

# Relocation of SVC from Shin-Shinano substation to Suruga substation

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**Abstract--** This paper reports on the successful relocation and reconstruction of an existing Static Var Compensator (SVC). In 1987, for experimental test purposes, an SVC with a controlled rating of 100 MVAR was installed in the Shin-Shinano 50 Hz–60 Hz frequency converter (FC) substation, on the 50 Hz, 500 kV side, to help control the voltage of the transmission network. Certain components of this test SVC were removed from service and returned to the factory to customize the design to meet the requirements of a new application, and to update and modify the equipment to meet the latest commercial operating requirements. This reconstructed SVC was installed in the Suruga substation, on the 154 kV side. In 2001, the SVC was successfully tested to verify its correct operation and application.

**Index Terms—** Static VAR compensator, Refurbishment, Relocation

## I. INTRODUCTION

Although Japan is not a large country, it has two transmission system operating frequencies, 50 Hz in the eastern half and 60 Hz in the western half. Therefore, in order to exchange electrical power between these two areas, frequency converter stations (FC) are required. Today, there are three (3) frequency converter stations in operation near Tokyo. Tokyo Electric Power Co. operates two frequency converters (No.1 FC & No. 2 FC) in the Shin-Shinano substation, and the Electric Power Development Co., Ltd. operates one frequency converter in the Sakuma converter station. Each FC has a bi-directional transfer capacity of 300 MW, for a total transfer capacity of 900 MW of electric power.

Due to increased demand for electric power transfer between the 50 Hz-60 Hz areas, Chubu Electric Power Co., Inc. has built an additional 300 MW FC at the Higashishimizu substation. This FC connects the 60 Hz system (275kV system) of Chubu Electric Power, and 50 Hz system (154kV

system) of Tokyo Electric Power. Since the 154 kV electrical system is weak, the 50Hz side can experience large voltage variations due to the operation of FC. In order to control these voltage changes, it was determined that an SVC with a controlled rating of 100 MVAR was needed in the Tokyo Electric Power's Suruga substation located near the Higashishimizu substation. In April, 1987, applied to 500kV system for the first time in Japan, an SVC was applied to the 500kV side of Tokyo Electric Power's Shin-Shinano substation, and a test operation period was initiated. The Compensator rating was 20 MVAR inductive to 80 MVAR capacitive with a controlled swing range of 100MVAR [1]. The primary function of this SVC was to control the 275kV or 500kV system voltage. The experimental purpose of this SVC was to check various control functions, the apparatus design technique, the tolerance, etc. The very successful test results of this project led to the installation of three additional SVCs, for 500kV system voltage control in Tokyo Electric Power's Shin-Tama, Shin-Tokorozawa, and Shin-Koga substations, in 1988.

By this time, the Shin-Shinano SVC had finished its test period; but it was kept in intact, in the substation. At about the same time, the requirement for installing an SVC in the Suruga substation, with a controlled rating of 100 MVAR occurred. Because the controlled MVAR ratings were similar, it was decided to reduce the cost of installing a new SVC, at the Suruga substation, by utilizing many of the components of the existing SVC located at the Shin-Shinano substation, which was no longer needed. However, the Shin-Shinano SVC was built as a test system and not a commercial system. Therefore, it was necessary to upgrade and reconstruct several of the existing SVC components to allow them to meet the existing difficult commercial component design requirements. The remainder of this paper discusses the design changes necessary to meet the commercial design requirements and how this project was completed.

## II. PURPOSE OF THE RELOCATION

As previously mentioned, since the 50Hz-154kV system is comparatively weak, the operation of the Higashishimizu frequency converter may cause large voltage variations. This may have an undesirable effect on certain electrical power consumers, particularly during the following operating scenarios:

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- (1) Phase shift operation for commutation failure prevention
- (2) A capacitor bank connected (switched) to the electric power system
- (3) Emergency electric power transfer between 50Hz and 60Hz (when carrying out full electric power operations from zero in about 10 cycles)

Due to these operating cases, the installation of an SVC in the Suruga substation near the Higashishimizu FC, was required. The relocation of the existing SVC installed in the Shin-Shinano substation was considered for the following reasons:

- (1) The Shin-Shinano SVC was a test project, the tests were successfully completed and its continued need at this location was no longer required.
- (2) The required controlled MVar capacity of the Suruga SVC was 100MVar, and this was the same as that of the existing Shin-Shinano SVC.
- (3) The requirement for an SVC at Suruga substation to accompany the Higashishimizu frequency converter installation materialized in 1993. Since, the Shin-Shinano SVC was not needed anymore and only six years had passed since its initial installation, it was decided to re-use the unit at the Suruga substation.
- (4) Although the Shin-Shinano SVC was built to test equipment requirements, it was determined that it could be upgraded to commercial equipment requirements through some reconstruction, change, and the introduction of a control protection panel equivalent to the present commercial equipment.
- (5) A large cost saving was expected by modifying the existing components, rather than manufacturing completely new SVC equipment.

