

Key Technologies of Multi-Source Data Integration System for Large Power Grid Operation

Guanghui Shao¹, Bing Wang^{2*}, Yang Liu¹, Yupei Jia², Tianyu An¹, Zhihong Yu² and Han Yue¹

¹Northeast Branch of State Grid Corporation of China, 110180, Shenyang, China

²State Key Laboratory of Power Grid Safety and Energy Conservation China Electric Power Research Institute, 100192, Beijing, China

Abstract. With the continuous expansion of the scale of the power grid and the continuous increase in the proportion of new energy and power electronic equipment, higher requirements are placed on the basic data of the online security analysis of the power grid. This paper proposes a multi-source data integration system for large power grid operation. It studies the rapid interaction and intelligent integration of multi-source heterogeneous information such as offline and online models, breaking the technical application barriers of various types of data, and quickly generating real-time power grid model. The analysis model provides a reliable data basis for the online analysis of the power grid. Finally, based on the PSASP simulation software, the correctness and effectiveness of the multi-source data integration system of large power grid are verified.

1 Introduction

With the rapid development of UHV AC and DC technology, the transmission power of regional power grids continues to increase, which makes the mutual influence of inter-regional power grids greater. With the continuous expansion of the scale of the power grid, the data information carried on the grid has become huge and complex, and the establishment of a detailed and accurate power grid analysis database has become a top priority^[1-3]. Especially when a serious failure occurs in the power system, it is more necessary to perform simulation calculation and analysis based on a system analysis library that is well-modeled and can reflect the real-time operating status^[4-6].

At present, the following problems exist in the real-time online security analysis of power grid operating data^[7,8]. Poor measurement data. Due to the close electrical connection of the power grid, bad data in individual areas will affect the overall calculation convergence and the rationality of the results. The state estimation data is secondary polluted. Due to the presence of erroneous data and redundant data in the measurement, the state estimates that to improve the qualification rate, some special processing will be performed on the data, which will bring secondary pollution to the online data^[9,10]. The online data lacks dynamic parameters. The online data is consistent with the actual operating state of the power grid, but the modeling range is small and does not contain transient parameters, which makes it impossible to accurately simulate the transient behavior of the power grid. The offline data has no real-time power flow. Although the offline data has complete modeling and accurate

parameters, it lacks real-time power flow. It often requires a lot of manpower to adjust the power flow of the offline model^[11,12].

In recent years, the emergence of new technologies such as standard power grid models and computer technology has made it possible to establish a unified data platform for dispatch centers^[13]. Various applications may be connected to the system by connecting to the data platform, avoiding a large number of many-to-many private data interfaces. However, how to use the existing large amount of data resources to merge multiple views of the current power system into a common data entity is a problem that cannot be solved by the application of standard models or common software technology^[14].

In response to the above problems, this paper designs a multi-source data integration system for grid operation, which can achieve the following functions. Establish the mapping relationship between the online real-time model and the offline accurate model. According to the mapping relationship between the online real-time model and the offline accurate model, expand the equivalent load of the step-down transformer of the online real-time model. After the equivalent load is expanded, the transient parameters of the offline precision model are integrated into the online real-time model to generate a grid analysis library, which provides a reliable data basis for safety analysis and calculation.

2 Comparative analysis of offline and online models

For a specific dispatching centre, it can manage several sub-dispatching centres, and its internal division is

* Corresponding author: wangbing@epri.sgcc.com.cn

divided into operation mode, dispatching, automation, relay protection and other departments according to their functions. This kind of agency division and jurisdiction relationship directly affects and determines the distribution, maintenance and use of power grid calculation data^[15].

Table 1. Comparative analysis of offline and online models.

	Offline model	Online model
Carrier or format	PSASP or BPA	QS(CIM/E)
Maintenance and use department	Mode operation office	Automation operation office
Modeling situation	Detailed and complete	High voltage main network
Parameters	Steady state and transient parameters	Steady state parameters
Topological function	No switch model	With switch, model
Power flow	No real-time power flow	With real-time power flow

The traditional power grid calculation data is mainly maintained by the mode operation office and the automation operation office. The mode operation office maintains the data used for offline analysis and the automation operation office maintains the online QS(CIM/E) data. In addition, the data maintained by the relay protection department also includes some of the primary and secondary equipment parameter. These data are different views of the actual power system.

