

PAPER • OPEN ACCESS

Research on Design and Application of Reactive Power Optimization Software for Distribution Network

To cite this article: Zhao Haojun *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **495** 012013

View the [article online](#) for updates and enhancements.

You may also like

- [A comparative analysis of PI & FLC based grid connected PV system with power backup to improve power quality](#)
Anurag Tiwari and Ruchi Agarwal
- [Power quality improvement by using STATCOM control scheme in wind energy generation interface to grid](#)
Sheeraz Kirmani and Brijesh Kumar
- [Research on Energy Efficiency Loss of Typical Distribution Network Equipment by Compound Power Quality Disturbance](#)
Yu Fu, Zhiyao Zheng, Zilun Shen et al.



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Research on Design and Application of Reactive Power Optimization Software for Distribution Network

Zhao Haojun^{*}, Zhu Ye, Wang Xiaofeng, Xing Yibin, Ding Simin and Chen Jian

Nanjing Power Supply Company of Jiangsu Electric Power Co., Ltd., Nanjing 210000, China

^{*}E-mail: leshisu45@163.com

Abstract. In view of the phenomenon of long power supply radius, low power factor, large line loss, and poor voltage quality in the single-radiation power supply mode of reactive voltage control in Jiangsu area, this paper studies and establishes a set of three-level coordinated control of reactive voltage in distribution network. The system can realize the three-level coordinated control of the substation, transmission line and distribution voltage reactive power compensation device according to the actual short-term load changes, which can effectively solve the high voltage, ground voltage and three-phase imbalance existing in the power grid in Jiangsu. The voltage qualification rate is increased to 100%; in addition, the system can also provide analysis of the power quality status of the distribution network, combined with the analysis and comparison of the results of power quality optimization governance, to achieve scientific results evaluation, for the energy-saving control of the power grid and power quality governance. Provide reference to provide basic data for power grid construction.

1. Introduction

In China's power distribution system, the existing voltage and reactive power control in Jiangsu mainly has the following problems: its distribution network widely uses a tree-shaped, multi-branch unidirectional radiation power supply method, resulting in a long power supply radius, low power factor, and power lines. Large loss, poor terminal voltage quality [1-2]; less reactive voltage regulation equipment, on-load voltage transformer and other equipment are still in the pilot stage in many regions [3]; most of the existing automatic control systems are voltage and Reactive power is adjusted in isolation, and the voltage and reactive power are not organically combined. Moreover, the voltage and reactive power adjustment equipment operates too frequently. Frequent adjustments cause frequent failures of the transformer, which seriously affects the quality and stability of the power supply. As a result, the automatic control of voltage and reactive power cannot be widely applied and promoted in actual work [4-5]; most of the existing systems cannot be unified with centralized control and decentralized control functions, and the distribution network has a single application function and is not practical. [6]. The communication functions of existing systems are generally weak. The overall structure of the distribution network equipment and communication conditions is not fully considered [7]; the communication mode in the distribution network generally adopts GPRS communication mode, the state promulgates the information security law, and the remote control and wireless communication mode are prohibited. Remote adjustment; lack of a set of system software for comprehensive coordinated monitoring of station areas, feeders, and user-side voltages [8-10].



Therefore, the comprehensive control of reactive voltage in the distribution network is urgently needed to realize the management of the reactive voltage equipment in the distribution network, the management and control of the reactive voltage equipment, the management of the voltage quality of the distribution network, and the reduction and energy saving of the distribution network.

Based on the above problems, a three-level coordination system for reactive power and voltage in distribution networks is developed in this paper, which can ensure that the voltage qualification rate is not reduced by the control of the power grid, reduce the network loss, and improve the power quality.

2. Components of Three-Level Coordinated Control System for Reactive Power and Voltage in Distribution Networks

The three-level coordinated control system for reactive voltage of the distribution network studied in this paper is mainly composed of distribution network reactive voltage coordination optimization software, medium voltage line reactive voltage coordination control APP software, station area reactive voltage optimization APP software, and station three-phase It consists of software such as imbalance control APP software. The overall operating mode of the system is divided into data uplink and data downlink. The overall architecture of the distribution network coordination and optimization software is shown in Figure 1.

