THE FIRST DEVELOPED ASVG IN CHINA PUTTING INTO OPERATION IN ZHENGZHOU ELECTRIC POWER SYSTEM

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Abstract: *An overview of a new developed advanced static var generator (ASVG) in China is presented in this paper, also with its designed electrical characteristics and the operating results coinciding with the theoretical analysis. This device has been put into operation in Zhengzhou electric power system since April 1997.*
***Key words**: ASVG, inverter, reactive power*

INTRODUCTION

With the increment of long distance transmission lines of super-high voltage, a new advanced static var generator with short response time is expected to be developed and applied in order to improve the stability limit of power systems, damp low-frequency oscillations, and suppress dynamic over-voltages. Also, shock loads, such as arc furnaces, electric locomotives, rolling mills, large power electronics inverter devices, are being used more and more. This has brought about bad effect on the voltage quality, since these devices absorb much instantaneous reactive power from the system and make the voltage fluctuate. So, a new type reactive compensator with large capacity, short response time and flexible continuous regulation is urgently demanded. Better economic property and higher performance must also be its merits. ASVG is just this new kind of device. Only DC capacitors of small capacity and combining transformers are needed, and reactive power can be generated and regulated continuously by using inverters.

Electric Power Bureau of Henan Province established a group to tackle the key problems in developing ASVG in October 1993. In May, 1994, the Electrical Engineering Dept. of Tsinghua University launched this joint developing project. A ±300kVar ASVG has been formally put into operation in the network since April, 1997 as the first phase of this developing project, and achieved good results. The success of this developing project filled in the gap of our country in FACTS. Following America and Japan, China has been the third country in which ASVG can be developed and also operated. This will exert a great influence on the development and application of power electronics technology in our electric power industry. The associate Minister of Electric Power Industry, Lu Yanchang , praised it to be a large and good project, after he saw the operation of ASVG and understood its operating performance. Then he asked the speed-up of finishing a±20MVar ASVG, and hoped there would be a break through in the theory and industrial application of Flexible AC Transmission System (FACTS). This paper presents an overview of the ±300kVar ASVG and its designed electrical characteristics, such as control laws and protection schemes. Finally, the operating results are also given.

DEVELOPING PROCESS

The±300kVar ASVG is developed by the following process:

1. Studying the basic theory of ASVG, the systematic overview of the device, and the method of developing;
2. Testing the control laws and protection schemes of single bridge ASVG; verifying the theoretical model of ASVG;
3. Making the rated ±300kVar ASVG.

During these steps, the basic theory and the systematic overview of ASVG have both been studied; digital simulations and experiments have also been done as ASVG operated under abnormal conditions, using the control laws and protection schemes. A rated ±300kVar ASVG put into operation in Zhengzhou in April, 1997, after some reforms for industrial product on a prototype which operated successfully in the experimental power plant of Tsinghua University in June, 1996.

OPERATING PRINCIPLE

Fig.1 shows the schematic circuit of the ASVG. The output voltage of ASVG V_1 (i.e. the output voltage of the multiple inverters) is synchronized with the system voltage V_s. The output reactive power can be regulated by controlling V_1 under this condition, that is, when $V_1>V_s$, ASVG will send out capacitance reactive power (the function of capacitors); and when $V_1<V_s$, ASVG will absorb capacitance power (the function of reactors). In fact, not only the magnitude but also the phase of the inverters' output voltage V_1 needs to be controlled, so that the system can make up for its internal losses—the switching losses of inverters and the active power losses of transformers, which makes it possible to keep the voltage of the DC capacitors constant.

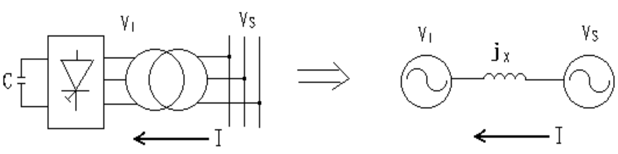

Fig.1. The schematic circuit of ASVG

THE DESIGNED ELECTRICAL CHARACTERISTICS OF THE±300KVAR ASVG

The main circuit of this device mainly consists of 18-pulse GTO voltage source inverters, DC storage capacitors and transformers combining with the system. The whole inverter is made of three 6-pulse inverters, each of which includes three single phase bridge inverters A, B, C. These three inverters are 0°bridge, 20°bridge, 40°bridge respectively, according to the different phase shift relative to the reference system voltage. Every triggering pulse of GTO (gate-turn-off thyristor) is a square wave of 50 Hz, conducting at 180°. In this way, the turning-on time of 18 GTOs on the left arms of the nine single phase bridges can be differ 20°in sequence, and so on the right arms. This configuration makes every GTO bear the same voltage and current, and the harmonics sent out by inverters can be to the minimum. The main circuit of the ±300kVar ASVG is shown in Fig.2.

As capacitors are used to support the voltage of the ±300kVar ASVG at the DC side, the steady-state input power and current are only related to angle δ (i.e. The angle difference between V_1 and V_s), not to angle θ (i.e. the conducting angle of the single phase bridge). So two independent control loops are adopted in the ±300kVar ASVG: one controls the reactive power using inverse nonlinear PI control law, the other controls the voltage of DC capacitors using classical PI control law. Reactive power controlled by δ and the voltage of capacitors controlled by θ is essentially different from the ASVG with constant voltage sources at the DC side. The new inverse nonlinear PI control law has shorter response time than classical PI control law, so it has more potentiality to improve the stability limit of power systems. Its inherent step response time, which is about 21~26ms, is mainly determined by the equivalent inductance and capacitance of the whole device, because the energy stored in the capacitors at the DC side only changes a little.

