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Two layer hydropower plant dynamic mathematical modelling using synchronized measurements

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ABSTRACT

The operation and control of electric power system highly depends on knowledge of dynamic conditions. Power plants, especially hydropower plants, have the highest impact on overall power system dynamics. Therefore, dynamic mathematical model of hydropower plant was developed in order to conduct a theoretical research of the dynamic conditions of the transmission power system during normal and abnormal operating conditions. To build the mathematical model of the hydropower plant, synchronized phasor measurements from the Phasor Measurement Units were used for a dynamic picture of a part of power system near hydropower plant. Relevant events recorded by WAM (Wide Area Monitoring) System were used for fine tune-up of the dynamic mathematical model of hydropower plant. Additional validation of the mathematical model was made by using MatLab calculations. An example of the proposed dynamic modelling was performed on reversible hydropower plant.

1. Introduction

For their daily business operations, transmission system operators (TSO) must have models of their own network and surrounding networks from neighboring TSOs. Those models are constantly being upgraded and spread in order to fulfill new requirements and challenges. Often, new business processes are dictated by security constraints, integrations of renewable energy resources (RES) and electricity market issues. Key role player for TSOs in Continental Europe is the European Network of Transmission System Operators for Electricity, ENTSO-E. ENTSO-E has published a regulatory document, the Network Codes [1], mandatory for all TSO members, which is organized in three areas:

- Connection codes.
- Operational codes.
- Market codes.

Code requirements can be fulfilled only by intensive exchanges of greater amount of data between the TSOs. Those exchanges will be done by means of a standardized data frame. TSOs were obliged to have a Common Grid Model (CGM) for data exchanges. The Common Grid Model Exchange Standard (CGMES) [2] is a superset of IEC Common Information Model (CIM) [3], developed and published by ENTSO-E for TSO data exchanges in the areas of system development and system operation. CIM supports the exchange of static and dynamic network models, topology data, input/output Energy Management System (EMS) data, graphical data of single line diagrams and network model data [4,5].

At present, new applications in control centers usually process a great amount of data, so called Big Data (BD) [6], and create Smart Grids applications [7] in control centers. Those applications need accurate models of transmission power network for two main operational areas:

- Real time applications.
  o Static calculations.
- Offline applications.
o Static calculations.
o Dynamic calculations.

CGMES project is an ongoing process divided into multiple tasks. An important and most demanding task is the dynamic modelling of transmission power network.

Modern transmission power systems are often in operation close to their stability limits. Consequently, in large power system blackouts occur [8,9]. Crucial research is focused on power system dynamics in order to create a mathematical model suitable for frequency, voltage and angle stability analysis. The dynamic model has to be validated and verified, which is a challenging task. The benefits of using PMU technology for monitoring protection and control of power system and

