Integration of PSS®E Web Application with Power System Simulation Platform

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Abstract: As power systems become larger and more complicated, power system simulation analysis requires more flexibility and faster performance. BPA is simulation software that is widely used in China and thus official power system data are in BPA format. However, BPA's flexibility and performance cannot meet the requirement of ultra-large-scale power system. PSS®E supports user-defined models and can handle large scale power system with up to 150,000 buses. From that perspective, PSS®E is much suitable for future network analysis. To take advantages of both BPA and PSS®E, it is required to build a simulation platform which is able to combine PSS®E with BPA to meet the requirements of large-scale power system simulation in the future. In this paper, PSS®E and BPA have been integrated into the power system simulation platform to perform power system study together. As data format and models are different between BPA and PSS®E, the focus is developing a converter that can convert BPA data to PSS®E data and creating dynamic models in PSS®E based on the dynamic models in BPA. Simulation results show the accuracy of PSS®E user-defined models and high availability of PSS®E Web application.

Key words: PSS®E, Web application, BPA, user-defined model.

1. Introduction

Power system simulation is an important role to guide construction and development of power grid and keep power system secure. The object of power system simulation study is focused on system safety in the future. With more new type electronic devices installed, renewable energy injected and power system network more complicated than ever before, the power system simulation becomes more difficult. Since the 1980s, BPA, which was developed by US Bonneville Power Administration, was introduced into China. After self-development and improvement many years by China Electric Power Research Institute, BPA has been transformed into a Power System Design power system simulation package, and a simulation platform has been developed to meet user's requirements. Although BPA was widely used in China, the

simulation package or platform is difficult to provide a user defined model interface, full API interface, and automation scripts. It is quite challenging to analyze behavior of new device accurately and quickly. Therefore, user-defined model function, both steady and dynamic, is necessary to address that concerns. PSS®E is able to perform simulation up to 30,000 generators, 300,000 loads, 10,000 controllable shunt reactors, 300,000 branches and 150,000 buses in system, the user can define the equipment model to adapt research with new type of models, and meet the requirements of the large power grid study by adding new equipment, e.g. electronic devices [1]. To realize Chinese large power grid interconnection strategy and large-scale and renewable energy project, the power network is going to be larger and larger, it could cause power flow diverge. With worldwide reputation, PSS®E is capable of fulfilling that interconnection strategy in the future. This paper describes how PSS®E was integrated into power system simulation platform with Web interface and how to resolve the base data issue.

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2. PSS®E Web Application Based on Platform

BPA simulation platform, based on B/S (Browser/Server) pattern, has good flexibility and excellent scalability. PSS®E program is able to be integrated into the platform conveniently and shares the platform data and computing resource. In order to develop PSS®E Web application on the simulation platform, the database architecture and interface are designed according to the data structure of the simulation platform. Based on ASP.NET MVC Web application framework provided by Microsoft [2, 3], BPA data conversion module and user-defined dynamic model, the calculation module and user interface module were developed, C#, python and JavaScript were used as development tools, the system architecture is shown in Fig. 1.

To integrate PSS®E into simulation platform, B/S pattern is also selected by PSS®E Web interface application. The server, on which the calculation core of the application is deployed, receives instructions from clients, sends the results back to internet explorer for user after completing data conversion, calculation and analyses. PSS®E Web Server system includes data source, data conversion, PSS®E calculation, the main data stream shown in Fig. 2.

Based on the simulation platform, PSS®E Web application is able to convert the system base data from BPA to PSS®E automatically, and avoid maintaining multiple sets of data, which improve the

user experience and efficiency of PSS®E drastically.

3. Data Conversion

It is an important part of this study to convert the BPA data to PSS®E because modeling in PSS®E based on BPA model is difficult [4]. There is a data conversion tool being developed in this research, which is able to convert the BPA power flow file (*.dat) and stability file (*.swi) into PSS®E power flow file (*.raw), dynamic data file (*.dyr), and sequence file (*.seq). The converted files could be used by PSS®E directly without any manual intervention, the data conversion process is shown in Fig. 2. The data conversion contains these components: the power flow data conversion, dynamic data conversion and sequence data conversion. Since the data structure is quite different between PSS®E and BPA, the data conversion should be carried out sequentially. E.g. some PSS®E dynamic simulation data come from BPA power flow data, therefore the dynamic data conversion process requires both BPA power flow data and dynamic data to process data files simultaneously.

Fig. 1 System structure of PSS®E Web application.

Fig. 2 Data stream of PSS®E Web application.