The protections of the ±300kVar ASVG can be divided into three levels: component protections, device protections and system protections. The main component protections of ASVG are over-voltage protection and over-current protection, including Snubber circuit, crowbar protection, current-loop over-current protection. $\frac{dV}{dt}$ protection and $\frac{di}{dt}$ protection are also very important component protections to ensure that GTO can work safely and reliably. The device protections mainly ensure that when disturbances occur in power systems, ASVG can damp power oscillations, improve the stability of the system while keeping itself safe. The system protections mainly include ASVG main protections and reserved regular line protections.

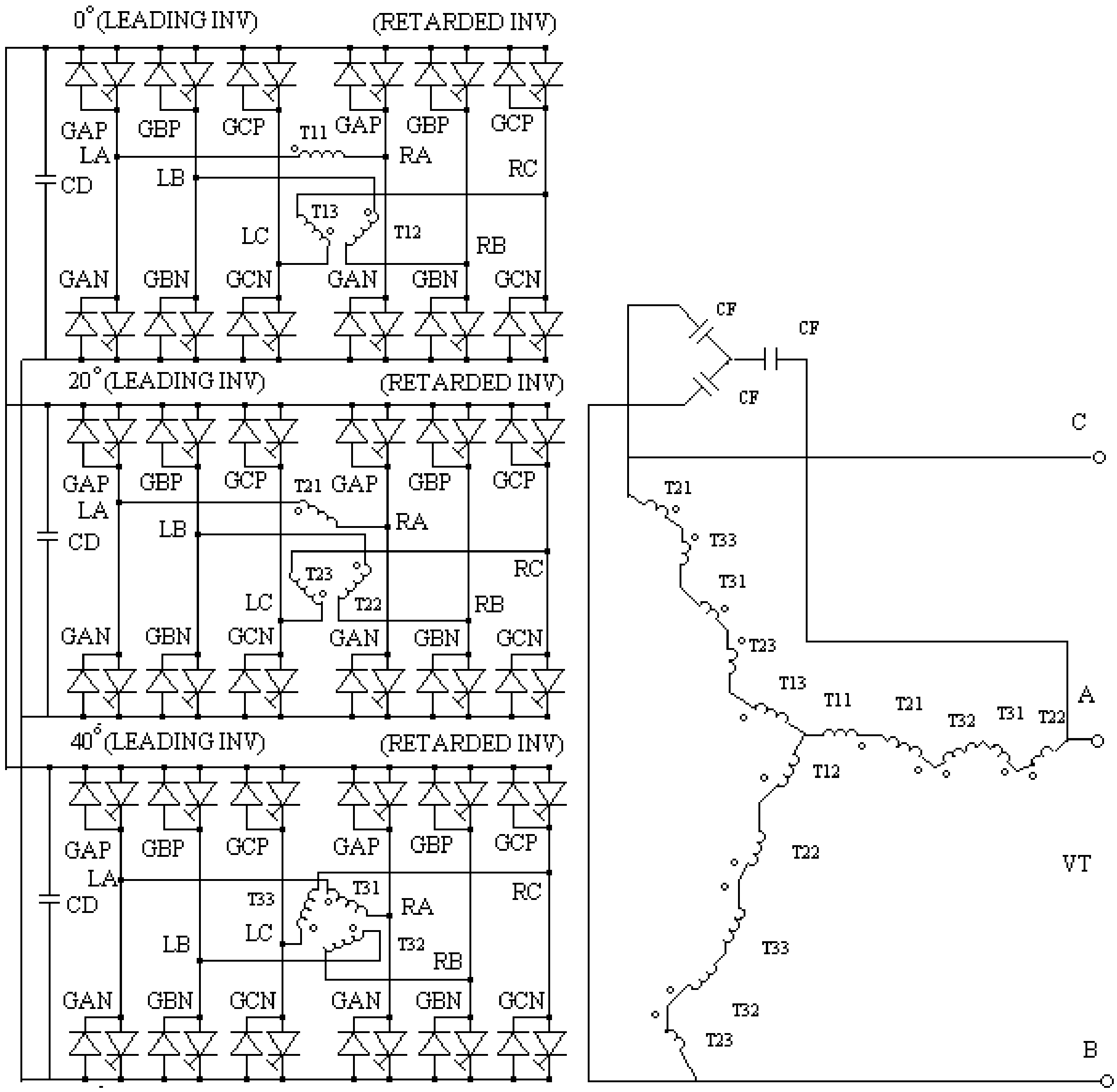

Fig.2. The main circuit of ±300kVar ASVG

RESULTS OF THE ±300KVAR ASVG OPERATION IN THE FIELD

A prototype ±300kVar ASVG has been put into experimental operation in Mengzhai substation of Zhengzhou Electric Power Bureau since April, 1997. Many performances of this device have been tested and perfected from then on. For examples, the active power losses are less than 8% in full-load conditions; the degree of the unbalance output voltage is 1.3% in no-load conditions; a long term operating is permitted when overload current is 10%; a short term operating for 30s is allowed when there is 20% overload current. It can also operate normally in the synchronizing voltage frequency range 49.2Hz to 51.3Hz. When there is a sudden decrease in reactive power of 225kVar, its dynamic response performances are delay time—10.5ms; rise time—14.5ms; peak time—27.5ms; regulating time—80ms[1]. All the situations proposed can illustrate that the ±300kVar ASVG has entered the practical application stage.

CONCLUSION

Electric Power Bureau of Henan Province and Tsinghua University have successfully developed a±300kVar ASVG, which has filled in the gap in this field of our country. The operating results in the field have proved its practical application. This success has established a good foundation for both the development of ASVG with larger capacity in the future and the further application of FACTS technology.

REFERENCES

[1] Zunyi Liu, etc. The characteristic harmonics analysis of the advanced static var generator. Journal of China Electric Power, Jan. 1998