〈General Thesis〉

Development of Wide Capacity Range Static Var Compensator (SVC)

Static var compensator, Voltage stability

Yoshinobu Ueda, Takashi Sugiyama,
Hiroshi Zaitsu, Yosuke Yatsuhashi

Abstract

The Static Var Compensator (SVC) is widely used as a measure against voltage fluctuations by load variations. In particular, there is a strong demand of SVC in an area where a power grid system is weak, like at the end of a power distribution system.

The required capacity of SVC is greatly varied by the system impedance and load variations. In commercializing the SVC, it was difficult to determine capacity series.

Against such background, we have produced a high-speed var-command Arithmetic/Logic Unit (ALU). By combining this ALU with our multi-functional active filter, we realized an SVC that can meet the various capacity levels.

1. Preface

When there is a load fluctuation by such a factor as a motor start-up voltage, fluctuation occurs due to the effect of system impedance and load currents. Since excessive voltage fluctuation can cause flickering in lighting or electrical facility malfunction, some adequate measures have to be taken. In particular, this would be the case at an area where the power grid is weak, like at the end of a power distribution system. In addition, the photovoltaic power generation and wind power generation have recently been widely employed in Japan.

Such distributed power sources can cause output variations with changes in weather conditions and they can result in voltage fluctuations. Therefore, taking measures against voltage fluctuations due to distributed power sources became a new challenge. As a solution, there are some direct methods such as reinforcement of the power grid (reduction of system impedance) and suppression of load variations (adoption of variable speed drives for induction motors, parallel installation of batteries to photovoltaic and wind power generation, etc.). In addition, measure by Static Var Compensator (SVC) is a solution widely-used.

However, the required capacity of SVC is greatly changed by the system impedance and load variations. In commercializing SVCs, it had been a challenge to determine the suitable capacity range series. We have produced an SVC that is applicable to a variety of capacities through the combination of a multi-functional Active Filter (AF) that can generate Volt-Ampere Reactive (VAR) output and the newly developed high-speed VAR-command ALU.

2. Configuration of the SVC

The SVC is composed of an output control unit (VAR-command ALU) computing VAR output commands, inverter blocks (INVs) with individual controllers which generate reactive power upon receiving commands from the output control unit, and an interconnection transformer. Fig. 1 shows a configuration diagram of the SVC. We use the INVs and the interconnection transformer which were originally designed for the AF. A single INV unit belongs to a capacity series of 50kVA to 750kVA Max. Since a single interconnection transformer can be connected with a maximum of 4 INV units, it is possible to configure a maximum 3MVA SVC

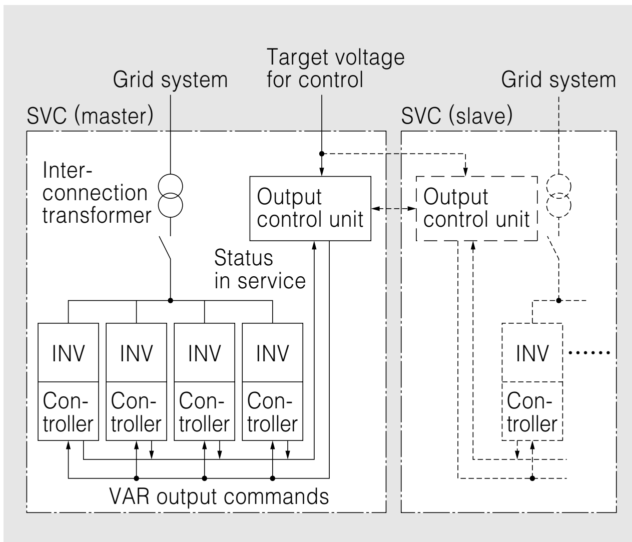

Fig. 1 SVC Configuration Diagram
The SVC is composed of the output control unit computing VAR output commands, inverters INV 1-4 with individual controllers, and an interconnection transformer. Two SVC units can be used for master-slave operation.

unit. If an SVC with a larger capacity is needed, two 3MVA SVC units may be combined to manage master-slave operation; it can generate maximum 6MVA. Because an output control unit is separated from individual controllers, the SVC capacity range can be increased only by changing a parameter at the output control unit when INV capacity range is changed for the AF in the future. This is a feature of this product.

Fig. 2 shows a control block diagram of the output control unit. Voltage control by the output control unit is realized by adjusting the VAR command with the use of Proportional Integral (PI) so that a system voltage (target point for control) can coincide with the target voltage, which is retained internally. At that time, the control mode can be either the target-voltage constant mode or the target-voltage floating mode. The former uses a fixed setup value for the target voltage, while the latter compensates only for sharp voltage fluctuations by changing the target voltage according to moderate variations in system voltage.

In consideration of the number of INV units currently in service, the output control unit installed on master side generates VAR command outputs to the respective INV units. Receiving the VAR command outputs from the master machine, the output control unit installed on slave side transfers these outputs to its own INV units. The slave machine is identified as a slave if the master machine is already present at the time of equipment start. It is automatically switched over to be a master machine if the master machine is not present then. For this reason, there is no need for any setup changes even when only a single SVC unit is operated in the middle of shutdown for inspection services.

