Analysis on the Operation of 750kV Controllable Shunt Reactor in Gansu Power Grid of China

Rong Xiaoyun[1,2], Shao Chong[3,4], Wang Weizhou[3], Hou Yanpeng[4], Liu Fuchao[3], Jia Cunxi[4] and Li Zhengyuan[3]

[1]*North China Electric Power University, Zhuxinzhuang, Dewai, Beijing, China*
[2]*The University of Edinburgh, School of Engineering, The King's Buildings,Edinburgh, U.K.*
[3]*Gansu Electric Power Research Institute, Qilihe District, Lanzhou, P.R. China*
[4]*Gansu Electric Power Maintenance Company, Anning District, Lanzhou, P.R. China*

Keywords: Controllable Shunt Reactor, 750kV Super-high Voltage Grid, Operation, Wind Power.

Abstract: Super High Voltage is the efficient way to achieve low power losses in long distance power transmission, but power frequency overvoltage and secondary current still exist. In order to improve the stability of the system, high voltage controllable shunt reactor (CSR) is added to the system. This thesis was based on the large amount of data about the 750kV controllable shunt reactor operated in the 750kV substation of Dunhuang, which is the first CSR applied in 750kV super-high voltage grid in China. The relationship between the variation of the voltage and the switching on/off of CSR was analized, the actual impacts of the CSR on the reactive power distribution and the active power loss were studied. Furthermore, a certain theory basis for the CSR maintenance was provided.

1 INTRODUCTION

Northwest of China is rich in wind power, a 10GW wind farm has being developed. In order to transmit and transform the large scale wind power, two 750kV super high voltage transmission lines have been constructed. Because of the long distance transmission of large scale power and the dramatic intermittency and unpredictability of wind power, the reactive power balance and voltage control problem of the grid became prominent (Wang, 2009).

As the controllable shunt reactor (CSR) can adjust reactive power of the system flexibly, inhibit overvoltage and secondary arc current, reduce network loss (IEEE Standard Requirements, 2008), improve the stability and the delivery capacity of the system (Belyaev and Smolovik, 2005), it becomes the first choice to solve the problems relating to the large scale wind power integration from long distance in Northwest China, especially in Jiuquan, Gansu (Pan et al., 2007). In November, 2011, the 750kV CSR, which has the highest operating voltage in the world, self-developed by China, was successfully put into comercial operation in Dunhuang substation of Jiuquan (Liu et al., 2012). The map of the position of Dunhuang and Jiuquan is as shown in Figure 1, marked with read circle.

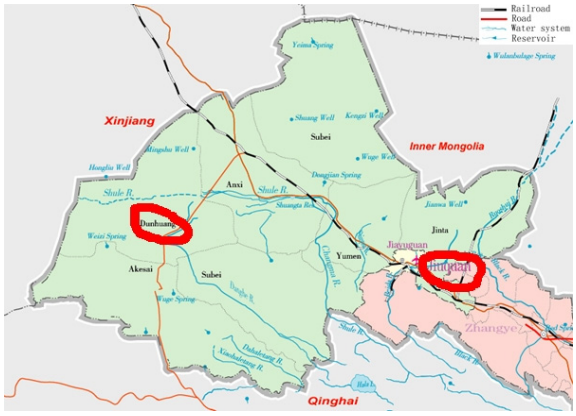

Figure 1: Map of Dunhuang and Jiuquan.

It has solved the reactive power and voltage fluctuation of the 750kV Dunhuang substation effectively, and improved the utilization rate of the 750kV wind power delivery system, as the 750kV Dunhuang substation is one of the main substations with large scale wind power integrated into power

Xiaoyun R., Chong S., Weizhou W., Yanpeng H., Fuchao L., Cunxi J. and Zhengyuan L..
Analysis on the Operation of 750kV Controllable Shunt Reactor in Gansu Power Grid of China.
DOI: 10.5220/0004358801050109
In *Proceedings of the 2nd International Conference on Smart Grids and Green IT Systems* (SMARTGREENS-2013), pages 105-109
ISBN: 978-989-8565-55-6

grid concentratedly (Li et al., 2010).

This thesis was based on 340 sets of data, measured from the related power system when the operation state of CSR in Dunhuang is changed . Later, combined with the actual operation state, the voltage of the 750kV Bus and the reactive power of the system, the operation states and the effectiveness of CSR were analysed, and the advises for operation and maintenance were given.

2 DUNHUANG CSR PROJECT

2.1 CSR Introduction

According to the different constitutions and basic principles, the CSR in the world can be classified into magnetic control CSR and high-impedance transformer CSR (Bryanteev et al., 2006). And according to the different applications, it can be sorted into the bus shunt reactor and the line shunt reactor (Xie and Chen, 2008).