In particular, the large cost savings was determined to be the main factor in the decision to relocate the Shin-Shinano SVC to the Suruga substation, even if some reconstruction and modifications were required.

### III. COMPARISON OF SHIN-SHINANO SVC AND SURUGA SVC

A single line diagram of the Shin-Shinano SVC is shown in Fig. 1, and a single line diagram of Suruga SVC is shown in Fig. 2. In addition, a comparison of the system ratings and the main apparatus specifications are summarized in Table 1. The main differences in the main circuit composition between the two items is shown below:

- (1) The fixed capacitor bank connection to the transmission system is different. At Shin-Shinano, it is connected in the primary of the SVC coupling transformer; at Suruga it is connected to the secondary of the SVC coupling transformer.
- (2) The bus voltage for control is different. At Shin-Shinano it is the 275kV or 500kV bus and at Suruga it is the 154kV bus.

These will also require a protection relay arrangement change.

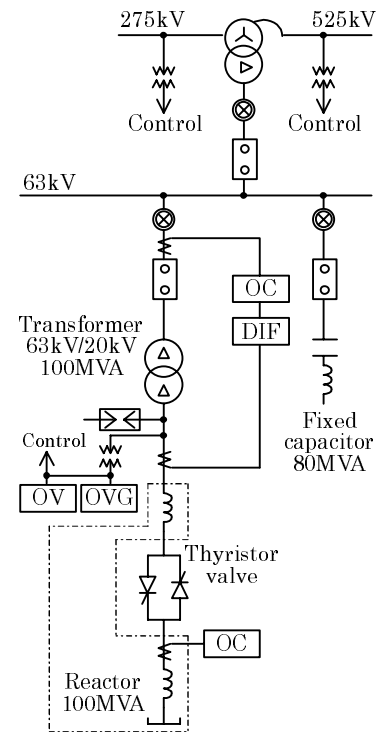


Fig. 1. Single line diagram of Shin-Shinano SVC

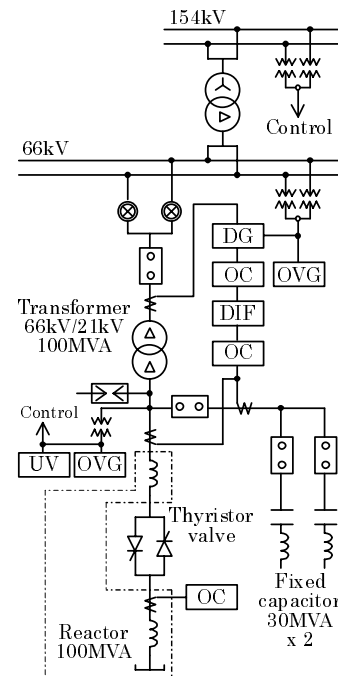


Fig. 2. Single line diagram of Suruga SVC

- (3) The primary side voltage of the step-down transformer for the SVC was changed from 63kV to 66kV. For this reason, the impedance of the step-down transformer for SVC is decreased accordingly.
- (4) The minimum control angle was changed to 93 degrees from 91 degrees. This is required to ensuring proper thyristor failure detection.

For these reasons, the over load capacity at the time of the highest operation voltage of 72kV decreased from 145MVA to 137MVA.

