. This solution presents hard power supply. The exception was only at node Sokolnice, where could be found another synchronous machine, which has to control the frequency of the power system by speed control.
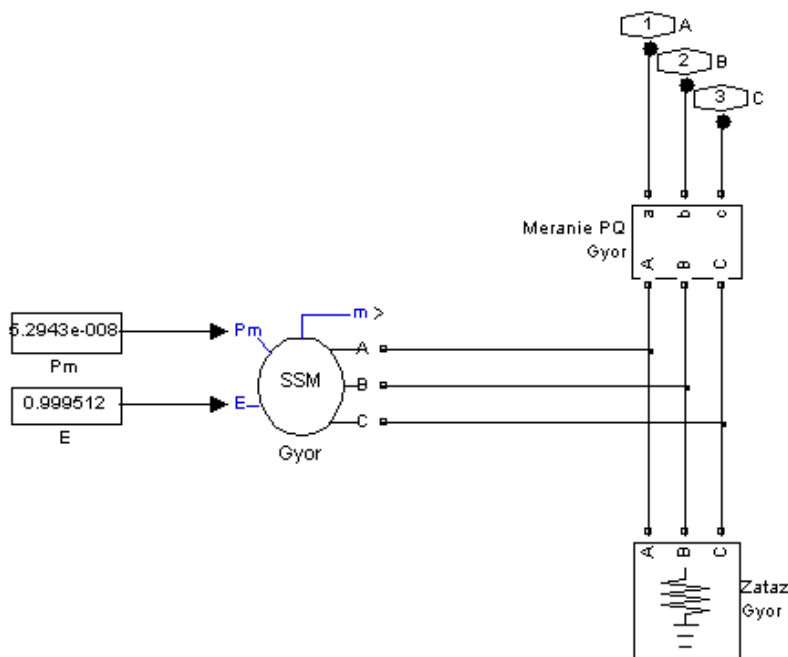

Fig. 11. Diagram of the foreign power system

Experiments

We've simulated many experiments to examine the model's functionality.
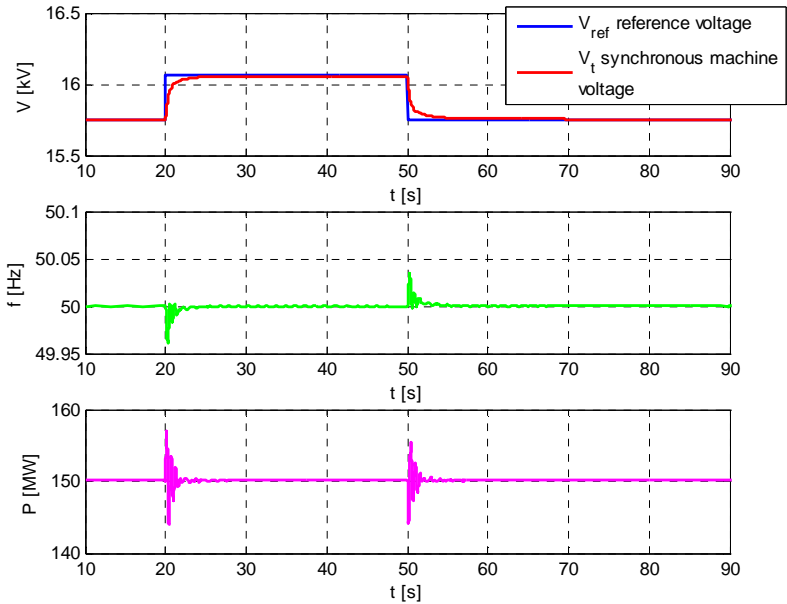

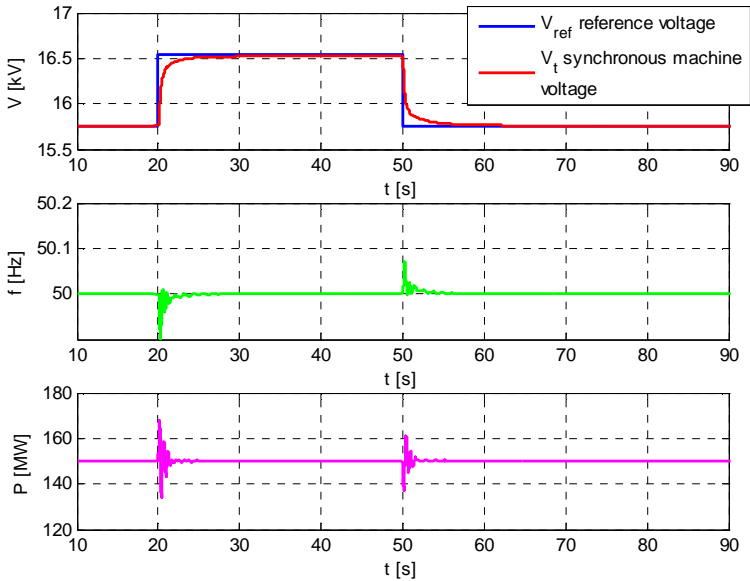Fig. 12. Step change of reference voltage value by 2% on synchronous machine EBO31.