Generally, the characteristic of online data is that it contains the operating information of the power grid, which can describe the operating status of the main power grid at a certain time relatively accurately. The characteristic of offline data is that it contains a relatively complete typical grid structure.

Table 1 compares the characteristics of offline and online models. The offline and online models of the power grid describe the same power grid, but due to different modeling reasons, it is difficult to simply integrate the two models directly. Therefore, it is necessary to design a data integration scheme based on the characteristics of offline and online modeling.

3 Multi-source Data Integration goals

The overall goal of grid data integration is to make full use of existing data resources, build a unified data platform, improve the quality of calculation data, reduce the difficulty and workload of data maintenance, and thus improve the application level of advanced calculation and analysis programs for the power grid. The specific goals of online/offline data integration include:

1) Maintain the integrity of offline data after integration;

2) After the integration, the main network tidal current operation mode is basically the same as that of the online;

3) The algorithm of intelligent analysis can automatically adapt to the addition, deletion and modification of online and offline model data to a certain extent, reducing the workload of manual maintenance largely;

4) Automatically adapt to the topology changes of the online power grid;

5) Provide convenient and complete data viewing, comparison, verification, and correction methods.

4 Key technologies for multi-source data integration

4.1 Mapping of offline and online models

In actual production, the plants and equipment of offline and online models adopt different naming methods. It is necessary to study the matching rules and strategies of plant and equipment mapping to provide basic conditions for the effective integration of offline and online models.

In fact, the grid equipment mapping includes the mapping of plants, lines, transformers, generators, high reactance, series compensation, loads, shunt capacitor reactors and other equipment. Among these mapping relationships, the plant-site mapping is the most basic mapping, which limits or to a large extent the mapping of a large number of other electrical equipment, and the number of plant-site mappings is small, which is easy to establish and maintain. Based on the above analysis, the main process of forming the device mapping table is as follows:

1) Combine manual designation and intelligent matching methods to generate plant station mapping table;

2) Formation of generator and auxiliary power mapping table;

3) Form the transformer mapping table;

4) Form the line, high-resistance mapping table;

5) Form the mapping table of series capacitors and other electrical equipment.

The maintenance function of online-offline equipment mapping information relies on the data management platform of the State Grid Simulation Center, which mainly includes two parts: batch import of initial mapping information and model mapping maintenance.

4.2 Expansion of online model

Since the 220kV transformer in the online model is equivalent to the load, it is necessary to extend the equivalent load to the transformer through the intelligent model function to meet the calculation requirements of the simulation analysis of the operation mode. The equipment requiring model expansion mainly includes two-winding transformers and three-winding

transformers. Among them, when expanding the 220kV transformer of the online model, it is necessary to recalculate the operating power, voltage angle and other state variables of the expanded transformer to meet the requirements of model data for power flow calculations, transient calculations and other simulation analysis calculations.

When calculating the power of the medium and low voltage side of the three-winding transformer, it is necessary to calculate the switching state and power of the medium and low voltage side capacitors according to the situation of the medium and low voltage side models (capacitor, load) of the offline three-winding transformer.

4.2.1 Expansion of two-winding transformer

In the power grid model, the two-winding transformer model is shown in the Figure 1, where the i is the low-voltage side and the j is the high-voltage side; K is the transformer ratio; S_i , U_i , I_i , S_j , U_j and I_j are the power, voltage and current of the transformer, respectively; Z is the impedance of the transformer^[16].

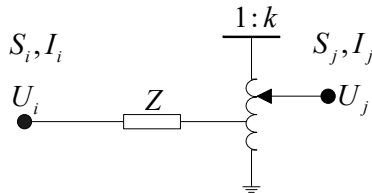


Figure 1 Schematic diagram of two-winding transformer

The voltage U_j and power S_j of the high-voltage side of the two-winding transformer are known.