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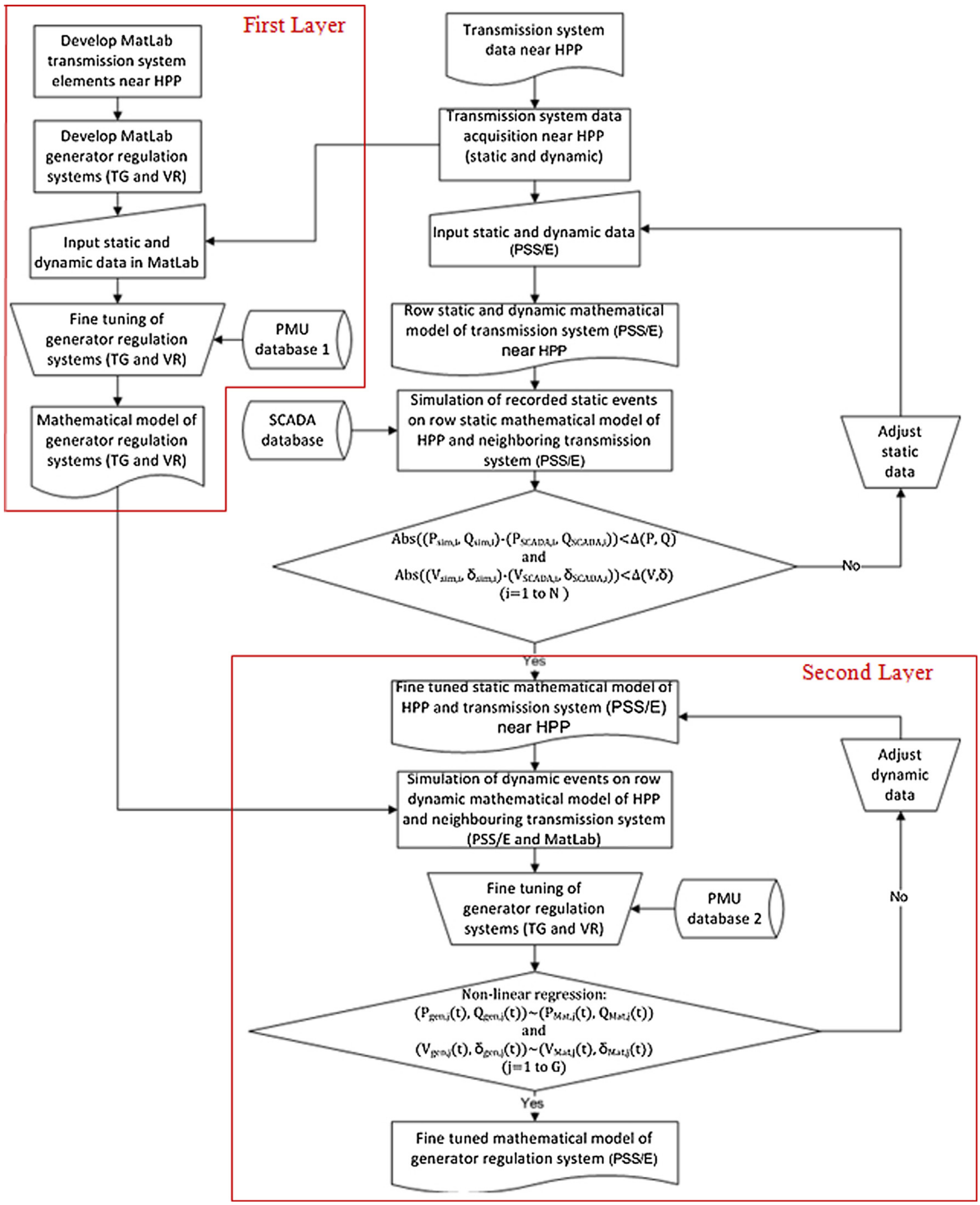

Fig. 1. Chart-flow of two step dynamic modelling of hydropower plant.

applications [10,11] for System Integrity Protection [10–13] are well known. Accurate dynamic mathematical model of transmission power system is the basis for calculations that results with threshold values for variety of applications and device settings. This accurate mathematical model implies specific recorded events occurring in transmission power system, which should be simulated in the dynamic mathematical model and if the results from simulation are comparable (tolerance should be defined) with recorded data (voltage, currents, power flow, etc.), the dynamic mathematical model is accurate for further use. Accurate dynamic mathematical models are used in modern control centers for tracing behavior and changes of transmission network. This paper proposes methodology for dynamic mathematical modelling of transmission power system based on synchrophasors.

2. Methodology for dynamic modelling of hydropower plant

Dynamic modelling of hydropower plant (HPP) relies upon a precise static model (or steady-state model) which is proven and accurately tuned. Dynamic models have to include all relevant elements that will affect the dynamic behavior:

- Relevant parameters of synchronous generators,
- Turbine and voltage regulation system – turbine governor (TG), excitation governor – voltage regulator (VR) or automatic voltage regulator (AVR), power system stabilizer (PSS) and automatic generator control (AGC),
- Neighboring transmission system parameters near hydropower plant