The Design of Control and Protection System of 150 MVAr SVC in Nuevo Vallarta Substation in Mexico

Xin Huang   DaoXiong Zhang   Chihan Chen   Haiying Li   Qiwen Zhou   Gang Du
NR Electric Co., Ltd.
China

huangx.nr@foxmail.com

SUMMARY

A Static Var Compensator has been in successful commercial operation in the Nuevo Vallarta substation in Mexico for three years. Firstly, the background of this project was introduced in the paper. Secondly, the paper presents the detail design parameter and the control strategy of this SVC project. The whole SVC system was designed and manufactured by NR Electric Co, Ltd. The reactive power range of the SVC is from -50MVAr inductive to 150MVAr capacitive. The SVC consists of two sets of TSC branches, one set of TCR branch and two sets of FC in the project. The primary voltage of the substation is 230kV and the secondary voltage of step down transformer is 13.8kV. Filter tuning frequency is 5th and 7th. The filter capacitors provide 30 MVAr capacitive-reactive power in total.

This paper also presents some control logics of the SVC. Such as TSC operation sequence, the auto degrade mode, voltage control logic. Two sets TSC need special sequence to keep the balancing of the total operation time between the two TSC. This special sequence method is considered as alternate switchover method. The SVC would deblock the longer blocked one of two TSC first when two TSC were both in blocked state. The SVC would block the longer deblocked one first when two TSC were both in deblocked state. A priority selection method has been created for this alternate operating purpose. The SVC would select the TSC with higher priority as the next deblocked or blocked TSC. The operation history and the TSC branch status are both considered in the alternate switchover method. This alternate switchover method keep the balance of two TSC branches operation and make the total operating times of TSC branched almost the same. The Nuevo Vallarta substation is an unmanned substation. The SVC also consider as an unmanned system. NR electric developed a web access human interface to monitor the SVC system. When some failure occurred during the SVC operation, the protection device would trip the breaker to stop SVC. Next, the SVC would open the disconnector of the failure branches and reconnect the rest branches to the power system. The failure branch will be out of service and the healthy branches will continue operating. The auto disconnecting failure branch and reconnecting the healthy branches is considered as auto degrade mode of SVC. The auto degrade mode would keep all the operation record messages and the transient fault recorded waveforms in the SVC HMI database and the user could have these information from the web access though the specific network. The commissioning test had been performed for verification of the SVC operation performance and the results indicated that the control strategy was correctly designed and the whole SVC working functionally.

KEYWORDS

1. Introduction

The SVC substation Nuevo Vallarta is located on the right side of Tondoroque Road in the State of Nayarit Mexico. The SVC provides 150MVAr capacitive to -50MVAr inductive reactive power for the transmission lines. The whole SVC system was designed and manufactured by NR Electric. The main purpose of the Nuevo Vallarta SVC is to stable the 230kV voltage and provide dynamic reactive power for the transmission lines. The three year commercial operation of the SVC has verified the dynamic performance of the system. The structure of the Nuevo Vallarta SVC and the SVC operation principle would be discussed firstly in the paper. Then the SVC control logic is given in the next section. The SVC commissioning test records would be displayed in the last.

2. The operation principle of SVC

Static Var Compensator (SVC) is traditional and typical static type compensator equipment. The STATCOM is the other kind of static var compensator. The synchronous condenser is rotating machine, therefore it's named as rotating type var compensator. The SVC would have some typical characteristics such as: the valve bank of thyristors which well-known as half-control switching components, the phase controlled reactors, and some specific tuned filter branches. The control system of SVC sends the trigger pulse via the fibre to trigger the thyristor valve. The key switching component thyristor is the half-controlled component and the typical valve bank is six-pulse branch. The Thyristor Controlled Reactor (TCR) produce continuously adjustable inductive reactive power and the filter branch (FC) and Thyristor Switched Capacitor (TSC) would produce the fixed capacitive reactive power. With firing angle control of TCR branch, SVC could give continuous output of reactive power from the inductive to capacitive.

