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Island Operations of Parallel Synchronous Generators – Simulators Case Study for Large Power Plants

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Abstract: While increasing integration of renewable energy sources (RES), which are unregulated and difficult to predict, a large system of nuclear power plants must provide balancing peaks in the production of renewable energy. It is also important to simulate the rapid changes in the power of individual NPP units, and for these regimes to train operators of nuclear units. Therefore the paper is aimed to Island Operations of More Parallel Electric Synchronous Generators Connected to One Substation of Power Grid. For the control of rapid and poorly predicted power peaks / deviations it is also necessary to use large Nuclear Power Plants. These control requirements are not yet required to NPP and therefore NPP Simulators can not be used for these purposes. Firstly, there are described the results of the Case Study: Engineering and Training Simulators for Large Conventional and Nuclear Power Plants. Initially there are presented the simulations of different island operations of power plant turbine generators connected to one substation into the power grid on the example of the Power and Heating Plant with six parallel operating synchronous generators. Generally the Power/Performance K-Factor (KF) are defined for the T&D Systems. K-Factor characterizes the electrical properties of the systems. On the simulator the instructor chosen size distribution system (i.e., KF) in which generators are electrically connected. For different island operations (whose electrical "hardness" depends on the size of KF) will be shown the results of the simulations on the Dispatcher Training Simulator (DTS) used for the training of parallel operations of two or more power turbine generators / blocks. The simulation models are created in MATLAB – SIMULINK. Secondly, a similar multi-block island mode will be also analyzed for a large Nuclear Power Plants.

Keywords: Smart Grids, Transmission and Distribution Systems, Inter-Area Oscillation Mode, Island Operations of Large Power Plants, Power and Heating Power Plant, Nuclear Power Plant, Engineering and Training Simulators.

1. INTRODUCTION

In the process the building of new Smart Grids the transmission and distribution systems remain more or less unchanged. At present very strong and for classic types of electricity networks is very negative impact of increasing Wind Power Generation on the North-South Inter-Area Oscillation in the European ENTSO-E System (Weber, et. al., 2014). Therefore in transmission and distribution systems the implementation and benefits of SMART GRIDS methods must arise in the coming years, especially from larger, more sophisticated intelligent deployment and application of advanced methods and equipment, such as Engineering and Training Simulators. The most imporatnt is the dynamic models for simulators in the states close critical (Neuman, et. al., 2009).

1.1 Islanding and resynchronising

The process of synchronization requires the following assumptions and steps in implementation (Neuman, 2009). In practice, when we establish permitted phase error we usually go from the requirement that the initial torque to turn the generator on the network was less than the rated torque. This usually corresponds to the phase error 8 to 12 °. SYNCHROCHECK realistic device model must be multiphase (three phase) because the device has a real function derived from the measurements of two of the three phases. These measurements are first digitally processed (filtering, reconstruction of the first harmonic components of 50 Hz), then set the differential voltage between the phases, on the side of both switching objects (Neuman and Jirkovsky, 2015).

The differential voltage determines the "phase difference voltage ΔU" (between the electricity network and generator), but also the difference angle $\Delta\varphi$, as well as the frequency difference Δf.
If $\Delta f \neq 0$, then it is a "synchronization ".
If $\Delta f = 0$, and $\Delta\varphi = \text{const}$, then it is a „connection to the circle".
In the closing time t_z „synchronization switch" delayed the closing command. In the time t_z the relative position of phasors U_1 and U_2 is changed by the following angle

$$\varphi_p = \Delta\omega .\, t_z = 2.\pi.\, \Delta\varphi .\, t_z$$

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The synchronization switch must send a closing command in advance, φ_p . The permissible angular difference $\Delta\varphi_{max}$ is limited by the switch closing time t_z , which must realistically model the SYNCHROCHECK device respect - details are given below. The SYNCHROCHECK device must also set the frequency of the turbine-generator, so that the acceleration torque generated by the turbine reaches acceptable values for synchronization. Synchronization - Conditions for manual synchronization of a turbo-generator.

