Research and Implementation for a class of Large-Scale Full-Range Power System Real-Time Simulator

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***Abstract*—In order to realize intensive research and analysis of the whole bulk power system, which contains all electronic elements not only includes generator, electronic grid system, but also includes power generation system, based on the thermodynamics and dynamics theory in power generation system and the electromechanical and electromagnetic transient theory in electronic grid system, we established a class of Large-Scale Full-Range Power System Real-Time Simulator (LFPSRS). The definition of LFPSRS is given, structure of the emulated objects is described, and physical and logical structures of LFPSRS are listed. Finally, the experiment results prove that the system is superior to the traditional simulation system. We confirmed that the proposed LFPSRS can play a major role in the further research on the whole bulk power system.**

Keywords-component; power system; RealTime; simulator; transient theory; coordination

I. INTRODUCTION

With the increasing of the power supply capacity in modern power system, the dynamic and static processes of power generation units have more and more important influence on the stability of power system. Power plants and power grids are be interdependent, mutual effect, the unity of opposite's entirety. The coordination control management between power plants and power grids has become an important issue that directly affects the security and stability of power systems. Therefore, it is a complex interdisciplinary issue that must be paid more attention in the development of large units and large power grids [1-3].

High fidelity simulator is an important tool for analyzing coordination problem in power system [4-6]. It is also an important basis for power grid dispatcher to determine the power grids operation mode, guide the power plants to increase or decrease load. The isolated power station simulator or the power grid simulator which is independent of power generation units cannot meet the needs of the research on the above problems. The establishment of Large-Scale Full-Range Power System Real-time Simulator with high reliability has become a research direction in the industry.

This paper introduces the limitations of the traditional power station and power grid simulation system firstly. Then we put forward the definition of a class of Large-Scale Full-Range Power System Real-Time Simulator. Immediately following the background, the framework of emulated objects structure, and the framework of physical and logical structure of this simulator are listed. A simulator is implemented, and an example is done to verify the effectiveness of this simulator. Finally, conclusion and prospect are given.

II. LIMITATIONS OF TRADITIONAL SIMULATOR

A. Power Plant Simulator

At present, the calculation environment of common power plant simulator, which is running in power plants, power companies or power training schools in China, is a common computer or a server computer with slightly higher performance. Considering the computing environment and the mathematical model size of the simulator for a whole power plant, the calculating step length for power plant simulator is in millisecond class. [7-8]

Taking the common thermal power station as an example, the power station simulation system is usually divided into four parts: boiler, turbine, generator and power grid. The mathematical model of boiler is based on thermodynamics theory whose calculating step length is always between 100ms~200ms. The mathematical model of turbine is based on dynamics theory, and its calculating step length is always between 50ms~100ms. Similarly, the calculating step length of the mathematical model for generator, power grid, which

is based on electromechanical and electromagnetic steady theory, is always between 10ms~50ms.

The simulator with the above computing environment is sufficient for power plant staff training, but it is insufficient for special researcher in power grid or generator. Such as, getting the instantaneous value of the system is impossible based on the above simulator.

B. Power Grid Simulator

Power system simulator, in a narrow sense, is refer to the simulation system of power grid. Although its running environment is varied, there are some common features in their system, such as, the basic theory is multi CPU parallel processing technology, and the performance of system depends on software instead of hardware, if the calculation step length and the bandwidth of I/O equipment is enough to meet the requirements. The system is designed on the basis of electromechanical transient and electromagnetic transient theory. The simulation calculation step length is all in microsecond class [9-10].

Take some current power grid simulator at home and abroad for example. The RTDS system, software of Canadian RTDS Company, use one CPU to simulate one power system component, the communication between CPUs is in parallel-serial-parallel mode. The digital simulation system (ARENE), developed by the French electric power company (EDF), takes the hardware, HP multi CPU parallel processing computer which is based on the HP-CONVE workstation, as its simulator calculation environment.

Grid simulation system can simulate more accurately transient changes of power system than traditional power plant simulator. Thus, not only effectively simulate the can be displayed in the system, but also the wave of instantaneous value can be generated too. Because the simulator is independent of dynamic power supply terminal simulation data, the simulator cannot make fully analysis of generalized bulk power system.

Combining the above two traditional simulation systems, it is necessary to build a high precision and large-scale power plant and power grid simulation system.