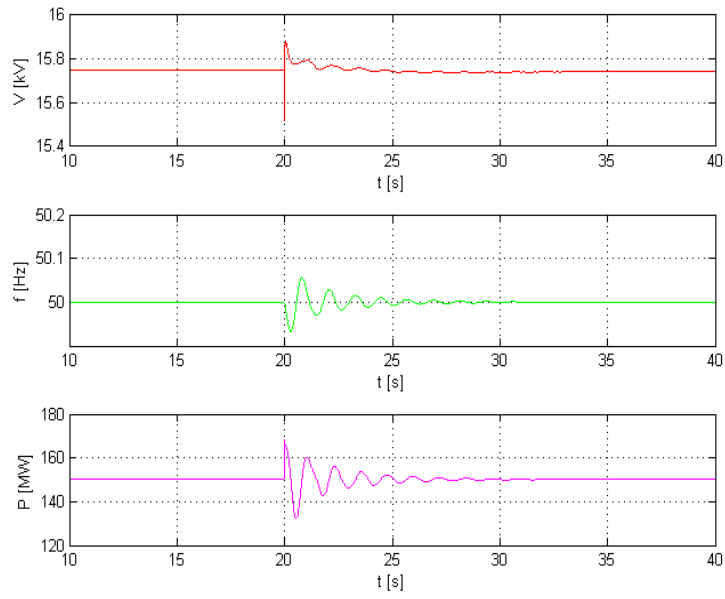Fig. 13. Step change of reference voltage value by 5% on synchronous machine EBO31.

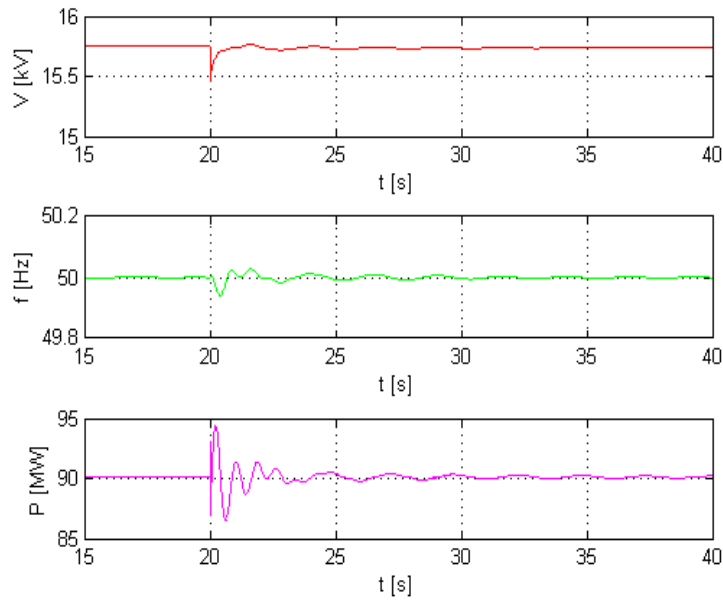Fig. 14. Disconnection the power plant Liptovská Mara, observed on EMO11