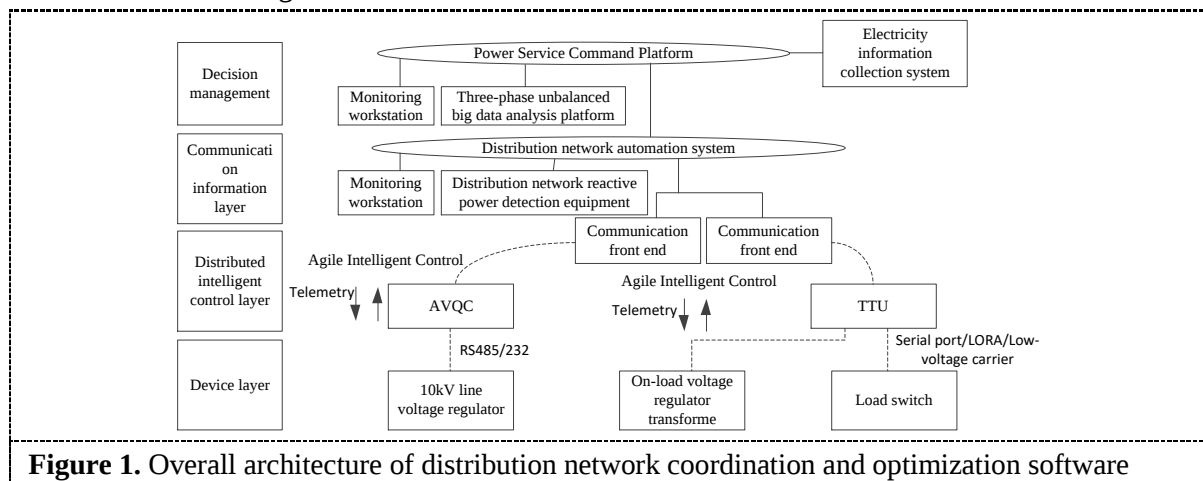


Figure 1. Overall architecture of distribution network coordination and optimization software

Data uplink: Reactive voltage equipment (on-load voltage regulating taps, reactive power compensation, etc.) on the station side communicates with the new intelligent distribution transformer terminal unit (TTU) through standard RS485/232 shielded twisted-pair wires using standard communication protocols (DLT645 / Modbus, etc.) TTU will upload the collected information to the main station of the four districts of the distribution network automation through the mobile public network channel in accordance with the IEC-104 protocol through the secure encryption chip deployed by the Chinese Academy of Electric Power. The feeder-side reactive voltage equipment (line voltage regulator, line reactive power compensation, etc.) communicates directly with the feeder AVQC device via RS485/232. The feeder AVQC device encrypts the collected information with the national network unified security encryption chip and encrypts it with IEC-104. The standard communication protocol is uploaded to the main station of District 4 of the distribution network automation through the mobile public network channel.

Data downlink: The distribution network AVQC module in the main station of the fourth area of the distribution network is based on the data of the main distribution station in the fourth area, and combines the load forecast and the comprehensive voltage qualification rate of the distribution network to calculate the optimal value interval of the bus of this substation. The optimized value is sent to the main network AVC. The distribution network AVQC module software is based on the data of all stations below this feeder, combines load prediction and the comprehensive pass rate of the stations below this feeder, calculates the target value of the reactive voltage optimization of this feeder, and sends it to the feeder AVQC by issuing a fixed value. Device.

