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RESEARCH ON KEY TECHNOLOGY OF EXTENDING POWER SUPPLY RADIUS IN SPARSE AREA

Guoqing Xu [1], Huili Wu [1*], Yue Fan[2], Senlin Yang[3], Lishan Ma[3], Lei Wang[3]

1 School of Mechanics Engineering and Automation, Shanghai University, China

2 State Grid Qinghai Electric Power company, State Grid, China

3 Guoluo Power Supply Company of State Grid Qinghai Electric Power company, China

ABSTRACT

The extension of power supply radius of every single substation by technology has become a primary task of electric power construction in western China. This paper proposes a new scheme to extend the power supply radius in sparse areas, simultaneously realizing voltage boosting and unified power quality compensation through two smart parallel power electronic subsystems. Dynamic voltage regulating technique is used to compensate voltage loss while three phase unbalance compensation, reactive power compensation and filtering are solved in one topology. After simulated by Matlab/Simulink and field-tested in Guoluo State, the result shows great changes in lifting voltage and improving power factor (to above 0.95), which utterly solves the problem of power supply radius extension and lays a foundation for further construction of smart grid in west area.

Keywords: smart gird, FACTS, dynamic voltage regulator, unified power quality compensator.

1. INTRODUCTION

The construction of electricity in western China is crucial to people's livelihood in the country. Users in these high-altitude western areas are often scattered so that the average power supply cost is rather high (about 100,000 RMB/household). To improve power supply coverage and ensure users' basic power requirements, establishing new traditional substations to extend the power supply radius no longer meets the demands of building an economic, efficient and smart grid in west, especially in these sparse areas. Therefore, it is urgent to study a novel method that can effectively extend the power supply radius of these western distribution network.

2. CHARACTERISTICS OF LONG DISTANCE POWER SUPPLY SYSTEM IN SPARSE AREAS

As shown from Table 1, the major characteristics of power supply system in sparse areas can be concluded as the following two aspects:

a. Apparent line loss: Voltage loss fluctuates heavily with different load rate especially in 10kV power supply line (ChaLang Transformer is at the beginning of 10kV power line while DeAng Transformer is at the end)

b. Low natural power factor(About 0.74):Due to the distribution parameters' influence on the transmission line, the capacitive current is large which cause low power factor in the natural state.

Table 1 Data from Guoluo State, Dari County's grid

Load rate	Substations Name	Measured Generatrix Voltage(kV)		Natural Power Factor
30%	ChaLang Transformer	110kV	115.82	0.751
		35kV	36.59	
		10kV	10.52	
	DeAng Transformer	10kV	8.99	
		0.4kV	0.339	
50%	ChaLang Transformer	110kV	115.54	0.739
		35kV	36.48	
		10kV	10.48	
	DeAng Transformer	10kV	7.43	
		0.4kV	0.275	

3. SYSTEM DESCRIPTION

3.1 Whole design

Based on the major characteristics of long-distance transmission system in sparse area mentioned above, the whole structure of the system described in this paper is shown in Figure 1. It is obviously different from the traditional distribution network planning concepts and methods which may extend the power supply radius only by changing the cross-sectional area of the transmission line or increase voltage level alone. The techniques proposed in this paper is a novel power supply radius extension scheme which truly reflects the concept of flexible AC transmission. This new FACTS device combines the functions of dynamic voltage regulation and unified power quality compensation together in one system which can be configured flexibly according to the mathematical model of full line minimum loss. Different from the Unified Power Flow Controller (UPFC) device, this system is composed of two parallel power electronic subsystems so that voltage regulating and power quality unified compensation can be completed in parallel without complicated coordination algorithms. Thus, the real-time control efficiency can be higher.

