ISLAND OPERATION OF DIESEL GENERATOR UNITS

M. Ernek, J. Murgaš

Ústav riadenia a priemyselnej informatiky, Slovenská technická univerzita, Fakulta elektrotechniky a informatiky Ilkovičova 3, 812 19 Bratislava, Slovenská republika

martin.ernek@stuba.sk, jan.murgas@stuba.sk

Abstract

The aim of this paper is to analyze the blackstart capability and island operation of the diesel generator units in Slovak power system during the crisis state after the major fault blackout. Simulation results will be given. The diesel generators have to prove several selection criteria for the blackstart service according to the local TSO's policies and in this paper we would like to discuss the following criteria [1]: Sufficient power capacity has to be proved for the diesel generator units, which provide the blackstart service. The capacity is needed for the own load of the main system power plant. It is also crucial to observe the dynamic response of the diesel generator during the startup of the main system power plant largest drive. The island frequency and terminal voltage of the diesel generator units have not to drop below the protection system thresholds during the drive startup.

1 Introduction

New power plants have been introduced to the Slovak power system, that serves as generation in specified time intervals and their main purpose is to control the load peaks. The new power plants are driven by diesel engines with nominal power above 1MW. The load peak control source was obtained by installation of couple of these diesel generator units in one power plant, which should be controlled automatically from central dispatching of local TSO. These power plants fulfill also another major task: blackstart service [2], which should be also understood as that they are able to provide voltage for the main system power plants after the major fault: blackout. The major fault blackout means the generation outage in the certain area. The cause of this outage are often generation shortage, power lines overload, malfunction of the power system part or three phase faults on the power lines and power stations.

The development of the dynamic simulation model of the diesel generator is needed first to verify the power plant blackstart ability. The dynamic simulation model has been constructed with help of Matlab/SimPowerSystems.

2 Dynamic simulation model

The synchronous generator model is described by the 6th order model (Eq. (1-4)) and is represented by subtransient electromotive forces E_q'' and E_d'' and transient electromotive forces E_q' and E_d' [3].

$$T_{d0}''\dot{E}_q'' = E_q' - E_q'' + I_d(X_d' - X_d'') \tag{1}$$

$$T_{q0}''\dot{E}_d'' = E_d' - E_d'' + I_q(X_q' - X_q'') \tag{2}$$

$$T_{d0}'\dot{E}_q' = E_f - E_q' + I_d(X_d - X_d') \tag{3}$$

$$T_{q0}'\dot{E}_d' = -E_d - I_q(X_q - X_q') \tag{4}$$

The parameters in the Eq. (1-4) are described in the table 1.

Table 1: SYNCHRONOUS GENERATOR PARAMETER DESCRIPTION

Parameter	*Description*
T_{d0}'	transient time constant d-axis
T_{q0}'	transient time constant q-axis
T_{d0}''	subtransient time constant d-axis
T_{q0}''	subtransient time constant q-axis
x_d	synchronous reactance d-axis
x_d'	transient reactance d-axis
x_d''	subtransient reactance d-axis
x_q	synchronous reactance q-axis
x_q'	transient reactance q-axis
x_q''	subtransient reactance q-axis

Electromechanical dynamics are described by swing equation Eq. (5), which defines the dynamics of the generator speed and rotor angle.

$$\frac{d\Delta\omega}{dt} = \frac{1}{M}(P_m - P_e - D\Delta\omega) \quad \Delta\omega = \omega - \omega_s = \frac{d\delta}{dt} \tag{5}$$

The electric power of synchronous generator is defined by Eq. (6).

$$P_e = (V_d I_d + V_q I_q + (I_d^2 + I_q^2)R) \tag{6}$$

The terminal voltage is defined by Eq. (7).

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \begin{bmatrix} E_d'' \\ E_q'' \end{bmatrix} - \begin{bmatrix} R & X_q'' \\ -X_d'' & R \end{bmatrix} \begin{bmatrix} I_d \\ I_q \end{bmatrix} \tag{7}$$

The electric power should be defined with electromotive forces (Eq. (8)) by substitution of Eq. (6) to the Eq. (7).

$$P_e = (E_d'' I_d + E_q'' I_q) + (X_d'' - X_q'') I_d I_q \tag{8}$$

The simulation model of the diesel generators power plant is shown in Fig. 1. The model consists of:

- Diesel generators power plant
- Asynchronous motor – which represents the largest motoric load in the main system power plant
- Passive components of power system: three phase transformers, power lines and loads