3. Scheme Principle

3.1. *Distribution network coordination optimization software*

The distribution network coordination and optimization software has obtained the access authorization of the main station of the distribution network automation area 4 and supports the national network information security specifications. It can also be used for distribution network equipment management and reactive voltage regulation equipment operation management to meet the needs of operation and maintenance personnel during maintenance adjustment. Update and demand for comprehensive analysis of on-load voltage regulation transformers, distribution network voltage quality (low voltage, high voltage, three-phase imbalance), etc., and can regularly provide problem cause analysis and suggestions for transformation and adjustment to improve the overall effect, and Meet the following functions:

(1) Global analysis and monitoring: comprehensively analyze the recommended end-to-end voltage values of each feeder and station area, and give a reasonable operating voltage range for the feeder and station area. Combined with the high-voltage distribution network AVC, the decision value or range is submitted to the high-voltage distribution network AVC as an indicator to achieve the optimal scheduling of the high-voltage distribution network AVC;

(2) Voltage correction: Monitor the line voltage and phase voltage of the distribution transformer at the same time, and support voltage correction in the case of three-phase imbalance: For a single distribution transformer, the voltage adjustment means include the on-load voltage regulating tap and distribution transformer of the distribution transformer Reactive power compensation device, when the substation voltage is unqualified and the reactive power is reasonable, the on-load voltage regulating tap of the substation is the main adjustment method. When the distribution transformer voltage is unqualified and the reactive power is unreasonable, the goal is to satisfy both the voltage regulation and reactive power compensation, and the reactive power compensation device is the priority action method;

(3) Optimized balance of reactive voltage: Combined with the need for voltage regulation, the reactive power flow is optimized, the power factor qualification rate is increased, and the loss and energy saving are reduced;

(4) Optimal balance of three-phase unbalance: Optimize the setting parameters of intelligent commutation switch and phase-to-phase reactive power compensation to improve equipment operation effect and service life;

(5) Short-term and ultra-short-term load forecasting: For loads with obvious daily curve changes, short-term and ultra-short-term load forecasting algorithms are used to estimate the change trend of the day's load and the ultra-short-term load value through the load changes of the recent period. The load forecasting algorithm takes into account the effects of holidays, and performs statistical calculations on holidays and ordinary days to ensure the accuracy of the forecast. By predicting the load of the feeder and the station area, combined with the simulation budget, the voltage distribution of the back end of the equipment is inferred, the optimal decision is given, and the local equipment is directly controlled;

(6) Sound evaluation system

Voltage evaluation: Perform voltage evaluation based on historical voltage data, analyze the voltage qualification rate and increase bottlenecks, and compare and analyze with the voltage monitoring system interface; Equipment operation situation evaluation: Through equipment operation times and success rates, equipment maintenance plans can be arranged.

3.2. *Tai area reactive voltage optimization APP software distribution network coordination optimization software*

The Tai area reactive voltage optimization APP software should be based on the distribution transformer terminal (TTU) equipment to achieve the dynamic coordinated control of the lower-end control equipment (on-load voltage transformer, etc.), while satisfying the following functions:

(1) Calculation function

Equipped with continuous quantity optimization and discrete quantity optimization algorithms to ensure convergence, calculation accuracy and real-time performance to meet the needs of online control. It can adapt to the load operation mode by itself according to the boundary conditions. It has the function of sensitivity or power flow check, and can perform pre-control evaluation on the given control strategy to avoid control oscillation.

(2) Control function

The remote control and remote adjustment of the lower-end control equipment are realized according to the local serial communication interface. It has load adaptive voltage correction, three-phase imbalance management and reactive power optimization functions that take into account the voltage adjustment. The control target priority can be set to optimize the equipment action. Frequency, automatic discrimination and manual setting of the input / withdrawal state controlled by the equipment, as well as real-time state and research state facilitate debugging and simulation.

(3) Control mode

The control of the system should be able to be triggered by periodic, manual and event triggers; with process monitoring function, it automatically restarts the failed process to ensure the real-time and autonomy of the system; it can completely record the adjustment status of each reactive device for at least 12 months and Curve records, and can be easily inquired; statistical analysis of equipment control effects.