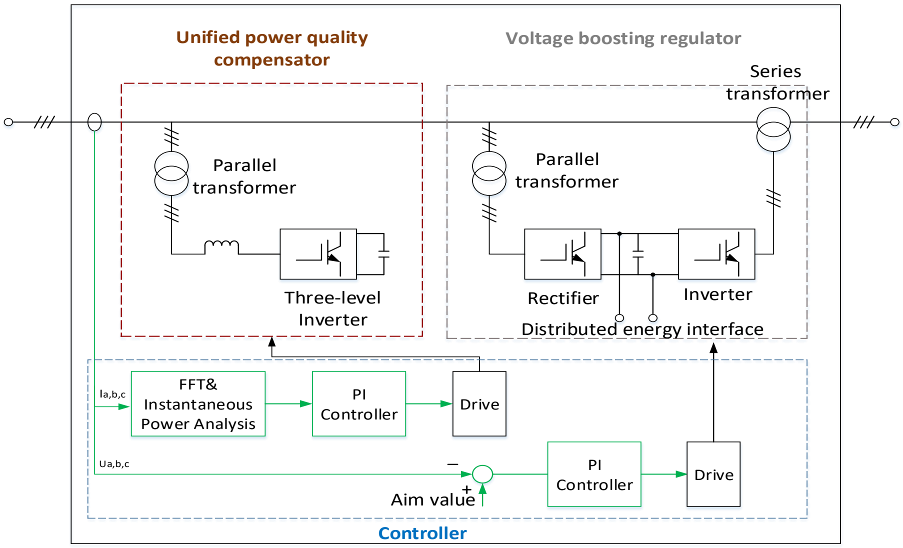


Fig 1 Structure of whole system

3.2 Key technologies and control strategies

3.2.1 Voltage boosting regulator

Dynamic voltage regulating technique based on same phase compensation method is used to boost voltage in the system. The compensation voltage amplitude is obtained by subtracting the measured value from the target voltage value and the phase angle can also be figured out by PLL. The aim voltage waveform can be generated by controlling the dc-ac converter using SVPWM modulation technique. The source of this dynamic voltage regulator mainly comes from the power gird which can offer a wide range of voltage regulating (about 50%). We also design several distributed energy interfaces shown in Fig2 to let wind and solar energy have access to the grid, which is regarded as the important features of smart grid and can take great advantages of the climate of these western regions.

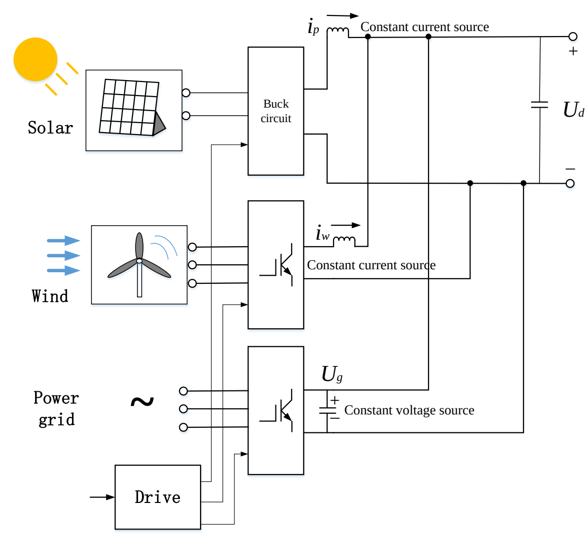


Fig 2 Distributed interface of voltage boosting regulator

3.2.2 Unified power quality compensation

The circuit of unified power quality compensation subsystem can be seen from Figure 3. The unified power quality compensator uses instantaneous power method and fast Fourier analysis to figure out the negative sequence current, zero sequence current, and 19th or lower harmonic current of transmission line. These undesirable current components are synthesized into a current waveform which is regarded as the aim current waveform after rotated by 180° . Based on the principles of active compensation, the SVPWM modulation technique is used to control the inverter generating the aim current waveform on the primary side of the compensation transformer. Thus, the secondary side can inject the aim current to the transmission line which achieves the goal of solving three-phase unbalance, eliminating the higher harmonics, and improving the power factor, thereby improving the power quality.

