Research On the Application of Chain STATCOM Redundancy Technologies in Power Grid

Songshan Hui1, Guangming Yu2, Shuo Yang2, Zhan Zhang2, Jun Ma2

1State Grid Liaoning Electric Power Supply Co., Ltd. Dandong Power Supply Branch, Dandong, Liaoning 118000, China

2Rongxin Power Electronic Co., Ltd., Anshan, Liaoning 114051, China

Abstract

Compared with traditional reactive compensation equipment, STATCOM features complicated structure and numerous components. And STATCOM utilizes multiple redundancy technologies to meet long-term stable operation requirements of power system for the equipments in the substation. This paper introduces the principles of redundancy technologies currently in STATCOM control system and power system, and analyzes its practical application effect.

Keywords: chain STATCOM, redundancy technologies, H bridge power unit

Introduction

Now, STATCOM is ready for large-scale application in domestic LV and MV power transmission and distribution networks. STATCOM is often used in load center substation with fairly higher requirements on stability of the equipment in the substation. Therefore, the designers adopt multiple redundancy technologies to guarantee its long-term stable operation according to the features of STATCOM.

Redundancy design of STATCOM control system

Two master control enclosures A and B are connetced with the switching enclosure in order to ensure that the system can be switched to B in case A fails for stable operation under the control of B.

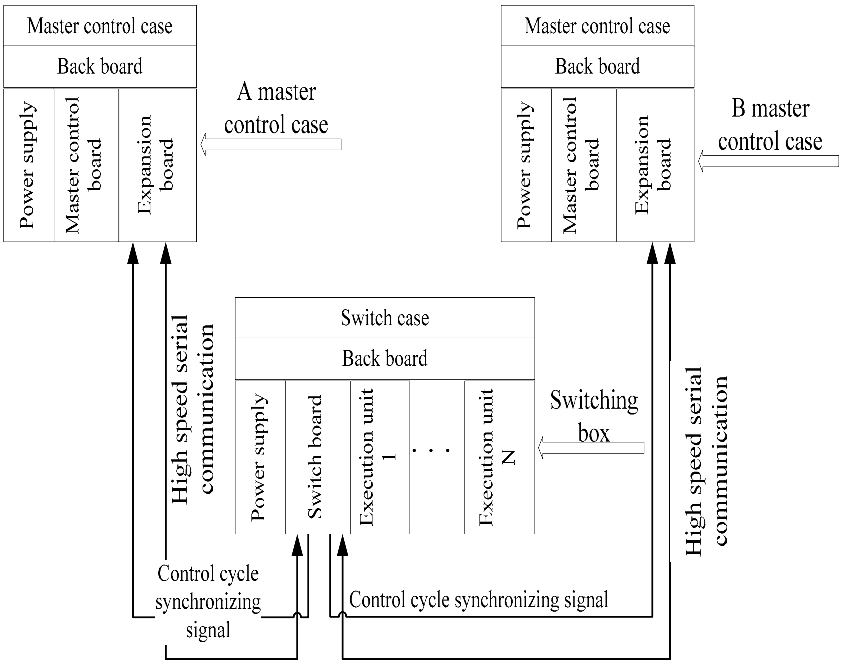


Fig. 1 Redundancy Design Diagram of STATCOM Control System

This design mainly guarantees the reliability of STATCOM control system. Since STATCOM also includes power unit part, specific redundancy design is also required.