(4) Safety requirements

Applicable to automatic control in steady state, support blocking and alarm function in case of failure of reactive voltage equipment; support anti-oscillation function of equipment under load forecasting; from the perspective of the entire network to equipment of different voltage levels, different types of The equipment performs coordinated control, reduces the number of adjustments of discrete equipment, and optimizes the timing of adjustment. The number of device movements must be strictly controlled within national and industry standards.

3.3. Feeder AVQC device

A feeder AVQC device is installed on the feeder side, and directly communicates with the adjustable equipment on the feeder side through the RS-485/332 communication line to realize local control of the equipment.

The feeder AVQC device should be configured with at least two 10/100 adaptive network interfaces, two USB interfaces, one TF card interface supporting hot plug and SD Memory Card protocol v2.0, one SIM card interface, two 232/485 Serial interface, 2 CAN interfaces and support EMC protection. Optional 1 way 3G / 4G module interface, 1 way WIFI module interface. Supports IEC61970, MODBUS and other standard communication protocols. With rule setting engine and expert system, it can realize one-to-many control strategy; it has various adjustment functions such as voltage optimization, reactive power optimization, three-phase imbalance management, equipment operation frequency optimization, energy saving optimization, etc.; supports multi-device distributed deployment , The device can automatically load balance; equipped with multi-device coordination error prevention mechanism in case of abnormal communication.

3.4. Medium voltage line coordination control APP software

The medium-voltage line coordination control APP software can be based on the feeder AVQC device, and according to the local serial communication interface, it can realize the local dynamic coordination control of the lower-end control equipment (10kV line voltage regulator, etc.), and it can give the best voltage according to the load prediction. Target value. At the same time, the following functions can be met: the target value can be set by self-learning, the voltage distribution can be determined according to the topology, and localized optimization control can be achieved; load forecasting can be realized, the power grid trend can be predicted, the operation efficiency can be improved, and switching vibration can be avoided; The number of times can be controlled to improve

the service life of the equipment; while controlling the quality of the voltage, the operation mode of the power grid should be optimized to achieve energy saving in the distribution network; local optimized coordinated control based on time difference and set value coordination can be realized.

3.5. Three-phase unbalance management APP software in Tai Area voltage line coordination control APP software

The three-phase unbalanced management and control APP software in the station area should be able to realize the dynamic coordinated control of the lower-end control equipment (intelligent three-phase load balance switch, etc.) based on the distribution transformer terminal (TTU) equipment, and it should meet the following requirements:

(1) Data display function

It should have three-phase imbalance and load rate curve display; three-phase imbalance distribution display; three-phase imbalance ratio display; zero-line current curve display.

(2) Taiwan area statistics function

It should have statistics of monthly average three-phase unbalance and monthly average load rate in this station area; it should have statistics function of maximum three-phase unbalance and maximum load rate in station area.

(3) Three-phase unbalance analysis function

It shall have the function of analyzing the cause of three-phase imbalance; it shall have the function of long-term three-phase unbalance analysis; it shall have the function of unreasonable load distribution analysis; it shall have the auxiliary function of three-phase imbalance treatment plan.