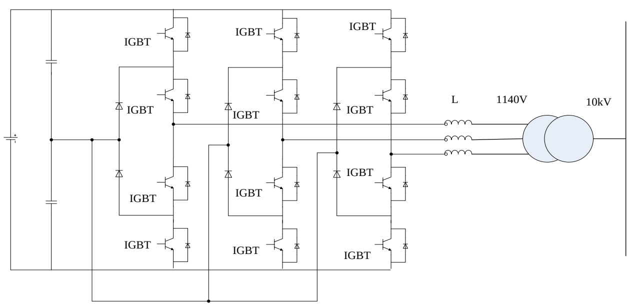


Fig 3 Topological structure of the unified power quality compensation subsystem

4. RESULTS

4.1 Quantitative and qualitive analysis of voltage loss

In order to tell the differences of supply capabilities between the new power supply scheme and the traditional supply scheme more precisely and intuitively, a mathematical model of voltage loss is developed by MATLAB. We suppose that the load (P=3MW,Q=0.3MW) is under extreme condition (all at the end of the line), the length of the supply radium is 200km and the type of the line is LGJ-120(R=0.27+j0.335Ω/km), the quantitative analysis results can be seen from Table 2.

It can be figured out that under the same voltage level, we can transport 3MW of electricity to the place 200km away using the new technology with a small loss easily rather than lift the voltage level to 110kV. This new device can be configured flexibly according to the different load conditions which can extend the supply radium of the line as well as ensure the qualified voltage and least loss.

4.2 Simulation result

Table 2 Contrast between traditional and new scheme (Under extrem load condition)

<table>
<tr><td>Voltage level(kV)</td><td colspan="2">U_{loss} Voltage loss(kV)</td><td colspan="2">P_{loss} Active power loss(kW)</td><td>Meet the demand(voltage drop ≤5%)</td></tr>
<tr><td colspan="6">Traditional supply mode</td></tr>
<tr><td>10</td><td colspan="2">85.521</td><td colspan="2">4908.6</td><td>No</td></tr>
<tr><td>35</td><td colspan="2">6.7728</td><td colspan="2">400.7</td><td>No</td></tr>
<tr><td>110</td><td colspan="2">1.7060</td><td colspan="2">40.567</td><td>Yes</td></tr>
<tr><td colspan="6">Novel supply mode</td></tr>
<tr><td>Voltage level(kV)</td><td colspan="2">Distance between two devices(km)</td><td>U_{loss} Voltage loss(kV)</td><td>P_{loss} Active power loss(kW)</td><td>Meet the demand(voltage drop ≤5%)</td></tr>
<tr><td>10</td><td colspan="2">20</td><td>1.77</td><td>4408.2</td><td>No</td></tr>
<tr><td>10</td><td colspan="2">6</td><td>0.4832</td><td>4408.2</td><td>Yes</td></tr>
<tr><td>35</td><td colspan="2">40</td><td>0.85995</td><td>327.88</td><td>Yes</td></tr>
</table>

Before field-tests in Guoluo state, the model was simulated by Simulink. Part of the result can be seen from Figure 4. We suppose that the voltage has fall to 9.9kV so a compensation voltage of 600V is generated to life the segment voltage to 10.5kV.