Detection of the target control voltage is based on AC instantaneous voltage waveforms. Through high-speed conversion into rms values in the output control unit, exchange of VAR command values is carried out by high-speed transducers between master/slave output control units and between the output control unit and each INV unit. In so doing, we managed to produce high-speed control.

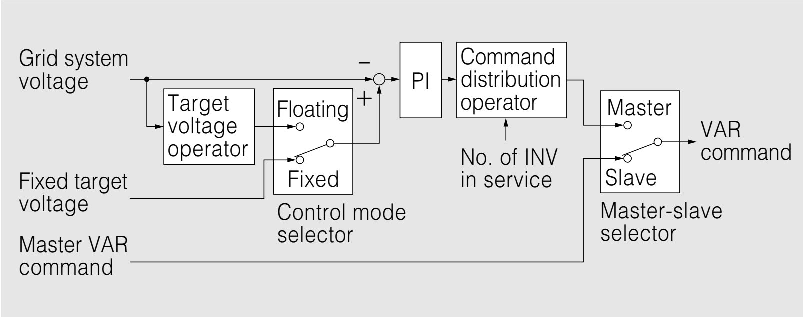

Fig. 2 SVC Control Block Diagram

In master operation, VAR commands are computed by PI control so that the grid system voltage (control target) can coincide with the target voltage. In slave operation, var output follows commands from the master.

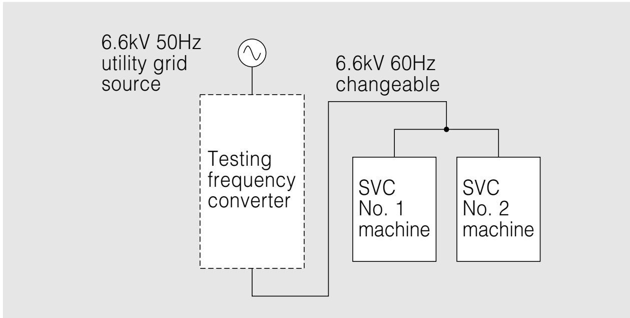

Fig. 3 SVC Testing Circuit Diagram

Two SVC units were connected and a frequency converter was used as a 60Hz changeable source.

3. Shop Test Results

A series of operation tests was carried out on two 6.6kV 2MVA SVC units. Each 2MVA SVC unit consists of three 667kVA INV units. Fig. 3 shows the SVC testing circuit diagram. In most cases, the frequency converter is used for 60Hz equipment test. Output voltage is kept constant by the Automatic Voltage Regulator (AVR).

In the case of SVC testing, however, the AVR is put off no matter if it is 50Hz or 60Hz in order to simulate the SVC-applied condition, like in the case of an end of power distribution system. The voltage then fluctuates in line with the load variations.

The response characteristics of an SVC No. 1 unit were verified first. The SVC No. 2 was used as a dummy load and a voltage dip was generated by changing the VAR manually. Fig. 4 shows the result of voltage dip compensation by SVC No. 1 under the target-voltage floating mode. Fig. 4 (a) shows overall waveforms of operational data obtained from testing. The waveform on the second tier from above shows the rms values of the grid system voltage. When SVC No. 2 generated a VAR power, voltage lowered momentarily (see 4th tier from above, as it worked as a reactor load). Soon after that, SVC No. 1 generated an output and the original voltage was recovered (see 3rd tier from above). After that, SVC No. 1 output was gradually reduced and voltage was also lowered in proportion; this was because SVC units were working in the target-voltage floating mode.

Fig. 4 (b) shows an enlarged voltage waveform of rms values obtained at an instance of load fluctuations (output variations in SVC No. 2 machine). In this diagram, the SVC working time was based on the voltage before the occurrence of fluctuations and showed the time from the occurrence of a deviation from ±3% until it returned to the designated voltage range. As a result of testing, we confirmed that there is ample margin in the target value of 32ms because actual working time was 16.1ms.

Next, we evaluated the compensation characteristics using two SVC units. We suddenly changed the