TABLE I  
COMPARISON OF SYSTEM RATING AND MAIN APPARATUS SPECIFICATION

Purpose		Suruga SVC Commercial equipment	Shin-Shinano SVC Test equipment
System voltage		154kV	500kV
SVC bus voltage capacity		Primary:66kV Secondary:21kV	Primary:63kV Secondary:20kV
Maxmum SVC bus voltage		72kV	72kV
Over load		137MVA <sub>r</sub> (at 72kV)	145MVA <sub>r</sub> (at 72kV)
Rated frequency		50Hz	50Hz
Environmental temperature		5 – 40 degree C	-20 – 40 degree C
Equivalent salt adhesion density		0.12mg/cm <sup>2</sup>	0.01mg/cm <sup>2</sup>
Earthquake-proof		0.3g resonance sine wave, safety factor 2	NA
Thyristor valve	Rated Voltage	21kV	20kV
	Rated Current	1591A	1667A
	Max. voltage	22.9kV	22.9kV
	Max. current	1981A-continuous	2110A-30minutes
	Thyristor Element	SL1500GX21 (4kV-1500A)	SL1500GX21 (4kV-1500A)
	Thyristor Element Configuration	24S-1P-6A	24S-1P-6A
	Triggering method	Light triggered	Light triggered
	Cooling method	Deionized water Air cooler	Deionized water Cooling tower
Control angle	93 – 180 electrical degree	91 – 179 electrical degree	
Transformer Impedance		12% (at 63kV)	11.15% (at 66kV)
Audible noise		65dB(A)	65dB(A)

The following are the main modifications required by the major SVC components:

- (1) The thyristor valve cooling system was changed to a system of direct style, and cools the deionized water with air-cooler from an external cooling tower.
- (2) The cooling system of the SVC-TCR reactor was changed from a self-cooled radiator system into a forced cooled radiator system.
- (3) A damage-from-salt-water specification (equivalent salt deposit density 0.12 mg/cm<sup>2</sup>) was added.
- (4) An earthquake-proof specification (safety factor 2 of 0.3G 3 cycle of sine wave at resonant frequency) was added.

For above reasons, a reexamination of the structure design, structure strengthening, etc. was required.

- (5) The composition of a digital control system was changed into a double system from the Mie system.
- (6) The protection relay system was changed into a digital double system from an analog 1 series system.

Since these reasons, all of the control protection panels of the Shin-Shinano SVC were replaced with new manufactured panels for the Suruga SVC.

#### IV. SCOPE OF THE REFURBISHMENT WORKS

In order to upgrade the SVC equipment from test grade to commercial grade equipment, various modifications were made to selected major components. The following is a summary outline of these modifications:

##### A. Thyristor valve and valve base electronics

The thyristor valves were reconstructed and modified, except for the thyristor stack, the snubber circuit, the ferrite core, and the modular structure object. Fig. 4 is a modular structure figure showing a reconstruction portion. Fig. 5 and Fig. 6 are thyristor valve photographs of a Shin-Shinano substation unit and the Suruga substation unit.

- (1) In the existing test project equipment, the PG-LEC (Pulse Generator • Light/Electricity Converter) attached to the thyristor valve base was removed, and replaced with a new independent PG-LEC panel, it is a double system.
- (2) In order to satisfy the earthquake-proof specification, an insulator was added to the module frame.
- (3) The optical connector of Light-triggered thyristor (LTT) was changed to BNC type, which facilitates the easy attachment of a light guide (optical fiber).
- (4) New light guides were supplied. (Since the PG-LEC panel is separated from the thyristor valve base, the light guide length became longer.)
- (5) In connection with the optical fiber having become a BNC connector, new OVP (Over Voltage Protection), FV (Forward Voltage detection), and RV (Reverse Voltage detection) cards were provided.
- (6) Because the cooling system was not in operation for a long period of time, there was concern about any possible degradation of Teflon pipes of the cooling piping and the insulation. Therefore, they were replaced with new components.
- (7) A new flow meter for the deionized water cooling system and a new water thermometer were provided.

##### B. The coupling transformer for SVC

The Shin-Shinano substation SVC transformer was sent to the factory, and the following work was performed.

- (1) Since the transformer was made for a test project, the following measuring instrument material was mounted inside the tank structure. To upgrade this component to have the reliability of commercial equipment, this equipment was removed.
  - The leak flux measurement element, which aids in determining the effect of being partially magnetized by direct current
  - Temperature measurement element

- Vibration measurement element (accelerometer pickup)
- (2) A unit air cooler for increasing the redundancy of the cooling system was added.
- (3) An oil pump, a thermometer, a flow meter, a gas detection relay, etc. were replaced by new equipment.

In addition, the sound isolation tank was directly delivered from Shin-Shinano to Suruga.