The data converter generates PSS®E data files based on the BPA data files. BPA power flow data includes four types of data card: area control data card, node data card, branch data card, and correction data card. Each of them contains equipment card. The equipment data are comprise of bus, load, fixed shunt equipment, generators, non-transformer branch, transformer, area exchange, two-terminal DC system, voltage source converter-based DC system, multi-terminal DC system, multi-line model, control area data, the owner of the data, FACTS equipment, switchable shunt capacitors etc.

For convenience, the data convertor can read and convert data that are from either simulation platform database or other BPA data files. And the converter could be integrated into the simulation platform and invoked by other process.

4. Development of Dynamic Models in PSS®E

BPA dynamic data cannot be used by PSS®E directly because PSS®E standard dynamic library does not contains all BPA models. To facilitate using BPA dynamic data parameters directly, developing BPA dynamic models in PSS®E is necessary. With new developed BPA-dynamic models by PSS®E user-defined model interface, PSS®E is able to use converted files to perform study.

This paper takes BPA governor model GJ-GA-TB as an example to demonstrate how to develop a BPA-model in PSS®E. In BPA, the GJ (automatic regulatory system model), GA (electro-hydraulic servo system model), TB (prime mover model) come up with the speed control system, as shown in Figs. 3-5 [5-7].

The BPA GJ mode comprises of three logics, pressure regulating stage feedback control, DEH open-loop control and load feedback control. In the pressure regulating stage control mode, P_m and $\Delta\omega$ as the system input, compared with P_{ref} , the results as PID feedback regulation's input, and output P_{cv} until the Eq. (1) is satisfied. In DEH open-loop control, $\Delta\omega$ as the system input, compared with P_{ref} , output P_{cv} . In load feedback control mode, $\Delta\omega$ and P_e as input, compared with P_{ref} , go through PID feedback control and protection link and output P_{cv} .

$$P(\Delta\omega)_1 + P_m = P_{ref} \quad (1)$$

In the BPA GA model, the input is the GJ output P_{cv} comparing with feedback LVDT as PID's input, the switch status and position of the oil motive can be determined by comparing the over-speed coefficient to drive the valve in turbine.

BPA TB model take P_{GV} as input go through turbine controller to output mechanical power based on the plus of output torque from the high, medium and low pressure cylinders [8, 9].

Fig. 3 The GJ mode in BPA.

Fig. 4 The GA mode in BPA.

Fig. 5 The TB mode in BPA.

According to the principles of the model, the governor dynamic model can be developed in PSS®E by user-defined model interface to match with converted data. With user-defined models, PSS®E is able to use converted BPA dynamic data, including exciters, stabilizers, speed governors and other dynamic models. For the recently developed BPA model, developing corresponding model in PSS®E is possible. The new model as PSS®E model extensions is able to be called by the platform applications [10-12].

5. Example Verification Operators

In order to verify the availability of PSS®E Web application, in particular to verify the user-defined model in PSS®E, a typical BPA data has been

converted into PSS®E data by Web applications.

In this paper, a generator set has been chosen for a case to verify the user-defined models. In this case, the generator contains FJ, SP, GA-GJ-TB controllers, the test data of the generator are shown in Table 1, and the testing system is shown in Fig. 6.

Through this testing system, power flow and dynamic simulation have been performed in both BPA program and PSS®E program, and the simulation results were compared, shown in Figs. 7-12.

Besides small testing system, a real case was tested and compared. The case was exported from simulation platform. Two scenarios being selected for three-phase fault and lost a power plant study was performed. The dynamic result was shown in Figs. 13-16. Blue color is PSS®E result. Black color is BPA result.

Table 1 The test data of the generator.[illegible]

Fig. 6 The experimental system.

Fig. 9 Reactive active power of the simulation results.

Fig. 7 Machine angle of the simulation results.

Fig. 10 Terminal voltage of the simulation results.

Fig. 8 Active power of the simulation results.

Fig. 11 Excitation voltage of the simulation results.

Fig. 12 Mechanical power of the simulation results.

Fig. 13 The 500 kV bus voltage after three-phase fault.

Fig. 14 The 500 kV transmission line after three-phase fault.

Fig. 15 System frequency after lost power plant.

Fig. 16 Swing bus generator angle after lost power plant.

By comparing the simulation curves of the generator variables, although there are little bit differences, the same trends can be seen in the results of two products, and the curves almost coincide. Simulation results show that, the user-defined dynamic model in PSS®E is consistent with BPA, the simulation result before and after the data conversion is consistent with each other, and the user-defined models and data conversion are successful and accurate.

6. Conclusions

Based on the existing simulation platform, BPA data provided by simulation platform can be converted and used directly by PSS®E. PSS®E Web application is developed. Both PSSE and BPA can be on the same simulation platform so that the complementary advantages and mutual verification purposes can be obtained.

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