III. DEFINITION AND FRAMEWORKS OF LFPSRS

A. Definition

The Emulated objects range of Full-Range Power System Real-Time Simulator (FPSRS) includes prime mover, generator, power grid and other important components. Each component of the system is translated into digital mathematical simulation model, and it is implemented in their respective computing units by parallel mode. The high frequency communication interface between the computing units is used to realize the real-time data communication of each mathematical simulation model. The running simulator can deal with the external disturbance in time and achieve real-time operation effect. Considering the factors of thermodynamic theory, the calculation step length of prime mover model should be kept in milliseconds class. Considering the theory of electromechanical and electromagnetic, the calculation step length of generator and power should be kept in microsecond level.

When there are more than one set of prime mover model in the whole power grid model, and the running state of the system will interact with each other, the system constitutes a Large-Scale Full-Range Power System Real-Time Simulator (LFPSRS).

B. Framework

The framework of emulated objects in our simulator is listed briefly in Fig.1. The system is divided into power plant side and power grid side, which including all elements in the power system, some important elements are especially listed in the graph, such as power grid, generator, and prime mover. The icon of prime mover is displayed in brief with a turbine icon. In fact, according to the characteristic of different power plants, the prime mover may be boiler, steam turbine, water turbine, fan and so on.

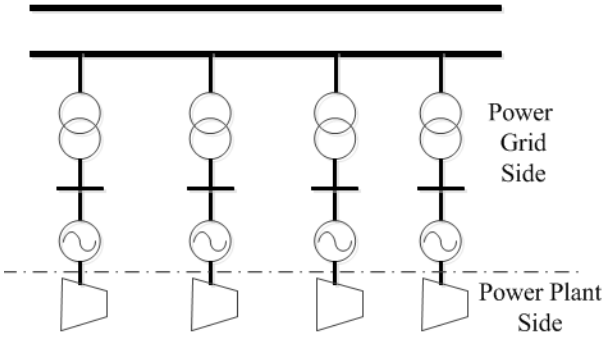

Figure 1. Framework of emulated objects stucture in LFPSRS

The physical structure of the simulator is shown as follows. The prime units in the simulator are model storage unit, model calculation unit, history backup unit, control area unit, and other physical interfaces, and so on. All the units communicate with each other via Ethernet.

The model storage unit contains all the models involved in the system, including prime mover, generator, transformer, power grid and so on. The calculation unit is running in parallel computing way, and then exchanges data through high speed communication protocol.

The processing power of the computing engine is divided into several levels. For example, some part of the engine can finish all calculation in millisecond level, which is designed for thermodynamics and dynamics model, and some done in microsecond level, which is used for electromechanical and electromagnetic transient model.

The control units provide storage space for all monitoring related files, display the monitoring interface, receive all the operation command and get and send to computer screen the result of request of operator etc. In short, this is the control center of the whole system.

The historical station unit is responsible for storing important experimental historical data. Other physical interface units leave space for subsequent access to other systems.

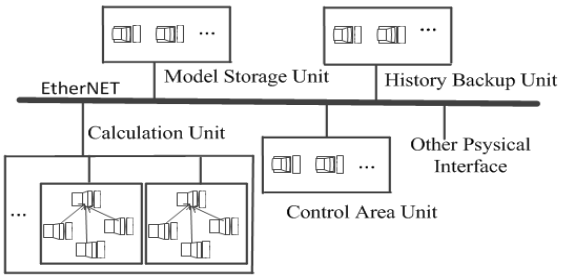

Figure 2. Framework of physical stucture of LFPSRS

The logical structure of the system is shown as follows. The bottom layer is the data module zone, which includes power plant database, power grid database and some user configuration files. The intermediate layer stores various models, such as, boil, turbine, primary system, secondary system and other computer configuration content. The top layer includes control engines and view methods of our system. For example, energy and flow balance calculation, transient calculation, stability calculation and some analysis in simulator.

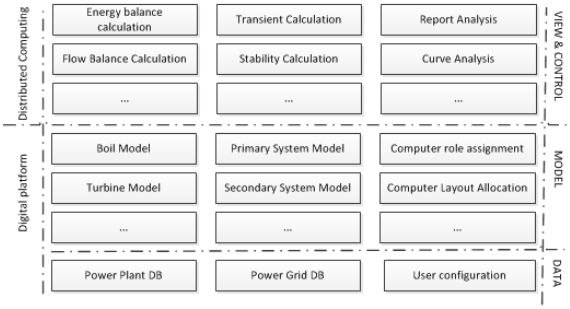

Figure 3. Framework of logical stucture of LFPSRS

IV. Implementation of LFPSRS

Based on the above theoretical foundations, a Large-Scale Full-Range Power System Real-Time Simulator is built successfully for Electric Power Research Institute of GuiZhou Power Grid Co., Ltd. In this simulator, the mathematical model of prime mover is implemented on CyberSim platform, simulation software developed by Beijing Sifang automation Co., Ltd. At the same time, the mathematical model of power grid and generator are running on Advanced Digital Power System Simulator (ADPSS), which is a digital simulation system developed by China Electric Power Research Institute. The simulator is a part of technology project (GZ2015-1-0001) in Guizhou Power Grid Co., Ltd.

