Development of Optimization Parameter System for AVC in Hebei Low Voltage Grid

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Abstract – Proposing the optimal AVC coordinating parameters and comparing effects of different grid planning for reactive balance in a scientific manner is one of the functional characteristics of smart AVC. In this paper Optimization Parameter (OP) system is developed in Hebei low voltage grid for this purpose. The data are taken from EMS. The state estimation is carried out periodically after obtaining real-time data. Taking state estimation results as the basic power flow and simulating AVC operations, the voltage variations and line loss analysis can be calculated for comparison. The system can compare optimization parameters for the real grid or the virtual grid. It’s depending on whether considering the actual capacity of reactive power compensation equipments. The structure, hardware configuration and data exchange of the system are illustrated. Finally, several analysis tools of the OP system are introduced. With the system, it can be evaluated that effects of reducing line loss benefited from the AVC operations. It can propose coordinating priority of capacitors or on-load regulating transformers. Also it can provide the optimal AVC coordinating parameters and the optimal grid plans, which lead to better voltage control and better layout of reactive power compensation equipments.

Keywords: Automatic voltage control, Low voltage grid, Optimization parameter, Line loss, AVC coordinating parameter, Planning grid

1. Introduction

The problems of power system became important with the increase of grid capacity and voltage level upgrades, such as the reactive power balance and voltage control. The voltage of the key point is much high in valley load period in recent years. Therefore, the insulation of transformations, transmissions and consumer equipments must bear over-voltage, greatly shortening the life of these equipments and probably affecting the safe operation of them [1–3]. Automatic Voltage Control (AVC) system has been applied as a means for controlling voltage and adjusting reactive power because it has many special excellences [4–8]. However, in low voltage grid or rural grid, AVC system only have reactive compensate effect, for not enough reactive capacity. It has been a problem to get better plan for the layout of reactive power compensation equipments. Meanwhile, there are few ways to compare effects of different AVC coordinating parameters on the voltage regulation. It is an urgent need to develop Optimization Parameter (OP) system.

The main function of the OP system can be described as follow: (a) It can check whether the available AVC coordinating parameters are optimization. (b) It can evaluate reducing line loss benefited from the operations. (c) The OP system can provide the decision-supporting function for planning new power capacitors or on-load regulating transformer of substation, which can reduce the line loss of low voltage grid or rural grid.

The main motive of this paper is to provide the purpose, system structure, hardware configuration and data exchange of the OP system. Blueprint of developing OP system to smart AVC system is shown, though still in the research. Furthermore, a number of important concepts about the coordinating priority, such as the voltage-capacitor sensitivity and the voltage-tap sensitivity, are also given. Finally, several analysis tools of the OP system are introduced.

2. The structure of the OP system

With the real-time data taken from EMS, the OP system is the on-line monitoring and analyzing system for Hebei low voltage grid. The state estimation is carried out periodically after obtaining real-time data. Taking state
estimation results as the basic power flow, the theoretical voltage variations and line loss analysis can be carried out within the virtual equipments such as capacitors and transformers. It can calculate the voltage-capacitor sensitivity, which is voltage variation of one key bus dividing the reactive variation when regulating a unit of capacitor. Also the OP system can calculate the voltage variation of one key bus while regulating the transformer tap, which is voltage-tap sensitivity. These sensitivities decide the coordinating priority of capacitors or transformers. All the voltage variations can be viewed with Hebei grid geographical diagram.

The OP system in Hebei grid contains five subsystems. The flowchart of it is illustrated in Fig. 1.

2.1 Planning grid subsystem

The planning grid subsystem can establish and save different planning grid models. The planning grid models include actual grid model and virtual equipment models (transformer, line, bus, generator, capacitor, etc). Based on two data sources (real-time data and historical data), the virtual equipment models can be added via user interface. If establishing the virtual equipment models is not needed, the subsystem only obtains measurement value and carries state estimating with actual grid model. The models deposit in virtual database.

2.2 AVC parameters simulation subsystem

It is used to build AVC control models and save different AVC coordinating parameters such as capacitors coordinating velocity and min capacitors switching amount by one operation. They can affect the reactive power balancing and voltage coordinating. Every AVC control model can deposit a number of parameter schemes.