Fig. 15. Disconnection the transmission line V425, observed on EGABC1
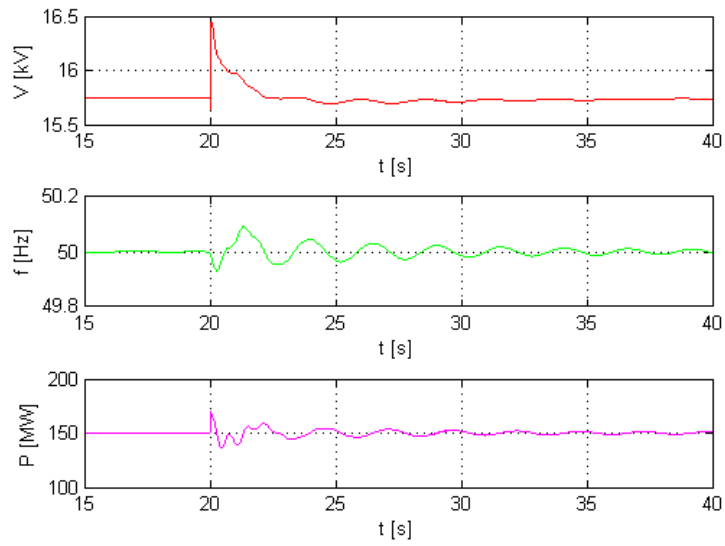
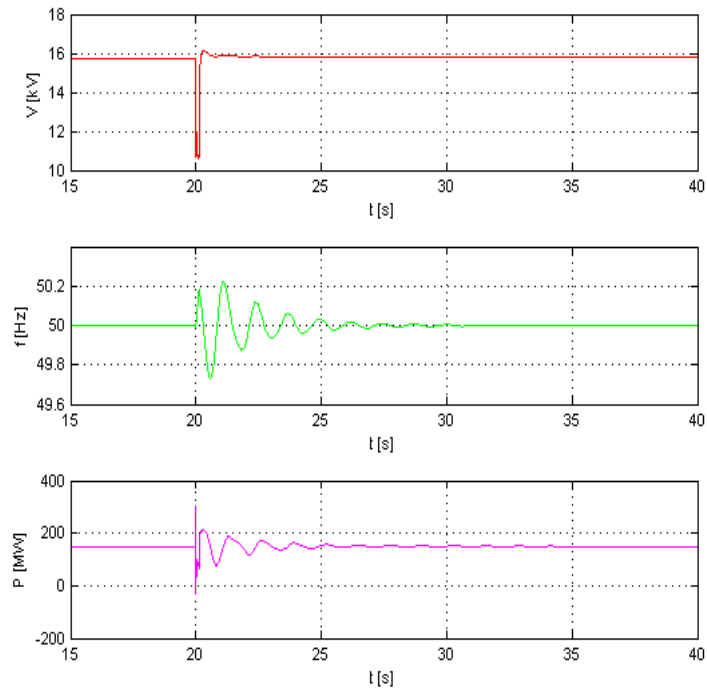Fig. 16. Disconnection of the transmission line V425, observed on EMO11

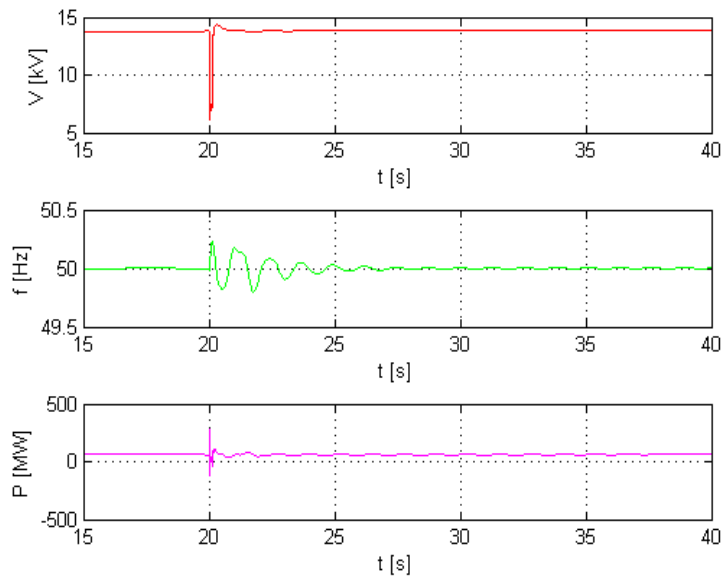Fig. 17. Three phase fault at node Rimavská Sobota, observed on EMO11

Fig. 18. Three phase fault at node Rimavská Sobota, observed on EVO21

Conclusion

With help of this model it's possible to simulate experiments, which will do in real world enormous economical loses. By analyzing this kind of disturbances, engineers could find solutions for them and minimize the risks and consequences of them. Also it's possible to tune the parameters of control units and raise the effective of the power system. The model could be used in the educational system too.

This model consists of:

Synchronous machines:

Nuclear power plant Mochovce: EMO: EMO11, EMO12, EMO21, EMO22
Nuclear power plant Jaslovské Bohunice EBO: EBO31, EBO32, EBO41, EBO42
Coal power plant Vojany EVO2: EVO21, EVO22, EVO23, EVO24
Water power plant Liptovská Mara LMAR: LMAR1, LMAR2, LMAR3, LMAR4
Water power plant Gabčíkovo EGABC: EGABC1, EGABC2, EGABC3, EGABC4, EGABC5, EGABC6, EGABC7, EGABC8

Nodes:

Domestic: Stupava, Podunajské Biskupice, Gabčíkovo, Križovany, Bošáca, Varín, Sučany, Spišská Nová Ves, Lemešany, Moldava, R. Sobota, Levice and Horná Žďaňa
Foreign: Sokolnice(Cz), Nosovice(Cz), God(Hu), Gyor(Hu), Mukačevo(U), Krosno(Pl)

Transmission lines: V043, V044, V046, V047, V497, V498, V448, V429, V439, V424, V425, V490, V491, V492, V493, V449, V426, V427, V428, V440, V477, V495, V496, V404, V405, V406, V407, V408

Acknowledgement

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