The difference of phase angles (at the moment of pressing the synchronization button):
$\Delta\varphi \leq 12°$ … depends on the value x''_d

Corrected difference of phase angles:
$\Delta\varphi_{kor} \leq 15°$… mnemonic " five minutes to twelve "
The difference frequency of two synchronously coupled systems: $\Delta f \leq 0{,}5$ Hz
The voltage difference: $\Delta U \leq 6$ kV

1.2 Simulation and operational results

The synchronization equations are following:
$\varphi_p = \Delta\omega .\, t_z = 2.\pi .\, \Delta\varphi .\, t_z$
$t_z = \varphi_p / 2\,\pi .\, \Delta f = \varphi_p / 360 .\, \Delta f$

Synchronization **Example 1:**
$\varphi_p = \Delta\varphi - \Delta\varphi_{kor} = 16{,}29 - 13{,}29 = 3°$
$t_z = 3 / 360 .\, 0{,}03 = 0{,}27$ [sec]
Results: good synchronization
dfi = 16.29 °
dfi_{kor} = 13.29 °
df = 0.03 Hz
dU = 1.69 V

Synchronization **Example 2:**
$\varphi_p = 45{,}68 - (-4{,}32) = 50°$
$t_z = 50 / 360 .\, 0{,}56 = 0{,}248$ [sec]
t_z = cca 0,25 [sec] … closing time
Results: poor synchronization
dfi = 45.68 °
dfi_{kor} = -4.32 °
df = 0.56 Hz
dU = 1.69 V
Note: The generator torque during good and poor synchronisation is not important for operator training.

Note: The inaccuracy of t_z calculations is given by the communication data interval from the model SIMULINK into SCADA system InTouch.

2. SIMULATORS OF LARGE POWER PLANTS

Using SSCG allows researchers to search for solutions for problems inherent to smart systems, such as a balance between production and consumption, peak management, renewable energy integration and storage, and energy saving.

2.1 Simulators of Nuclear Power Plants interconnected in Transmission Systems

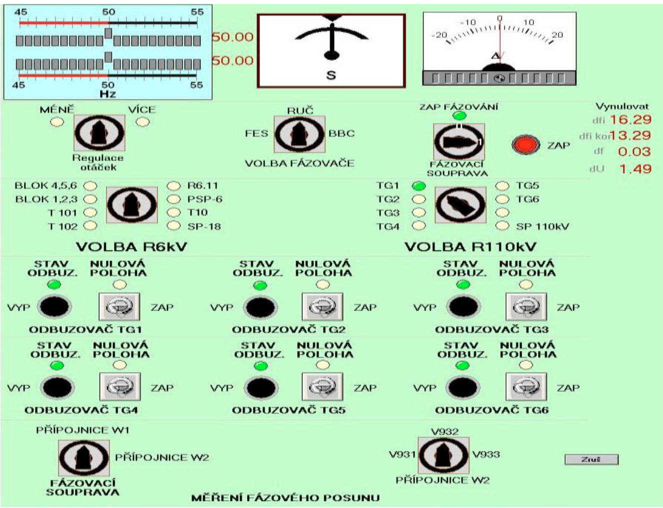

Fig. 1 Emulation synchronization cabinets, Instructor Stations - state "phased", **Example 1**
The emulated figures (VOLBA = Choice, Vynulovat = Reset)

Scope of modeling one NPP unit is in accordance with the applicable standards for nuclear power, but Smart Simulator modeling is insufficient. At such a simulator can not simulate parallel operation of more generators and therefore not realistic island regime with more energy sources – power units.

2.2 Simulators of Power and Heating Plants interconnected in Transmission or Distribution Systems

For Power Plant Opatovice (EOP) were performed transient simulation calculations and evaluated the ability of island operations. It can not only prevent damage to the electric system, but also to ensure a successful operational implementation, and required certification of Island Operation (Neuman, et. al., 2009). Principles of Smart Grids on the generation electrical and thermal energy and control of heat consumption within the District Heating Networks (Neuman et. al., 2014).

3. SMART SIMULATORS GRID

Smart Simulators of Complex Grids (SSCG) must include not only the narrowly defined technological part of the power system, but must extend to neighboring areas. For example, the simulation model not only power plant but also led out electrical power to the distribution or transmission system (Neuman, 2009). Using SSCG allows researchers to search for solutions for problems inherent to smart systems, such as a balance between production and consumption, peak management, renewable energy integration and storage, and energy saving (Neuman, 2012b). Very important is also Simulation Model of a Smart Grid with an Integrated Large Heat Source (Vasek, et. al., 2014).

3.1 Smart Training Simulator of power plant electricity substations in island mode operation.

In terms of a simulation of island regime and more parallel generators are simulators of electrical substations advanced, because there is such modeling quite normal (Neuman, 2011).