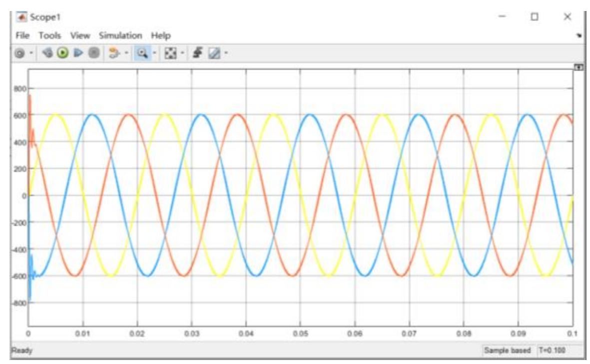


Fig 4 Aim voltage curve generated by dc-ac converter

Fig 5 Field-tests in GuoLuo State

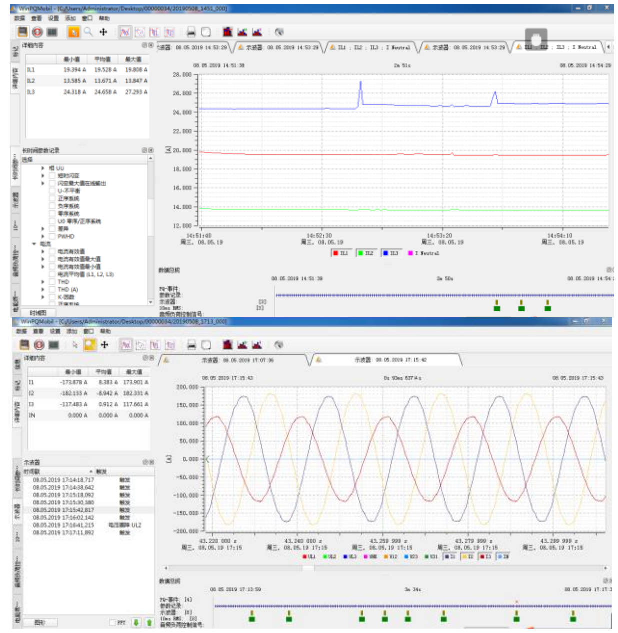
4.3 Field-tests in Guoluo state

To further confirm the effectiveness of this new scheme, based on the simulation result, we carry out field tests in Guoluo state on 10kV transmission line Da three road, seen from Figure 5. The source of the device only from the power grid. The results can be seen from Table 3. Compared with Table1, it is obvious that after using this new scheme, the voltage fall has been compensated to aim value and the power factor has also been improved to above 0.95.

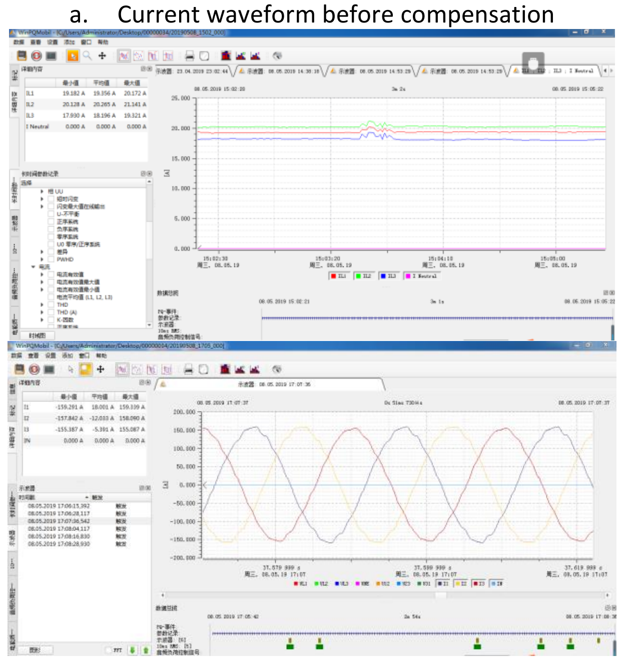
Table 3 Data from Guoluo State, Dari County's grid (after compensation)

Load rate	Substations Name	Measured Generatrix Voltage(kV)		Natural Power Factor
30%	ChaLang Transformer	110kV	116.12	0.976
		35kV	36.74	
		10kV	10.57	
	DeAng Transformer	10kV	10.50	
		0.4kV	0.397	
50%	ChaLang Transformer	110kV	116.12	0.972
		35kV	36.75	
		10kV	10.57	
	DeAng Transformer	10kV	10.31	
		0.4kV	0.387	

The current waveform before and after compensation can be seen from Figure 6. It is obvious that the current quality has been compensated to standard sine wave after compensation.



a. Current waveform before compensation



b. Current waveform after compensation

Fig6 Comparision of current waveform

5. CONCLUSION

This paper proposes a new scheme to extend power supply radium in western sparse area. The simulation results and filed-tests in Guoluo state both show obvious effects in lifting voltage and improving power factor (to above 0.95). But how to make full use of the climatic characteristics of the western region remains further study. But without any doubt that this new scheme truly embodies the idea of flexible ac transmission and its high reliability and economy contribute to the construction of smart grid in western China.

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