3. Structure of Nuevo Vallarta SVC

The SVC consist of two sets of TSC branches, one set of TCR branch and two sets of filter branches in this project. The single line diagram is shown as below:
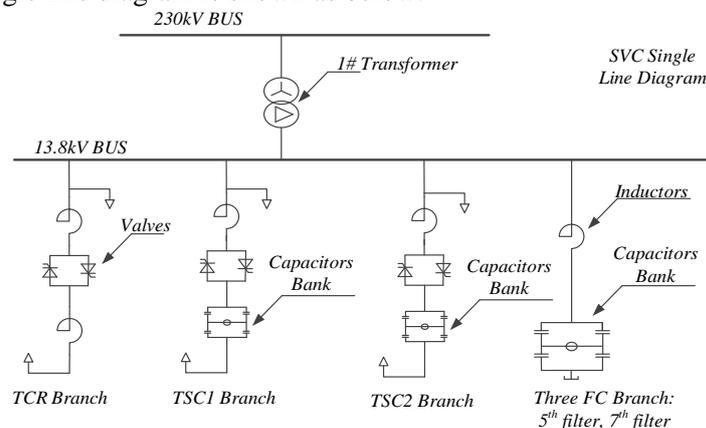

Fig 1 SVC single line diagram

The TCR Branch capacity is -80 MVAr inductive and the TSC Branch is 60 MVAr capacitive, the total capacity of FC is 30 MVAr. So the rated capacitive reactive power of SVC is 150MVAr when TCR branch output 0 MVAr and all TSC branches and FC branches were in service. The Nuevo Vallarta SVC have two type valve bank: TSC valve and TCR Valve. The Fig.2 and Fig.3 shows the thyristor bank of the SVC.
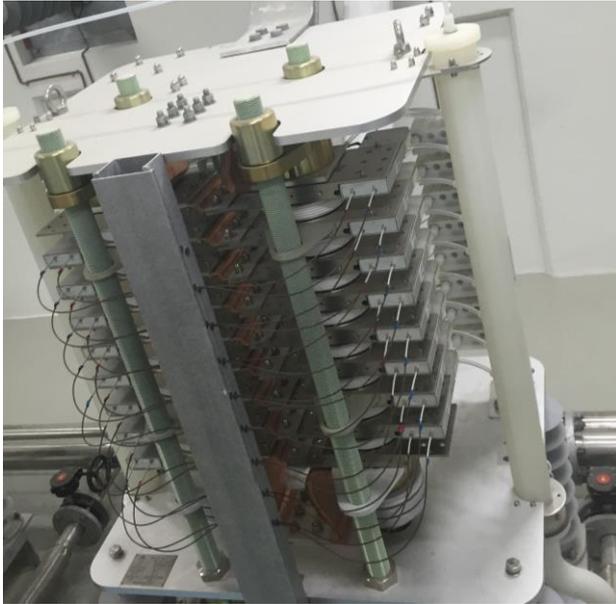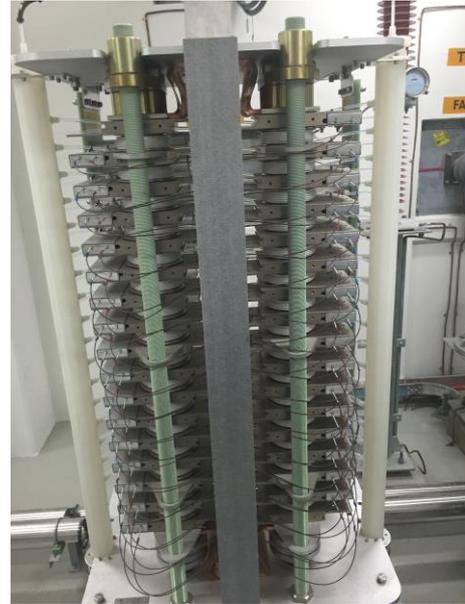
Fig 2 TCR valve bank

Fig 3 TSC valve bank

The valve bank of TCR and TSC are of the same structure in which thyristors are assembled with the pressure between the upper and lower electro pole plate. The thyristor control units (TCU) give the feedback signals to the control system and receive the trigger signal to trigger the thyristor. The de-ionized water is flowing through the cooling pipes and heat sinks to carry the heat of the valve thyristor to the outside heat exchanger.