3.6. Commutation switch type three-phase load automatic adjustment device

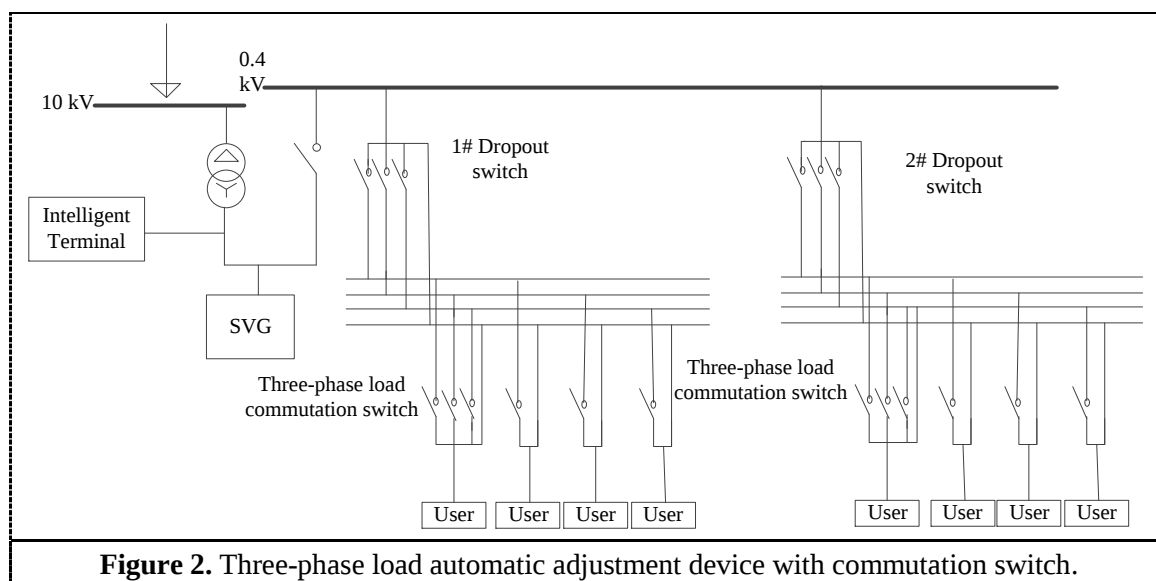


Figure 2. Three-phase load automatic adjustment device with commutation switch.

Commutation switch type three-phase load automatic adjustment device (low-voltage load automatic commutation device) is composed of an intelligent commutation terminal (responsible for load monitoring and automatic commutation control) and several commutation switch units (responsible for performing load commutation operations). The intelligent commutation terminal monitors the three-phase current of the low-voltage outgoing line of the distribution transformer in real time. If the unbalance of the three-phase load on the low-voltage side of the distribution transformer exceeds the limit within a certain monitoring period, the intelligent commutation terminal reads the low-voltage outgoing line of the distribution transformer and all commutation switch units Real-time data of current and phase sequence of each load branch, perform optimal calculations, and issue optimal commutation control instructions. Each commutation switch unit performs commutation

operations in accordance with the specified commutation process to achieve user load phase sequence adjustment and distribution station area. Three-phase load balancing. It is suitable for three-phase four-wire 380V / 220V low-voltage power distribution system, and can quickly and accurately detect the three-phase imbalance problem of low-voltage power distribution system. The overall architecture of the low-voltage power distribution system is shown in Figure 2.

4. Case Analysis

During the peak power consumption period in July in July, the power grid was heavily loaded, and a large number of stations under Lukou Substation had different levels of power quality problems. At the same time, in order to avoid large-scale and continuous station areas under Lukou substations during peak power hours Low voltage problem. The power supply company adjusted the 10kV bus voltage to the upper limit operation in the 110kV Lukou Substation, but this action also caused a large number of station voltages under the upper limit of the Lukou Substation. Show. This paper collects and analyzes the relevant data of 65 typical stations with different power quality problems, and analyzes them. The data are shown in Table 1.