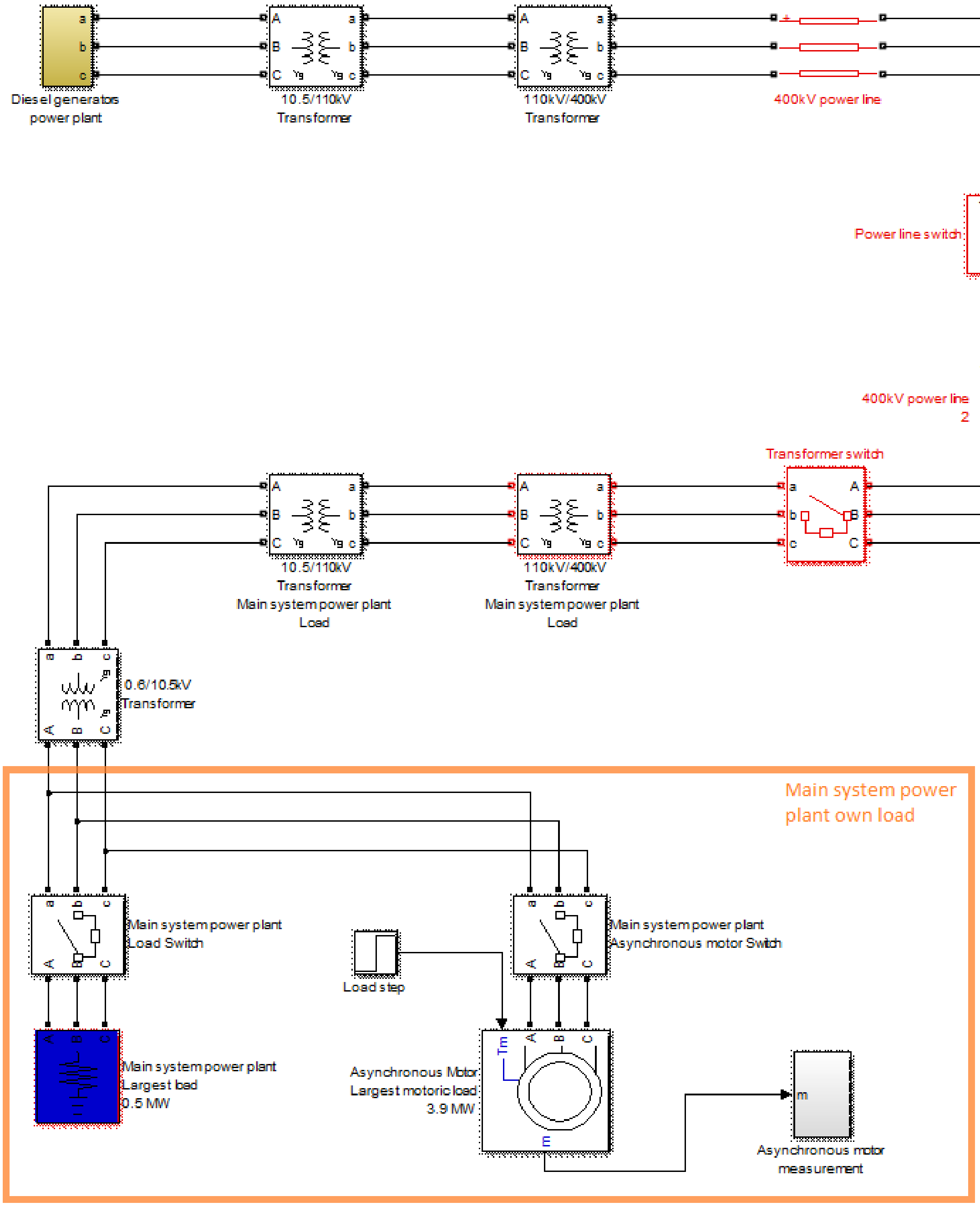

Figure 1: Diesel generators power plant simulation model

3 Experiment setup and simulation results

The transmission network switching from the diesel generators power plant to the own load power station of the main system power plant was verified by steady state calculation. The calculation has verified the transmission abilities of network, voltage profile along the route to main system power plant from own load (Ferranti effect) and the voltage level in the own load power station. The voltage and frequency control abilities and the maintaining of the power system variables in the desired limits have been verified by the dynamic simulations. The speed response of the diesel generator unit on the load increase is shown in Fig. 2. The deviation of the diesel generator unit speed during this experiment is 2% and the recovery time of diesel generator unit speed after the load increase has occurred is 1.5 s. The voltage drop on the diesel generator unit after the load has been increased is shown in Fig. 3. Despite of the large voltage drop on the terminals of the diesel generator unit the dynamic response is stable and the voltage stabilized in the desired level.