Two filter branches of SVC are designed for filtering the harmonic current of TCR and providing 30MVAr of the capacitive power. The tuning frequency of filters is 5th and 7th, considering the six-pulse TCR produced specific characteristic harmonic current.

The TSC branches were carefully designed with some special consideration. The capacity of TSC is 60MVAr and the tuning frequency is about 4.5^{th}. The rated average current of the thyristor is 2810A and the repetitive peak forward voltage is 6500V.

The Human Machine Interface system screen shot of Nuevo Vallarta SVC shows the whole structure of the SVC which is as below:
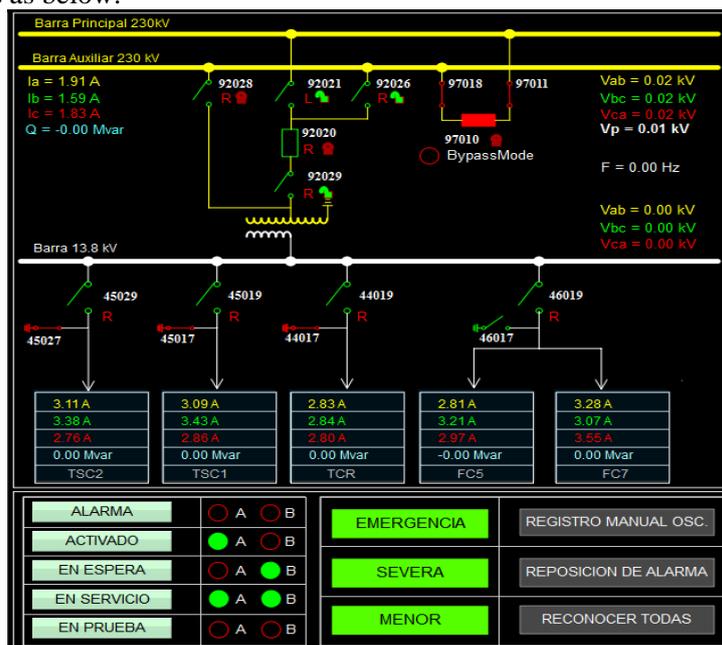

Fig 4 The HMI system of SVC

The breaker 92020 and the 97010 could control the SVC to be in service or out of service. The disconnector and earthing connector could keep the faulty branch out of service and other branches in service. Three levels of SVC status on the HMI system display the whole system operating state which is classified as Emergence, Severe, and Minor. The emergency level is the most critical fault, and SVC should be out of service when this level of fault arises. The voltage RMS values and current RMS values are also displayed on the screen.

3. Control Strategy of Nuevo Vallarta SVC

A. The basic V-I characteristic of SVC

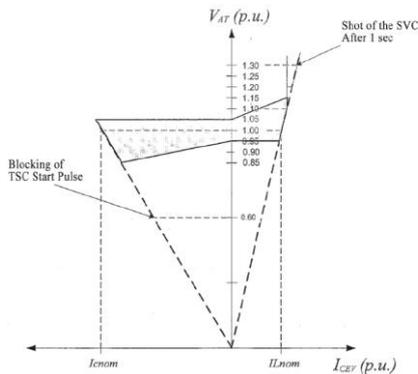The V-I character of the Nuevo Vallarta SVC is shown as below:

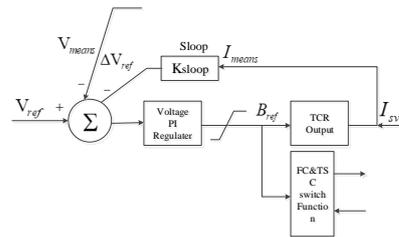Fig 5 The V-I characteristic of SVC   Fig 6 The voltage control logic of SVC

The upper voltage limit is 1.3 p.u. of 230kV voltage and the lower limit is 0.6 p.u. of 230kV voltage. The SVC would trip when the 230kV voltage over 1.3 p.u. lasting for 1 second. The TSC would block when the power system voltage were under 0.6 p.u. The over voltage would cause SVC branches over load. The different slope parameters make SVC has different V-I character in the different zone. The control logic is shown as Fig.6. The SVC output current would decide different slope parameter for the feedback gain of voltage control logic. The slope input with the error between the desired voltage and the actual voltage are processed by the PI function to give the susceptance of the TCR.