Table 1. Lukou voltage data collection table

Line name	Tai name	Voltage over limit time	Lower voltage limit time	Qualified time of voltage	Voltage statistics time	Voltage over the upper limit (%)	Lower voltage limit (%)	Qualified rate of voltage (%)	Voltage average	Maximum voltage	Minimum voltage
Luzhen Line	Lingqiao New Station	33570	0	100350	133920	25.07	0	74.93	236.9	245.4	218.6
Oss Line	Osborn 24 change	7800	0	126120	133920	5.82	0	94.18	232	237.8	225.2
Matang Line	Ma Fu Guanyin Temple Station	7575	0	126075	133650	5.67	0	94.33	227.2	247.3	208.5
Beizhuang Line	Stand before success	6495	0	127110	133605	4.86	0	95.14	230.8	240.8	211.2
Beizhuang Line	Zhangqiaoqian Station	0	2790	16460	119250	0	2.34	97.66	218.1	234.9	188.6
Beizhuang Line	Fangjiawan Station	45	2010	122730	124785	0.04	1.61	98.35	222.7	236.8	190.8
Beizhuang Line	Wujia Station	0	1680	131925	133605	0	1.26	98.74	219.2	227	195.8
Beizhuang Line	Lizhuang Station	0	1560	125610	127170	0	1.23	98.77	215.9	230.8	196.2
Beizhuang Line	Wuchaqiao Middle Station	0	1215	128295	129510	0	0.94	99.06	219.8	228.6	194.2
Matang Line	Guanyin Temple Station	7575	0	126075	133650	5.67	0	94.33	227.2	247.3	208.5
Beizhuang Line	Zhangqiao Jinling Station	6225	0	123060	129285	4.81	0	95.19	233.5	240.6	209.6
Beizhuang Line	Success new station	6285	0	127320	133605	4.7	0	95.3	230.7	241.7	209.1
Beizhuang Line	Success East Station	5715	0	123525	129240	4.42	0	95.58	231	240.3	210.2
...	...	...	...	...	...	...	...	...	...	...	...
Beizhuang Line	Baiyun Zhangye Station	1605	750	131250	133605	1.2	0.56	98.24	228.4	243.1	191.9
Beizhuang Line	Kung Fu East Station	2235	0	124935	127170	1.76	0	98.24	228.1	238.8	201
Matang Line	Zhangqiao Water and Soil Station	495	0	129690	130185	0.38	0	99.62	225.6	237.8	214

The above table shows that the monthly data of the supply voltage pass rate of 65 typical stations can clearly see that the voltage pass rate of 5 stations including Zhangqiaoqian Station , Fangjiawan

Station, Wujia Station, Lizhuang Station and Wuchaqiao Middle Station are low, and there is obviously a low voltage phenomenon. They were 2.34%, 1.61%, 1.26%, 1.23%, and 0.94%. It can be seen that the voltage of 37 stations such as Lingqiao New Station and Guanyin Temple Station are longer than the upper limit for a longer time, the higher the upper limit is, the lower the voltage qualification rate, and there are high voltage problems. At the same time, the above table shows that there is a certain degree of three-phase imbalance.

According to the needs of low-voltage problems and high-voltage problems, the station's reactive voltage optimization APP software, distribution transformer terminal unit (TTU), and on-load voltage transformers are configured for low-voltage and high-voltage management respectively. AVQC medium-voltage line APP software, medium-voltage line coordinated control APP software, and 10kV line voltage regulators need to be deployed in the region. By optimizing the line voltage regulators, the quality of line terminal voltage can be greatly improved and the comprehensive voltage of distribution transformers Pass rate. The data after software adjustment are shown in Table 2.

Table 2. Lukou voltage data collection table after software adjustment

Line name	Tai name	Voltage over limit time	Lower voltage limit time	Qualified time of voltage	Voltage statistics time	Voltage over the upper limit (%)	Lower voltage limit (%)	Qualified rate of voltage (%)	Voltage average	Maximum voltage	Minimum voltage
Luzhen Line	Lingqiao New Station	33570	0	100350	133920	25.07	0	74.93	236.9	245.4	218.6
Oss Line	Osborn 24 change	7800	0	126120	133920	5.82	0	94.18	232	237.8	225.2
Matang Line	Ma Fu Guanyin Temple Station	7575	0	126075	133650	5.67	0	94.33	227.2	247.3	208.5
Beizhuang Line	Stand before success	6495	0	127110	133605	4.86	0	95.14	230.8	240.8	211.2
Beizhuang Line	Zhangqiaoqian Station	0	2790	16460	119250	0	2.34	97.66	218.1	234.9	188.6
Beizhuang Line	Fangjiawan Station	45	2010	122730	124785	0.04	1.61	98.35	222.7	236.8	190.8
Beizhuang Line	Wujia Station	0	1680	131925	133605	0	1.26	98.74	219.2	227	195.8
Beizhuang Line	Lizhuang Station	0	1560	125610	127170	0	1.23	98.77	215.9	230.8	196.2
Beizhuang Line	Wuchaqiao Middle Station	0	1215	128295	129510	0	0.94	99.06	219.8	228.6	194.2
Matang Line	Guanyin Temple Station	7575	0	126075	133650	5.67	0	94.33	227.2	247.3	208.5
Beizhuang Line	Zhangqiao Jinling Station	6225	0	123060	129285	4.81	0	95.19	233.5	240.6	209.6
Beizhuang Line	Success new station	6285	0	127320	133605	4.7	0	95.3	230.7	241.7	209.1
Beizhuang Line	Success East Station	5715	0	123525	129240	4.42	0	95.58	231	240.3	210.2
...	...	...	...	...	...	...	...	...	...	...	...
Beizhuang Line	Baiyun Zhangye Station	1605	750	131250	133605	1.2	0.56	98.24	228.4	243.1	191.9
Beizhuang Line	Kung Fu East Station	2235	0	124935	127170	1.76	0	98.24	228.1	238.8	201
Matang Line	Zhangqiao Water and Soil Station	495	0	129690	130185	0.38	0	99.62	225.6	237.8	214