Magnetically controllable shunt reactor has advantages like continuously adjustable reactive power, small and low harmonic component, and economical control system. It is mainly used as bus shunt reactor. But because of low response speed, it is not suitable for line shunt reactor, and can not be used in 750kV wind power delivery system characterised by frequent fluctuation of power (Zhou et al., 2003) .

High-impedance transformer CSR (stepped controllable shunt reactor) always has great losses, high-level harmonics and noises when applied into super high voltage system. Compared with magnetical CSR, high-impedance CSR has simple principle, faster dynamic response speed, easier operation and maintenance. When its control system is in failure, it can operates as fixed reactor (Zhou et al., 2007). The structure principle of the 750kV CSR is as shown in Figure 2. This kind of CSR is appropriate for large scale wind power concentrated integration in Hexi area in Gansu province of China (Li et al., 2010).

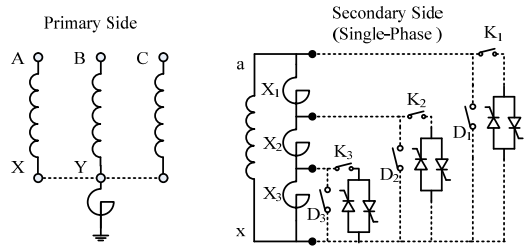

Figure 2: Structure Principle of the 750kV CSR.

2.2 750kV Dunhuang Substation

At present, about 5.5GW wind power as the first-stage construction of JiuQuan super wind power base in Gansu have been integrated into 330kV power system and connected with the 750kV system through seven 330kV booster stations and two 330kV transformer stations. Expected total wind power in 2015 will reach to 1270 million watts[1-3]. At that time, 750kV Dunhuang substation would be rated as the biggest capacity and highest voltage level single substation in the world for the wind power integration, as almost all the wind power of Jiuquan would integrate into its 330kV bus (Zhou et al., 2006).

As wind power fluctuate frequently, the highest voltage of the 750kV bus of the Dunhuang substation had reached 802kV and the lowest 755kV. The voltage and reactive power adjustment of the power grid is very difficult.

In order to enhance the voltage stability, balance reactive power, reduce grid losses, improve the reliability and security of the systems operation, the 300Mvar stepped CSR was developped as the 750kV bus CSR of 750kv Dunhuang substation. The adjustable range is 25%, 50%, 75%, 100% of the nominal capacity (Pan et al., 2007).

2.3 Operational Data of the CSR

This thesis is based on the CSR operational data, collected from 14 January, 2012 to 6 August, 2012, 340 valid sets altogether. Contents mainly included are actuation time, adjustment level, voltage change and the reactive and active power in high and medium voltage side of the primary transformer. For example, at 04:24, 6 August, 2012, the capacity of the CSR was adjusted from 75% to 50% automatically, bus voltage was adjusted from 755kV to 758kV, the active and reactive power in high voltage side of the primary transformer 2 were -735MW and 156Mvar, in medium voltage side were 736MW and 56Mvar. As for primary transformer 3, the active and reactive power in high voltage side were -734MW and 156Mvar, in medium voltage side were 736MW and 57Mvar.

3 DUNHUANG CSR OPERATION STATE ANALYSIS

The voltage level and power capacity of 750kV Dunhuang substation CSR are both the highest in the

world. Its operating environment is really harsh (plateau section, gobi desert). A plentiful operational data has been accumulated, after one-year running. Operational data mining has great practical significance for the improvement of the operation and maintenance performance of this CSR and for the optimal structure designing of other CSR.

3.1 CSR Capacity State Analysis

The adjustment level of CSR illustrates its capacity, operation states and corresponding action of thyristor. The analysis of this sets of data is conducive to the maintenance of CSR.

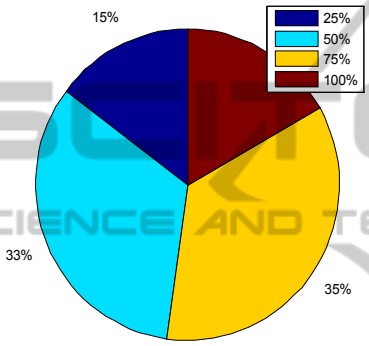

Figure 3: Percentage of Capacity States.

Figure 3 is the percentage of the four different capacity states which is obtained from 340 sets of statistical data. It is obvious that 50% and 75% accounts for the largest percentage, nearly reach to the twice of 25% and 100%. The state that the whole capacity is out of service never shows up.