B. The Bypass mode of SVC

The 92020 and 97010 breaker could both control SVC into service. The SVC could detect which breaker is controlling SVC based on the disconnector position. The logic is shown as below:
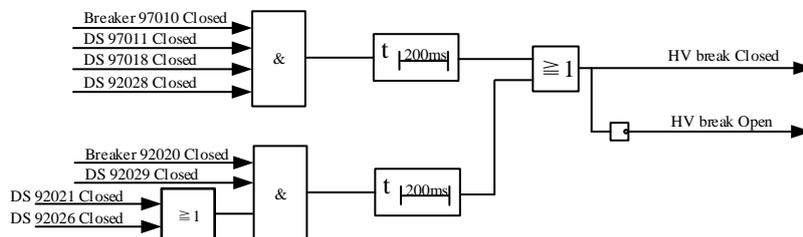

Fig 7 The bypass mode of SVC

Where: DS means disconnector.

When the disconnectors 97011, 97018 and 92028 were closed and the breaker 97010 closed, the SVC was energized by the bypass breaker 97010. Otherwise the main breaker 92020 provided connection of power system. The SVC control unit uses the High Voltage (HV) breaker position in the SVC control logic. The breaker control logic will give the different breaker order by the disconnector position.

C. The Auto-degrade mode

The Nuevo Vallarta substation is an unmanned substation, and the SVC should keep a high level of available rate. The redundant control system is one method to keep the SVC more available. The SVC has two sets of control system. One of them would be in active status and the other in standby status. If one of them detects some fault arising in the active one, the standby will be switched over to become active one. The SVC would trip when both system detect the faults. One system failure will not cause trip of SVC. The other way of keep high availability is the Auto-degrade function. The logic is shown as below:
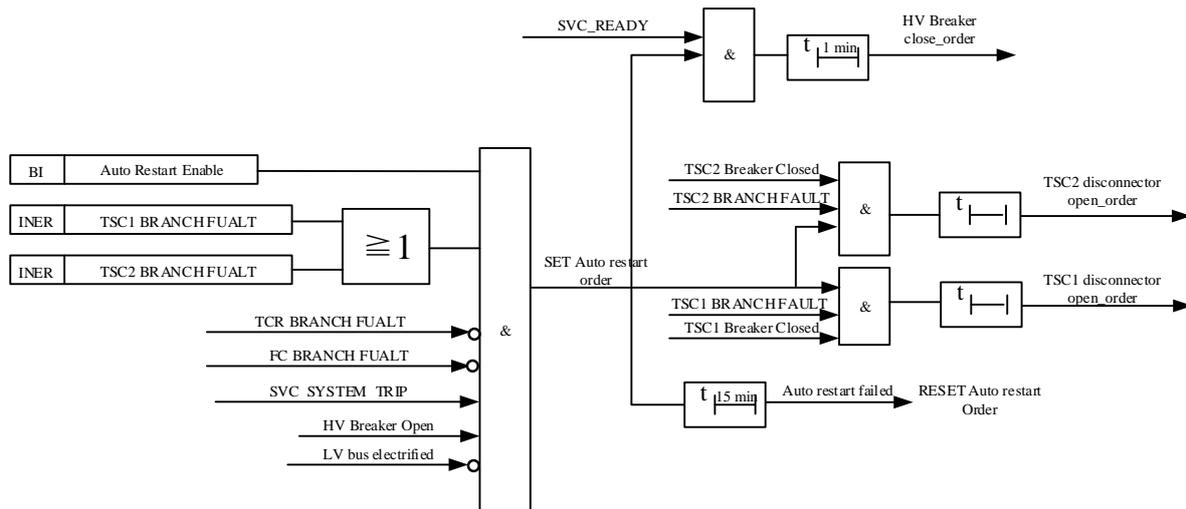

Fig 8 auto degrade mode of SVC

When the control system detects some branch failure, the trip order would be sent to the HV breaker. And the control system opens the disconnector after the discharging of capacitors. The control system tag the fault branch a "faulty" tag and then the SVC would reconnect to the power system if no more fault detected. The messages of SVC operation would be sending to the engineer of the substation. The SVC would be in a degrade mode running until the engineers have a maintenance for the SVC to repair the fault branch.