Basic features of STATCOM power unit

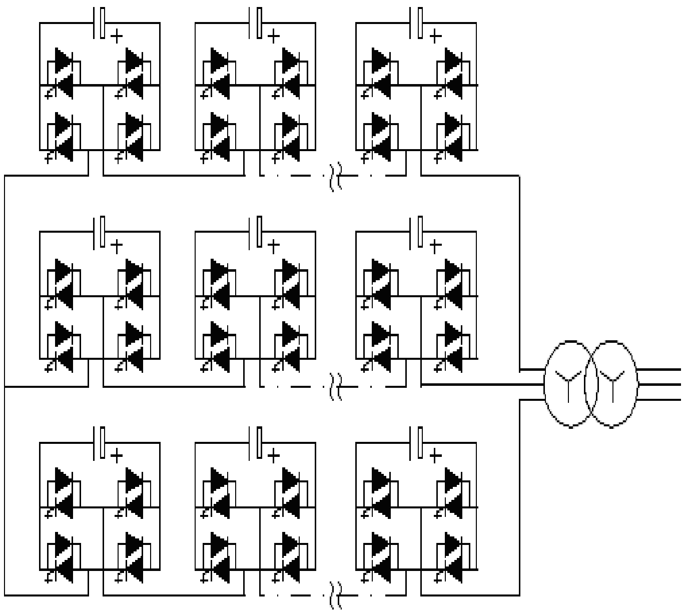


Fig. 2 Structure Diagram of Chain STATCOM Main Circuit

Fig. 2 shows 35kV chain STATCOM device, which adopts angle connection, each phase includes 9 H bridge power units, and each unit requires 2 phase modules.

During operation of STATCOM, phase voltages VA/VB/VC of the converter chain in each phase are the voltage sum of 9 power units in corresponding converter chain respectivel.Assume the conduction angle of each bridge to be $\pi - \beta_i$, i=1-9 respectively. Due to odd symmetry of voltage waveform, the voltage of each bridge is:

$$Vi = \sum_{n=2p+1,p=0}^{+\infty} \frac{4}{\pi} Ed\left[\frac{1}{n}\cos(n\beta_i)\right]\sin(nwt)$$

(1)

Fundamental wave amplitude of phase voltage is:

$$V_{A1} = \frac{4}{\pi} Ed\left[\sum_{i=1}^{9}\cos(\beta_i)\right]$$

(2)

Define the modulation ratio M as the ratio of fundamental wave amplitude of line voltage to the voltage on DC side:

$$M = \frac{U_{AB1}}{Ed} = \frac{\sqrt{3}V_{A1}}{Ed}$$

(3)

Theoretically, nine βs can be calculated from the following system of equations in the principle of preferential elimination, and the 5th, 7th, 11th, 13th, 17th, 19th, 23rd and 25th harmonics can be eliminated.

$$\frac{4\sqrt{3}}{\pi} Ed\left[\sum_{i=1}^{9}\cos(\beta_i)\right] = M \qquad \sum_{i=1}^{9}\cos(n\beta_i) = 0$$, n=5, 7, 11, 13, 17, 19, 23, 25. (4)

Take $\beta_1 = 5°$, and reduce the last limit equation, i.e. give up the restricted conditions of eliminating the 25th harmonic. Use Newton iteration to calculate Mmax=16.67, thus voltage harmonic distortion factor THD=2.85%. When M=16.67, and each angle selects the above-mentioned value, effective line voltage value of the device:

$$V_{AB} = \frac{4\sqrt{3}}{\pi\sqrt{2}} Ed\left[\sum_{i=1}^{9}\cos(\beta_i)\right] = \frac{MEd}{\sqrt{2}}$$

(5)

Then device utilization rate:

$$UTF' = \frac{\sqrt{3}\cdot V_{AB}\cdot I_0}{\frac{EdI_0}{\sqrt{2}\pi}\cdot 108} = 83.99\%$$

(6)

It can be seen that, the device utilization rate is very high when chain structure STATCOM is used. Advantages of such structure include low cost and low loss of the device, and its disadvantage is that once one of the H bridge power units is damaged, and the entire device will stop work. While a high capacity high voltage STATCOM device might contain over one hundred H bridge power units, failure is inevitable. In order to enhance fault resistance of STATCOM, combined redundancy design of H bridge power unit fault bypass device and backup H bridge power is adopted according to the features of STATCOM.