There is the following relationship^[10]:

$$\dot{U}_i + k\dot{I}_j Z = \frac{\dot{U}_j}{k} \quad (1)$$

Then the low-voltage side voltage and power of the two-winding transformer can be obtained as:

$$\dot{U}_i = \frac{\dot{U}_j}{k} - \left(\frac{\tilde{S}_j}{\dot{U}_j} \right)^* kZ \quad (2)$$

$$\tilde{S}_i = \dot{U}_i^* I_i = \left[\frac{\dot{U}_j}{k} - \left(\frac{\tilde{S}_j}{\dot{U}_j} \right)^* kZ \right] k \left(\frac{\tilde{S}_j}{\dot{U}_j} \right)^* \quad (3)$$

From the above derivation, the low-voltage side power and voltage of the two-winding transformer can be obtained, and the expansion of the two-winding transformer is completed.

4.2.2 Expansion of three-winding transformer

The three-winding transformer is equivalent to three two-winding transformers in the offline model, so the medium and low voltage side power and voltage estimation of the three-winding transformer are similar to the above method. However, the low-voltage side of the three-winding transformer may be a load or a capacitor, and the capacitor switching state and power should be calculated according to the modeling situation of the offline transformer low-voltage side.

4.3 Data integration

Traditional power grid offline analysis generally does not support topology analysis, nor does it have switch modeling. Therefore, it cannot directly form the whole network topology by analyzing switch states in a conventional manner. The topology change of offline data can only be done by changing the node to which the device is connected or the state of the device.

The data integration program is the core part of the entire system. It integrates online and offline models into a set of models for subsequent calculations according to certain rules. The difficulty lies in analyzing and judging the topological structure of the power grid based on the state of the switch or equipment of the power grid, that is, connecting various devices (such as generators, loads, shunt capacitive reactance, transmission lines, transformers, etc.) according to the state of the switches or equipment, and Identify electrical subsystems that are isolated from each other. The topology can be quickly regenerated when the state of the switch or device changes.

4.4 Example analysis

Taking the Northeast Power Grid as example, the real-time online model adopts the QS data closest to the fault time, while the offline model is based on the typical winter peak mode, and the multi-source data integration system is used to generate the model.

In this model, the stable transient parameters of various equipment adopt the typical data of offline model. State quantities such as startup, load, DC incoming/sending power, and 500kV voltage level are consistent with the real-time online model. The specific conditions are shown in the following table.

Table 2. The comparison of running state.

	Offline model	Online model
Load/ten thousand kilowatts	4412	4400
DC incoming and sending power	Lugu DC 5.70 million kW, Gaolin DC 3.00 million kW, Yimu DC 0.50 million kW, Heihe DC 0.52 million kW	
The voltage of 500kV plant	Around 530kV, the voltage level of all plants is close to each other.	

In addition, the offline model is adjusted according to the power flow boundary of the online model. Based on the PSASP simulation software, the integrated model and the offline model were simulated and compared by selecting typical faults. Intercept the generator power angle, busbar voltage and frequency curves for comparison.

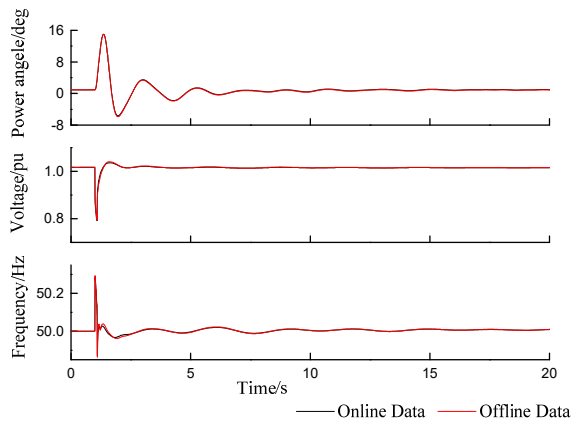


Figure 2. Transient process curve at fault.

As can be seen from Figure 2, when a fault occurs to the power grid, the simulation results of the integrated model and the offline model have basically the same variation trend. The simulation curve can well simulate the variation of electric quantity when the power grid fails.

The simulation results verify the correctness and effectiveness of the multi-source data integration system for large power grid operation.

5 Conclusions and prospects

This article initially proposes a multi-source data integration scheme, which studies the rapid interaction and intelligent integration of multi-source heterogeneous information such as offline and online models, breaking the technical application barriers of various types of data, and quickly generating real-time power grid model. Through the practice and application in the State Grid Dispatching Center, it is proved that the online and offline data integration technology proposed in this paper is scientific and practical, which basically meets the needs of on-site data integration, and improves the correctness and effectiveness of real-time simulation calculation.

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