2.3 Operation and voltage analysis subsystem

It is used to simulate the AVC operations. Firstly users should define when the operations taking place in one day or in any time segment. And via the subsystem users can use real-time EMS data or historical EMS data for simulation. The operations include switching of capacitors or adjusting on-load regulating transformer taps. Then the accurate results of power flow and voltage variations are calculated. These data are stored in virtual database for the line loss analysis subsystem. If the AVC coordinating parameters can’t match the coordinating requirements, the next step will go to viewing subsystem and propose the incompetent parameters in the form of table. Otherwise, it will enter into line loss analysis subsystem.

2.4 Line loss analysis subsystem

It can calculate line loss of the actual grid or the planning grid. Firstly users should establish line loss models and parameters. It can define or modify range of line loss statistics areas via user interface. The line loss models and parameters of added virtual equipments are stored in database and initialized automatically if updated. According to the aforesaid power flow stored in virtual database, the
integral calculation for line loss can be carried out. The results can be shown with Hebei grid geographical diagram.

2.5 Viewing subsystem

It is used to provide analysis tables and comparison curves for users. It also can show bus voltage or line loss with the geographical diagram of low voltage grid.

3. Hardware configuration and data exchange

The hardware configuration of OP system is shown as Fig. 2. The EMS server, EMS workstation and EMS database are built in power dispatch or control center of county in Hebei province. A data receiving server in Hebei Electric Power Research Institute is configured to receive models, graphics and data of Hebei low voltage grid. Two network cards are used in data receiving server. One network card connects with the EMS server to get power system data. The other one connects with OP system. Two OP servers are configured for storing five subsystems and the virtual database, they are used for calculation and analysis functions. And the system has data backup and recovery function. The files of it can be automatically forwarded to other storage facilities for data mirroring, disaster recovery or backup applications. A workstation is used for monitoring and operating. With the workstation, users can login OP servers, modify parameters and view the results.

Fig. 3 shows data exchange between five subsystems and EMS server. After state estimation, the EMS server sends correction value to OP system. As it is shown, the virtual database is very important in the system. It not only receives EMS real-time data or historical data, and stores voltage analysis and line loss results. Broken line means the date sending from OP system to AVC system. The purpose is sending the optimization coordinating parameters to AVC substations with control orders via AVC system. Moreover, it could modify AVC coordinating parameters on-line when large load variation happened or structure of low voltage grid changed. This is one of the functional characteristics of smart AVC [9–13].

![Fig. 2. hardware configuration of OP system.](image1)

![Fig. 3. data exchange between subsystems and EMS server.](image2)

4. The introduction of analysis tools and application

4.1 Sensitivity and priority calculator

It can calculate the voltage-capacitor sensitivity. It should be firstly defined the reactive variation when switching one unit of capacitors in one substation. Then the system calculates reactive output and voltage variation of different key points. Using the same reactive output variation, the tool simulates every substation with different load situations. The load situations include spring load,
summer load and winter load, for their distinct load characteristics in Hebei low voltage grid. When all voltage-capacitor sensitivities are given, user can define capacitor coordinating priority for some key point in different load situations. Capacitors with bigger voltage-capacitor sensitivity have higher coordinating priority. The process of providing voltage-tap sensitivity and on-load regulating transformer coordinating priority is similar.

4.2 Comparison curve

The main function of the tool is to show comparison curves for different types of data. A series of comparison curves have built in system such as active power, reactive power, voltage, line loss and so on. Users can display these comparison curves easily. Through the comparison, it is illustrated which planning new capacitors of substation or new on-load regulating transformers have better effects on controlling voltage or reducing line loss. The system also provides a user-define interface for comparison curve. Users can define various comparison curve scheme according to their requirements.

4.3 Table report

The main function of table report is to provide customization reports for users. The stored data in system can be proposed in the tables such as sensitivities data, priorities data, capacitors data, on-load regulating transformers data, integral time section of line loss, line loss and so on. Via the report, better layout planning for reactive equipments is revealed. The arithmetic of data in tables can be investigated by users. The format of tables can be defined flexibly. The customization report can be generated and published automatically.

5. Conclusion

In this paper Optimization Parameter system is developed. The structure, hardware configuration and data exchange of it are introduced. With the OP system, the traditional reactive compensate equipments can be united and developed to smart AVC system for rural grid. It is an important component of smart grid. It can propose coordinating priority of capacitors or on-load regulating transformers. It can evaluate reducing line loss benefited from the AVC coordinating parameters or the AVC operations. Also it can provide the optimal AVC coordinating parameters and the optimal grid plans, which lead to better voltage controlling and better layout of reactive power compensation equipments.

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References

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