Redundancy design of STATCOM power unit

The power units in STATCOM generally adopt H bridge structure. Fault bypass device is designed according to the features of such structure. The entire bypass device includes contactor KM and thyristors SCR1/SCR2. Contactor KM and two thyristors SCR1/SCR2 are connected in reverse parallel mode, and connected parallelly between two phase module output terminals OUT1 and OUT2 of H bridge power unit, see Fig.3.

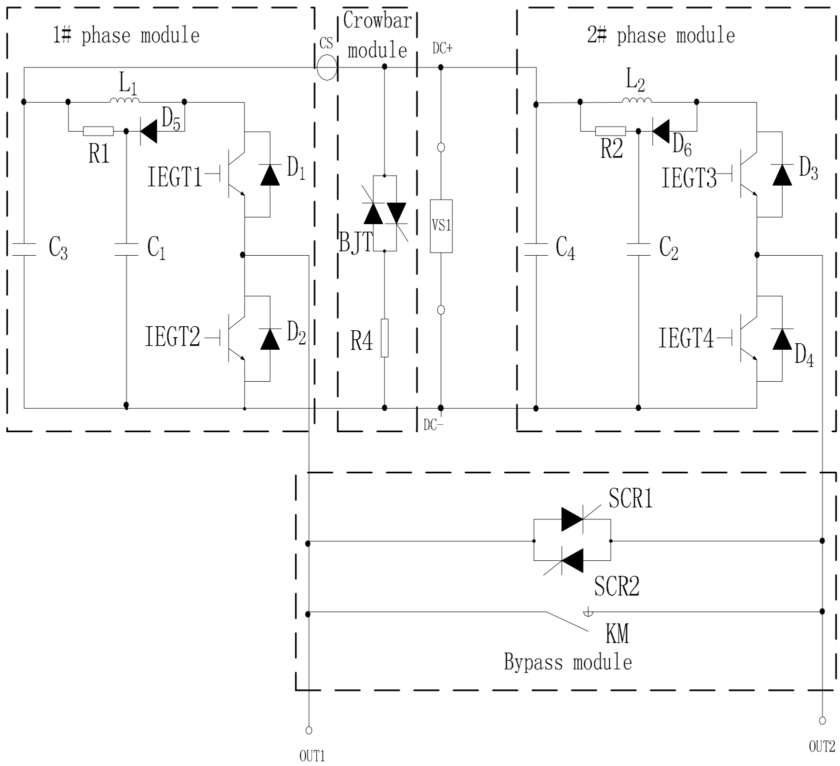
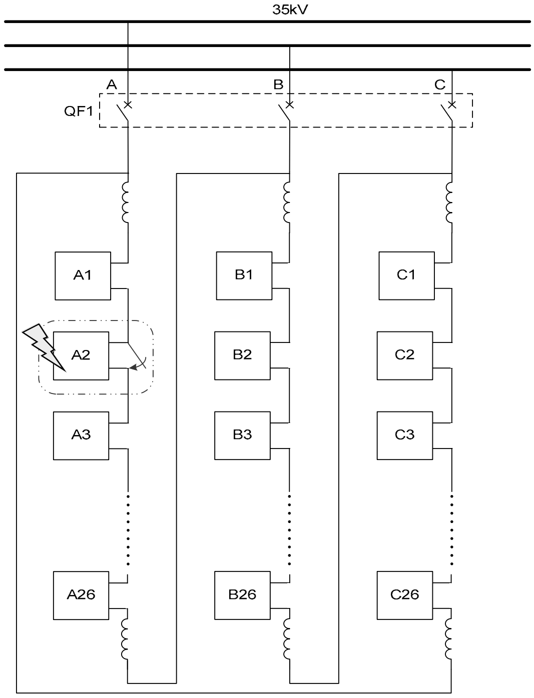
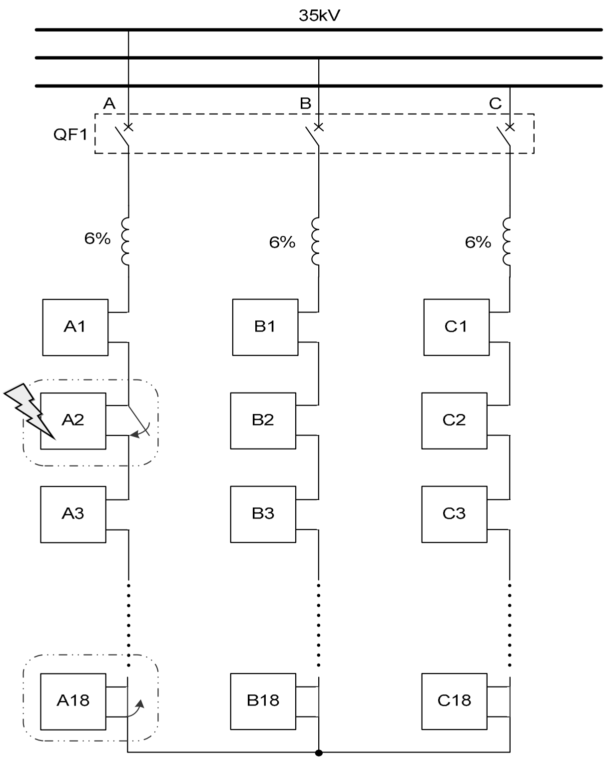