We have done the following experiment on the above platform to verify the effectiveness of the system.

The real accident occurred in October 12, 2011. A cross road hard connecting pipe, between a switcher B phase and a current transformer on a bus line, fell off from the original position. The underside end of pipe affixed to the ground, the upper end is leaning on the porcelain bottle of switch port. Then one power plant triggered bus differential protection.

The fault phenomena are simulated and tested on the simulation system, and the results are shown as follows. In order to keep the simulation wave sit at the same start point on time axis to the wave of real system, we set the real system's wave start time on axis to zero, and make the time axis unit to millisecond.

The graph above and graph below in Fig.4 show the bus voltage waves from real system and simulator respectively.

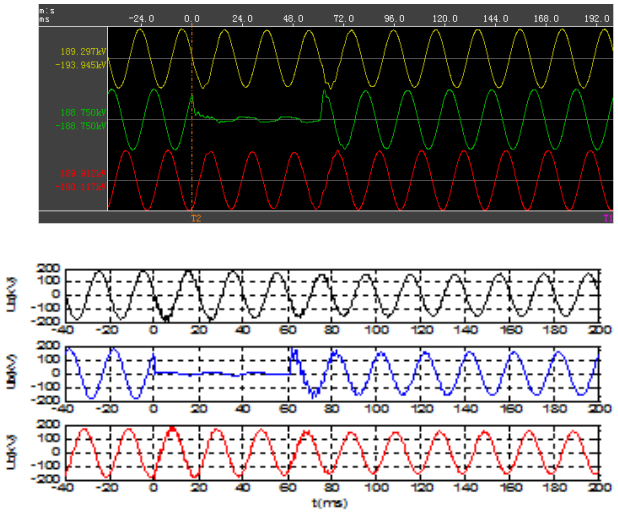

Figure 4. Voltage waves from real system and simulator

The graph above and graph below in Fig.5 show the bus current waves from real system and simulator respectively.

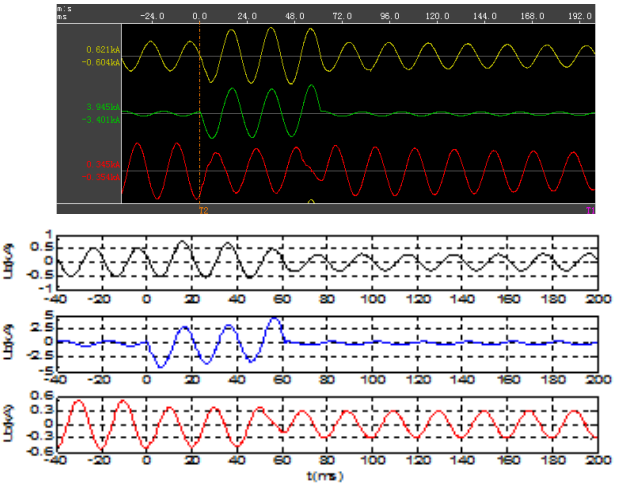

Figure 5. Current wave from real system and simulator

As shown in above graph, the voltage and current wave, which are drawn according to the result from LFPSRS, are similar to the recorded waves, which are collected from the real power system accident scene.

V. CONCLUSION

Considered the present research on the bulk power system, and combined with the characteristics of power plant part and power grid part respectively, we designed and implemented a class of Large-Scale Full-Range Power System Real-Time Simulator. This simulator has successfully solved the problems that previous conventional power plant simulation system cannot realize the instantaneous value of the system, and the traditional grid simulation system cannot demonstrate the relation with generator units. It provides a new research method for bulk power system research.

In this system, researchers can study in the coordination control management problem for bulk power system, and they can make a research on peak load adjustment mechanism for power plants, even for energy storage dispatch of wind energy, water energy and solar energy, and so on. In short, the LFPSRS simulator can play an important role in the research of bulk power system in the future.

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