Figure 3 indicates that the capacity of this CSR was reasonably designed, as more than half of the capacity is utilized. The rated capacity put into operation also happened but in a small proportion.

Figure 3 also shows that the valve bodies which control the 75% and 50% capacity act relatively frequent, so they should be treated as key elements during maintenance. And because 25% capacity is always put into operation, so it also needs more care.

3.2 Analysis of CSR Action Conditions

Figure 4 is derived from the action time statistics of CSR, and it is useful to design maintenance and inspection time.

Figure 4 is the distribution density of the total action times for these four different levels at different period. The action (put or cut) of the CSR mainly occurred between March and July, especially between early May and the end of June.

Taking the weather during this period in Dunhuang as reference, it is clear that the main reason which causes this variation is the wind speed in Dunhuang was really unstable from May to July,, causing grid connection capacity of wind power fluctuated frequently and the varying of voltage and reactive power of system, finally leading to the CSR switching frequently.

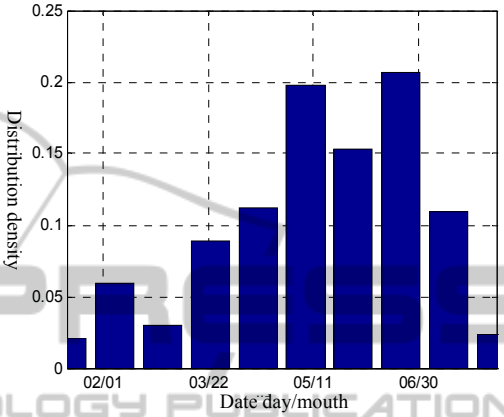

Figure 4: Numbers of Action and it's Time Distribution.

This indicates that the best maintenance time of CSR in Dunhuang is between January and March or May and July. Strengthened inspection of equipment must be done to prevent potential accident which may caused by the frequent switching.

4 CSR IMPACT ON VOLTAGE

The switching of CSR will cause the change of bus voltage.

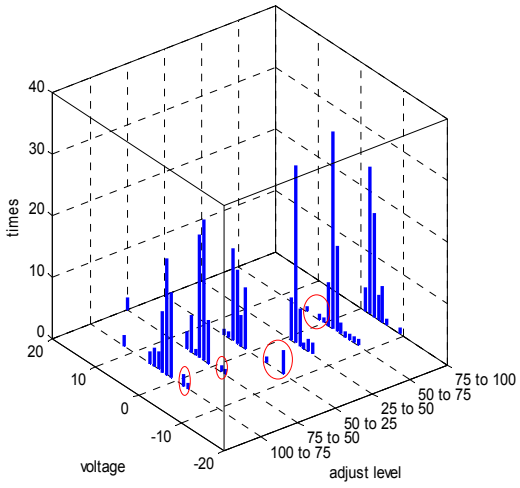

Figure 5: The Influence of CSR Switching on Voltage.

In theory, when CSR level is adjusted from low to high, the reactive capacity increases and the voltage decreases, vice verse. Three dimensional scattering projection diagram 5 is derived from 340 sets of statistic data. This figure reflects the occurrence number of some certain voltage difference caused by the change of capacity.

4.1 Main Impact on Voltage

When the operating capacity of CSR decreases, most of the voltage increases although the amplitude are generally small. Nearly 90% of the voltage differences are concentrated between 1kV and 6kV. Voltage differences reach to 10kV or 20kV also occurred, but most are 2kV. When the operating capacity increases，most of the voltage decreases. Nearly 90% of the voltage drops are concentrated between 1kV and 6kV. Voltage drops reach to 10kV also occurred, but most are 2kV as well. From above, CSR with total capacity of 300Mvar, switching at 75Mvar of each level, do not significantly affects the voltage of 750kV bus, as amplitude of variation always within 1%, tending to nominal value. Through the analysis of the data, putting the CSR into operation and its frequent switching won't influence the operation of 750kV equipment.

4.2 Analysis of Special Circumstances

As stated, after the switching of CSR, some voltage differences are not within 6kV. Two main classes, one is the amplitude of variation bigger than 6kV. For example, within the 340 sets of data, voltage differences (increase) reach to 20kV appeared twice, 12kV appeared twice. Voltage differences (decrease) reach to 9kV appeared once, 8kV appeared once. Although they conform to the theory but are different from normal situation. Another is when the operating capacity increases, bus voltage also increases and when the operating capacity decreases, bus voltage also decreases, opposite to the theory, as shown in Figure 5 within red circles.