Fig. 3. Electrical Diagram of Single H Bridge Power Unit and Bypass Module

During normal work of H bridge power unit, as shown in Fig.4-a, the electric control contactor corresponding to bypass module is disconnected; in case H bridge power unit fails, the electric control contactor corresponding to bypass module is OFF to cut off the trouble unit from the whole chain.



(a) Direct Bypass Design of Trouble Unit



(b) Design of trouble unit bypass and put-in-operation of standby unit

Fig. 4 Redundancy Design Diagram of STATCOM Power Unit

If the design shown in 4-a is adopted, during normal operation of the equipment, each power unit works as per n/n+1 rated capacity. Once failure occurs, certain trouble unit is bypassed, remaining n units run at rated capacity automatically. Since the capacity of each H bridge power unit is designed according to full capacity of n H bridge units, capacitor voltage on DC side is unchanged before and after the fault. During normal operation of the equipment, utilization rate of DC voltage is not high, yet equipment loss is high. In order to avoid the above-mentioned problems, the design shown in Fig. 4-b can also be adopted, in which a bypass module is connected with each H bridge power unit, and some H bridge power units are provided in each phase for backup purpose. If a normally working H bridge power unit fails, its corresponding bypass module can be used to stop it, while corresponding bypass module can be used to activate the backup H bridge power units.

Conclusion

The use of dual controller redundancy design and power unit redundancy design basically meets basic requirements of power system for long-term continuous operation of STATCOM. The key of dual controller redundancy design is to ensure reliability of the control cycle synchronizing signal, otherwise, it might cause system oscillation in case of switching. Additionally, MAN/AUTO/REMOTE switchover modes should also be available. While direct bypass design of faulty power unit features simple operation and DC voltage utilization rate is not high, the design with trouble unit bypass and standby unit put-in-operation features high DC voltage utilization rate. In this case, the operation is relatively complicated and high reliability of actuator is required.

References

[1] Hirofumi Akagi. Instantneous Power Theory and Applications to Power Conditioning [M]. Wiley-IEEE Press,2007.

[2] Ma Youjie, Gong Jinxia, Zhou Xuesong."STATCOM Parameter Selection and Impact on Voltage Stability", journal of Tianjin University of Technology,2007,23(5):46-48;

[3] S Sirisukprasert, A Q Huang, J S Lai.Modelling Analysis and Control of Cascaded-multilevel Converter-based STATCOM[C]. IEEE-PES General Meeting. 2003,4(7):18-17.

[4] M.Li,Chiasson,J.N.,Tolver,L.M.Capacitor Voltage Control in a Cascaded Multilevel Inverter as a Static Var Generator[J]. IEEE.2007,17(3):1709-1713