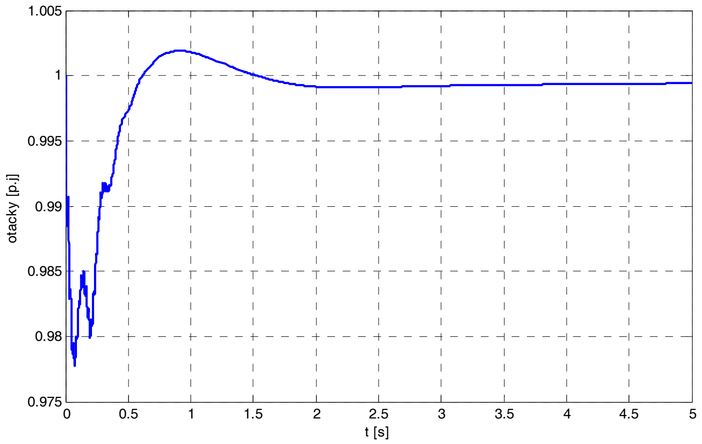

Figure 2: Diesel generator unit speed response on load increase

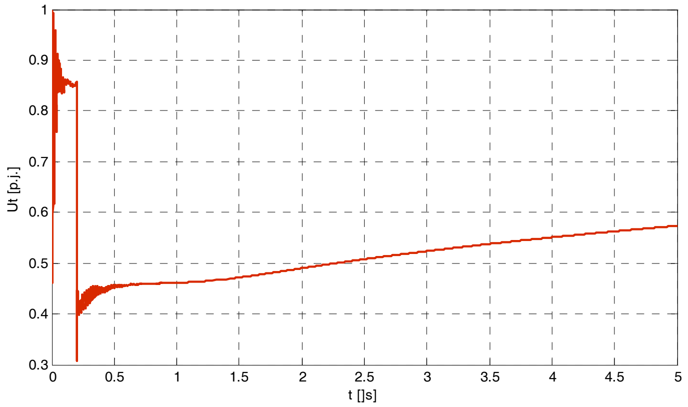

Figure 3: Diesel generator unit voltage response on load increase

Starting of the largest asynchronous motor has been verified in the following experiment. The dynamic response of the diesel generator unit on asynchronous motor switching is shown in Fig. 4. The voltage drop on the diesel generator unit is less than 10% and does not activate the protection system of the diesel generator unit. The deviation of the diesel generator unit frequency is above 0.1 Hz and is in the limits of the protection system of the diesel generator unit.

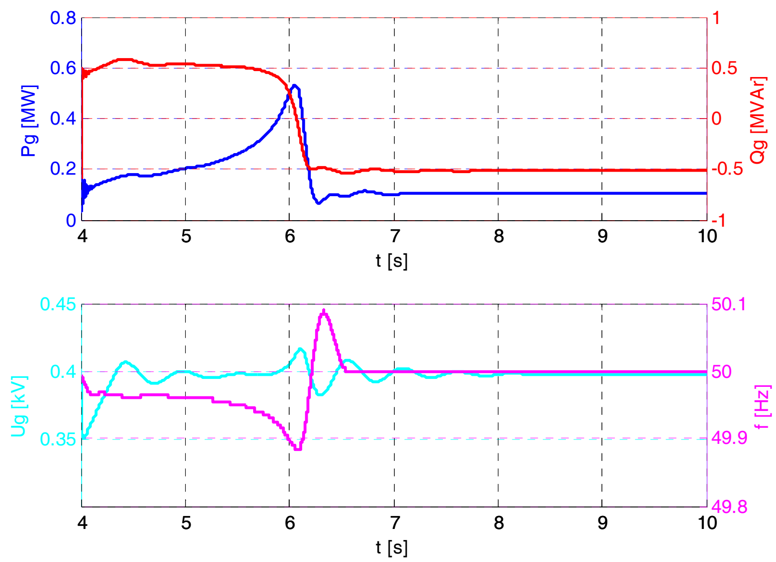

Figure 4: Diesel generator unit response on asynchronous motor switching

4 Conclusion

The aim of this paper has been to develop the simulation model of the diesel generator unit in Matlab/Simulink, prove the blackstart ability of the diesel generation units by dynamic simulations and power system restoration ability of the diesel generators power plant after the major fault blackout. The diesel generators power plant satisfy the dynamic simulation criteria of Slovak power system by proving the ability of maintaining the main power system variables in the desired limits. The dynamic responses have also shown that neither disturbance activates the protection system of the diesel generators power plant.

Acknowledgment

This work has been supported by the by Scientific Grant Agency VEGA under the contract VEGA 1/1256/12.

References

[1] M. Kret a kol, *Technické podmienkyprístupu a pripojenia, pravidlá prevádzkovania prenosovej sústavy*, 29.9.2014 [online] available at: <http://sepsas.sk/seps/Dokumenty/TechnickePodmienky/2014/06/09/TP-B_2014.pdf>

[2] Murgaš,J. a kol.: Správa k spracovaniu Plánu obnovy po poruche typu blackout. Výskumná správa pre SEPS, a.s., 2014.

[3] J. Machowski, J.W. Bialek, J.R. Bumby, Power System Dynamics Stability and Control Second Edition, John Wiley And Sons, Ltd., 2008.

Martin Ernek
Ústav robotiky a kybernetiky, Slovenská technická univerzita, Fakulta elektrotechniky a informatiky
Ilkovičova 3, 812 19 Bratislava, Slovenská republika
martin.ernek@stuba.sk

Ján Murgaš
Ústav robotiky a kybernetiky, Slovenská technická univerzita, Fakulta elektrotechniky a informatiky
Ilkovičova 3, 812 19 Bratislava, Slovenská republika
jan.murgas@stuba.sk