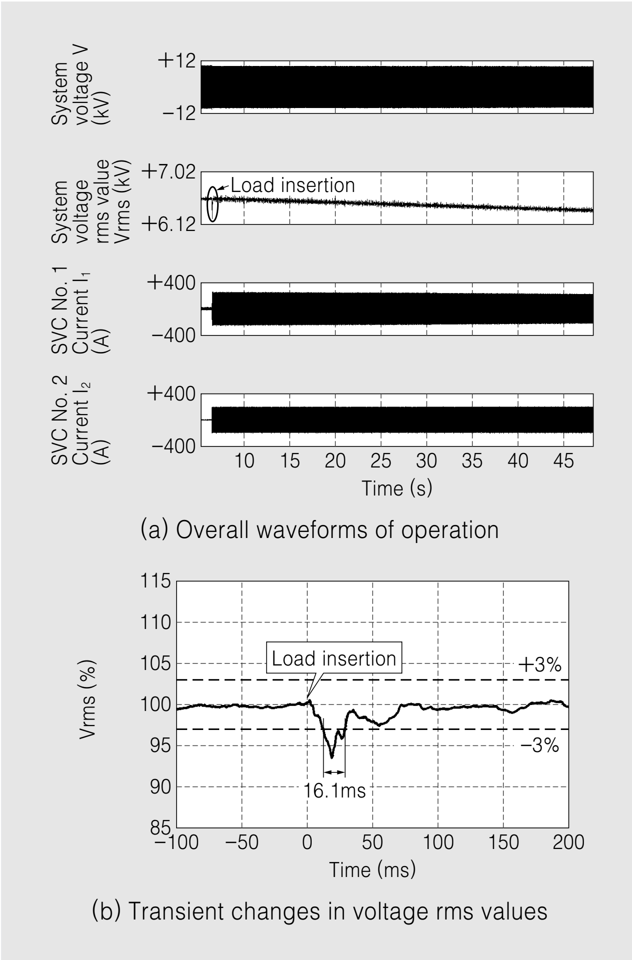

Fig. 4 Result of SVC Unit Response Test
The test result of load variations in SVC No. 1 machine is shown. (a) shows overall waveforms of operation and (b) shows transient changes in voltage rms values observed when load variations occurred.

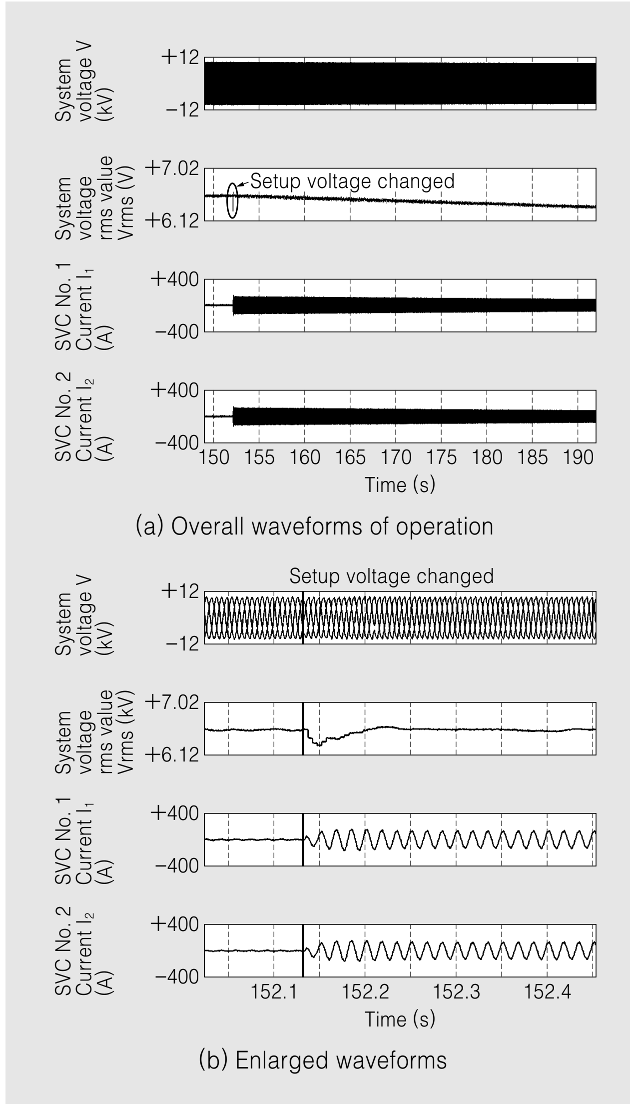

Fig. 5 Result of SVC Master-Slave Operation Test
This shows the result of operation test on source voltage fluctuations during master-slave operation: (a) shows overall waveforms of operation and (b) shows enlarged waveforms observed when source voltage fluctuations occurred.

output voltage setup value of a frequency converter in 10% and evaluated the performance of master-slave operation. Fig. 5 shows the test result under the condition when SVC No. 1 was a master machine and SVC No. 2 was a slave machine. Fig. 5 (a) shows overall waveforms of operation during the test. The voltage rms value lowered in a moment when we suddenly changed the output setup voltage of the frequency converter; however, this voltage was soon recovered to its original level while the SVC No. 1 and No. 2 machines generated reactive power. After that, outputs from the two SVC units were gradually reduced and voltage was lowered also.

Fig. 5 (b) shows the enlarged waveforms observed in a moment when voltage fluctuations occurred (output setup voltage of frequency converter changed). It is understandable that the slave machine, SVC No. 2, started var compensation with almost no delay following the master machine, SVC No. 1. Since the conditions for the occurrence of voltage fluctuations were different, it was impossible to make a simple comparison with operation of an independent machine. In master-slave operation, however, the measured operation time was 8.0ms and this figure verifies that there was an ample margin to the target time of 32ms.

4. Postscript

Through the combination of existing AF and newly developed output control units, we developed high-performance SVC units applicable to a wide capacity range of 50kVA to 6MVA. We have already manufactured and shipped 2MVA × 2 systems and a single 1MVA system.

In the future, we plan to release these systems as voltage security equipment for power distribution systems.