After the reactive voltage optimization of the coordinated control system, the qualified rate of the voltage at the gate of the medium-voltage line is 100%; the qualified rate of the pass voltage at the reconstructed station area reaches 100%. At the same time, the three-phase imbalance of the two stations involved is controlled within a reasonable range.

5. Conclusion

A set of three-level coordinated control system for reactive power and voltage of distribution network researched and established in this paper can realize three-level coordinated control of substations, transmission lines, and distribution voltage reactive power compensation devices, which can effectively solve the high-voltage, low-voltage and three-phase imbalance phenomenon. According to the comparative analysis of the data, it can be known that the application of the three-level reactive voltage control system for reactive voltage in the distribution network can make the voltage qualification rate increase to 100%; In addition, the system can also analyze the power quality status of distribution networks, analyze and compare the results of power quality optimization governance, implement scientific result assessment, provide references for power grid energy conservation control and power quality governance, and provide basic data for power grid construction .

References

- [1] Chen Yan. Steady-state analysis of power system [M]. Beijing: Water Resources and Hydropower Press, 1985
- [2] Li Jiwen. Reactive power control [M]. Jinan: Shandong University of Technology, 1995
- [3] Medina, Miguel A, Coello Coello, Carlos A, Ramirez, Juan M. Reactive Power Handling by a Multi-Objective Teaching Learning Optimizer Based on Decomposition [J]. IEEE on on Power Systems, 28 (4): 3629- 3637.
- [4] Yan Haojun. Improvement of Voltage and Reactive Power Comprehensive Control Strategy in Substation [J]. Power System Technology, 1997 (10): 47-49.
- [5] Zhao Dengfu, Si Yi, Yang Jing, et al. Development of a new type of substation voltage and reactive power integrated control device [J]. Power System Technology.
- [6] Han Wenqing, Zhou Zhiyong, Wang Yi, et al. Research on voltage and reactive power comprehensive control of regional substations based on load prediction [J]. Power System Protection and Control, 2012, 40 (8): 68-72.
- [7] Hu Cai'e. Research on Reactive Power Optimization Scheme of Rural Distribution Network [D]. China Agricultural University, 2001.
- [8] Wang Jianqiang. Reactive power compensation system for intelligent distribution network [J]. Power System Technology (7): 80-81.
- [9] Zhou Yifei, Zhao Jinrong. Voltage and reactive power automatic control software and its application [J]. Automation of Electric Power Systems, 2000, 24 (9).
- [10] Jun Liu, Weiguo He, Xiaoyin Zhan, et al. A decomposition and coordination algorithm for reactive power optimization based on block coordinate descent [C] // Electricity Distribution (CICED), 2012 China International Conference on. 2012.Luo G, Zhang D. Recognition of partial discharge using wavelet entropy and neural network for TEV measurement[C]//Power System Technology (POWERCON), 2012 IEEE International Conference on. IEEE, 2012: 1-6.