In the first situation, increasing 20kV for example, referring to the nearby switching actions and corresponding weather information, wind speed changed rapidly at that time so the grid connection capacity of wind power is bigger. At 14:29, 31/03/2012, the operation capacity of CSR dropped from 100% to75%, causing voltage increase from 756kV to 758kV, 2kV increment. Then at 14:38， 31/03/2012, the operation capacity dropped from 75% to 50%, causing voltage increase from 758kV to 778kV, 20kV increment. This phenomenon appears many times within small period furing 340 sets of data, and always accompanied with large amplitude of voltage variation. This phenomenon indicates that the primary causes of large amplitude of voltage variation after CSR put into operation are the big variation of grid connection capacity of wind power and lacking of CSR switching capacity within one operation time. Introducing short term wind power predicting outcomes into control logic of CSR is a promising method to solve this problem.

In the second situation, the variation of voltage goes against the theory. Firstly, because all the data were recorded manually, so man-made faults won't be eliminated. What's more, another possibility is if wind power changes quite fast, bus voltage fluctuated frequently, so during a small period the voltage increments or decrements caused by the wind power grid connection is bigger than the voltage decrements or increments caused by the switching of the CSR, so the variation of voltage goes against the theory.

5 CONCLUSIONS

CSR is the effective means in solving voltage and reactive power problems of the power grid caused by the large scale wind power integration. This thesis combines with the actual operation states of 300Mvar stepped CSR in Dunhuang 750kV substation of China, analyzed its operating characteristics, summarized the impact of switching actions on bus, the conclusion is as follows:

(1) 300Mvar CSR is sufficient in solving the voltage and reactive power fluctuation problems of the power grid of Dunhuang.
(2) The switching times of CSR is relatively high during the period when wind power fluctuates frequently. It is suggest that maintenance between January and March and strengthened inspection of equipment between May and July be arranged.
(3) The thyristor switching of 50% and 75% capacity act relative frequently and 25% capacity is always put into operation, so they all should be treated as emphasis during the maintenance.
(4) After putting the CSR into operation, the variation of bus voltage is limited nearly within the acceptable range. That means CSR don't have large impact on bus voltage.
(5) As wind power changes with large amplitude and frequently, large amplitude of voltage variation after the variation of CSR capacity may occurred. Introducing short term wind power

predicting outcomes into control logic of CSR is a promising method to solve this problem.

REFERENCES

N. B. Wang, 2009. Challenges and countermeasures of Jiuquan 10 million kilowatts of wind power base in Gansu. *Power System and Clean Energy*. (in Chinese).

IEEE Standard Requirements, 2008. Terminology and Test Code for Shunt Reactors Rated Over 500 kVA. *IEEE Std C57.21-2008*.

A. N. Belyaev, S. V. Smolovik, 2005. Steady-state and transient stability of 500kV long-distance AC transmission lines with magnetically controlled shunt reactors. *IEEE Power Tech Conference*, Russia.

X. Pan, X. L. Ding, M. L. Huang, et al, 2007. Simulation analysis on application of controllable reactors in 750kV Northwest China Power Grid. *Automation of Electric Power Systems*. (in Chinese).

H. E. Liu, H. M. Li, X. Lei, et. al, 2012. Simulation Research on the Stepped Controlled Shunt Reactor Based on PSCAD. *Electric Power Science and Engineering*. (in Chinese).

Z. Q. Li, Z. X. Zhou, D. X. Du, et.al, 2010. Dynamic Simulation of Stepped Controllable Shunt Reactor in Type of EHV/UHV High-Leakage Inductance Transformer. *Power System Technology*. (in Chinese).

A. Bryanteev, V. Dorofeev, M. Zilberman, et al, 2006. Magnetically controlled shunt reactor application for AC HV and EHV transmission lines. *CIGRE*, Paris.

Yan Xie and Baichao Chen, 2008. Applied Research on Controllable Shunt Reactor in Ultra-High Voltage AC Transmission System. *IEEE Electrical Machines and Systems*.

L. W. Zhou, Y. Xu, Q. Zhu, et al., 2003. Type selection analysis and principle of new controllable reactor. *Transformer*. (in Chinese).

Q. Y. Zhou, Q. Guo, G. Q. Bu, et al, 2007. Application of controllable reactors in China's power grid at extra and ultra voltage level. *Proceedings of the CSEE*. (in Chinese).

Ke Li and Zhongdong Yin, 2010. Simulation and Test Study on Module Based Controllable Shunt Reactor. *Power and Energy Engineering Conference*, Asia-Pacific.

Q. Y. Zhou, Q. Guo, Y. C. Feng, et al, 2006. Study on applying high voltage controllable reactors in Northwest China Power Grid. *Power System Technology*. (in Chinese).