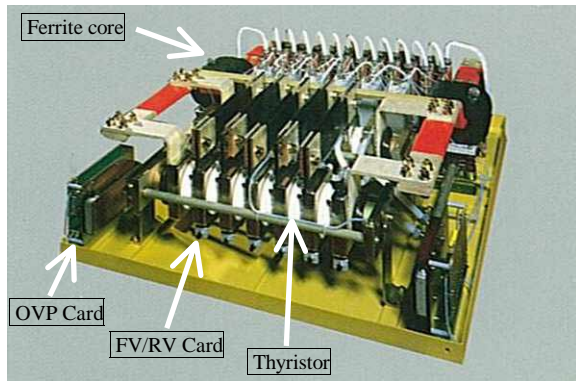


Fig. 4. A modular structure figure showing reconstruction portion



Fig. 5. The thyristor valve photograph of Shin-Shinano SVC



Fig. 6. The thyristor valve photograph of Suruga SVC

### C. The TCR reactor for SVC

The reactor was directly delivered from Shin-Shinano to Suruga, without bringing it back to the factory. The self-colded radiator was replaced by a new unit air cooler, and it was installed in the Suruga substation. The thermometer, the gas detection machine, etc. were also replaced with new components.

### D. Surge arresters

Surge arresters were delivered directly from Shin-Shinano to Suruga. No changes or modifications were made.

### E. Thyristor valve cooling system

The cooling system was modified to directly circulate deionized water between the thyristor valves and the outdoor air cooling system, thus increasing its reliability. In addition, new deionized water pumps and a new unit air cooler were supplied. A heater was also added for freeze prevention.

### F. SVC Control Device

- (1) The digital Mie system (2 out of 3) 4 panels were replaced with new digital double system 4 panels, currently used by the digital protection relay.
- (2) Since this was a fundamental change, all of these panels were replaced.
- (3) Cooperation of signal transfer with the new style VQC (voltage and var control) equipment installed at the same time was checked.

### G. SVC Protection Panel

- (1) The Shin-Shinano SVC used 1 series system of analog relays. To upgrade this system to commercial grade equipment, this system was replaced with a new system using digital relays, similar to other recent SVC projects.
- (2) It is now considered a digital double system.
- (3) Since the main circuit arrangement had changed, the protection relay arrangement was changed accordingly.
- (4) At the time of the SVC connection bus change, the potential transformer input voltage into the control panel was changed by software.

### H. Other panels

An on-site operation panel, a supervisor and operation panel, a failure recorder panel, AC/DC power supply panel, thyristor valve cooling control panels, and transformers and reactor cooling control panel were all replaced by new panels.

## V. SOME ADDITIONAL TECHNICAL POINTS

The following are some other technical subjects, which were considered in the relocation of the SVC equipment.

### A. Move of field test equipment

The existing SVC equipment was designed to test equipment standards and it was not designed to be relocated. Analysis was carried out to determine what components might experience degradation. Therefore, difficult engineering decisions had to be made to determine what components had to be returned to the factories to be modified or replaced; and what components could be shipped to the Suruga substation directly from a Shin-Shinano substation. In addition, the relocation work and the new construction had to be performed to minimize any interference with the operation of the two substations.

### B. Change of main circuit arrangement

The biggest change was that the electrical connection point of the fixed capacitor banks of the SVC were changed from the primary side of the coupling transformer for the SVC (Shin-Shinano SVC) to the secondary side (Suruga SVC). This is because the fixed capacitor voltage (20kV class) of 154kV substation differs from the fixed capacitor voltage (66kV class) of 500kV substation. In addition, because the 500kV system is a direct-grounded system and the 154kV system is a resistor-grounded system, the protection relay system had to be changed. Therefore, new protection panels were supplied.

### C. Difference of test equipment and commercial equipment

Since the existing SVC was designed for a test project, various sensors were embedded inside the coupling transformer. Moreover, the system was designed so that it may stop immediately after any abnormality occurs, and the reliability requirements of commercial equipment were also not applied to the protective relay system. Furthermore, it was located in an area where earthquake-proof specifications and damage-from-salt-water-proof specifications were not required, either. For this reason, selected major components were returned to the factory for modifications or replacement, and the supply of a double protection system was also provided.

## VI. CONCLUSION

The existing Shin-Shinano SVC, which was built and installed for test purposes in 1987, was decommissioned, modified and reconstructed to meet the latest commercial requirements. It was then relocated and installed in the Suruga substation and placed into commercial operation. Successful testing of this relocated and modified SVC was performed in June 2001. The relocation was performed with minimal disturbance to the operation of the two substations and it is

considered, by the utility, to be a very successful and cost effective project.

## VII. REFERENCES

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## VIII. BIOGRAPHIES



**Hideo Takeda** was born in Tokyo, Japan. He received his B.S. and M.S. in Instrument Engineering from Keio University in 1977 and 1979 respectively. After graduated he joined Toshiba Corporation and has been engaged in the system engineering of HVDC, SVC, and FACTS. Now he is in TM T&D Corporation. He is a member of IEEEJ.



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