D. The operation logic of TSC

There are two sets of TSC in this project and alternate operation sequence was designed. The alternate operation of TSC means two TSC works alternately and the total operation times are almost equally. The first deblocked TSC would be the first TSC to be blocked if needed; The first blocked TSC would be the first TSC to be deblocked if needed. One set of TSC would deblock when the trigger angle of TCR is smaller than the TSC-deblock setting for a short time. The other TSC would deblock when the trigger angle still smaller than the TSC-deblock setting for the delay time. A minimal deblock operation interval was also designed for the TSC operation stably. The TSC would block when the TCR trigger angle were larger than the TSC-block setting for a short time. And the other one would block too when it were deblocking and the TCR trigger angle still larger than setting. Sometimes one set TSC deblocking is enough for the reactive power requirement. A priority of TSC would indicate the next operation TSC of two. The TSC deblock logic is shown as below.
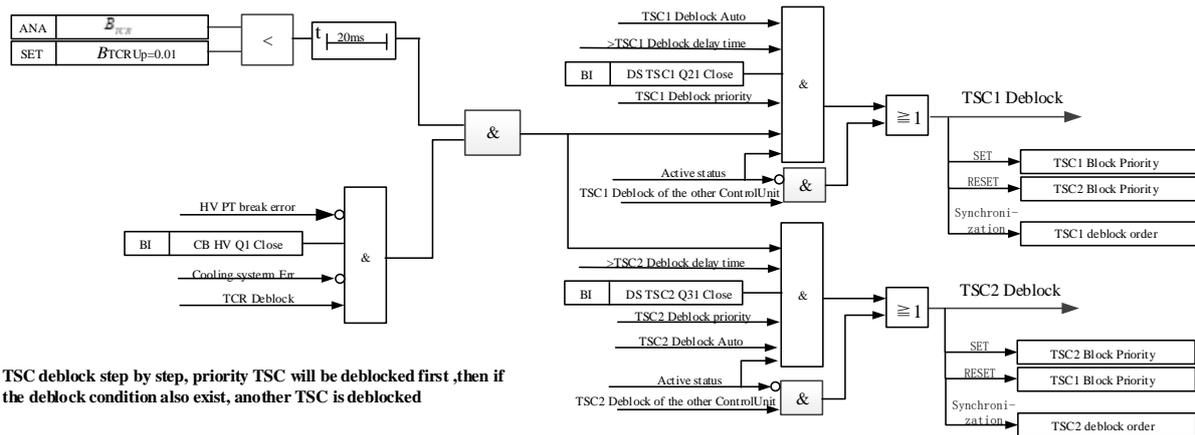
Fig 9 TSC deblock order logic of SVC

3. The site commission record of Nuevo Vallarta SVC

A. the voltage control function

In order to test the response time of SVC reactive output a response test has been designed and carried out. The test steps are shown as below:

1. Confirm the control mode is "voltage control" mode and Voltage slope reference is 0.01.
2. Set voltage inductive slope to "0.04" and capacitive slope to "0.03". Set voltage setting to "233kV" from "228kV".
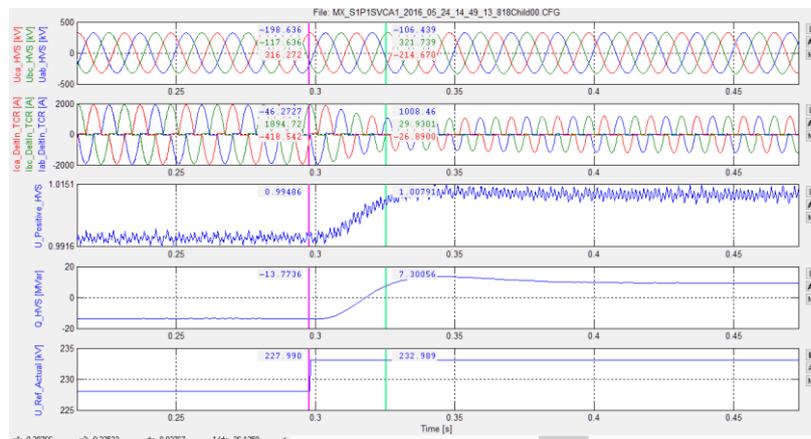

Fig 10 Response test of SVC voltage control logic

Where: the first channel from the top of Fig.7 is the voltage of 230kV side; the second channel is the TCR current, the third channel is the positive sequence voltage of 230kV voltage, and the fourth channel is the SVC reactive power output. The last channel is the voltage reference of SVC.
Several voltage tests have been performed and the test result of the voltage response time is shown as below:

From 228kV to 233kV Respond Time =27.67ms;

From 233kV to 228kV Respond Time =27.34ms;

From 238kV to 223kV Respond Time =30.6ms.

The specification of SVC system required is response time smaller than 200mS, therefore, the response time of SVC fulfill the requirement.

B. the auto-restart function test

In order to inspect SVC works status under the degraded mode. The test steps are shown as below:

1. Click "SVC Start/Stop" on "single line diagram" interface, auto start SVC.

2. Change the control mode into "Voltage control"; Confirm that the voltage setting is "237kV" and the capacity slope setting is "0.03" ; Enable the "Auto Restart" function on "single line diagram" interface;
3. Click "SVC Start/Stop" on "single line diagram" interface, auto start SVC;
4. Simulate the TSC1 branch fault by shorting the TSC1 protection trip signal ; Inspect the SVC will trip and restart;
5. After SVC restart automatically, Simulate the TSC2 branch fault by shorting the TSC2 protection trip signal; Inspect the SVC trip and restart; Record the sequential event;
6. After SVC restart automatically, Simulate the TCR branch fault by shorting the TCR protection trip signal; Inspect the SVC trip without restart; Record the sequential event;
7. Trig the "Alarm reset" control on the "single line diagram";

The Record waveform and the screen shot of HMI system indicated that the auto-degrade mode was functional.
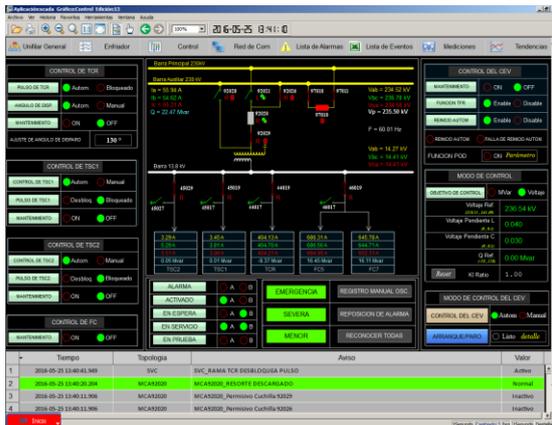

Fig 11 SVC is in service   Fig 12 SVC without TSC1 and TSC2

C. The Bypass mode test

In order to inspect SVC works status under the Bypass mode. The test steps are shown as below:
1. Close the high voltage disconnector 92028, 97011, and 97018; confirm the "Bypass_Mode" indication turns to red on "single line diagram" interface.
2. Close the 97010 breaker manually to start SVC;
3. Open the 97010 breaker manually to start SVC;
4. Close the 97010 breaker manually to start SVC;

The Bypass mode is the same as designed; SVC control system can only close, open, and trip the breaker 97010 under the Bypass mode;

4. The conclusion

The Nuevo Vallarta SVC is a turnkey project implemented by NR Electric. The stable and dynamic performance of the whole SVC have been verified by the commissioning test records and three years successful commercial operation. The specific function of SVC also were designed for the Nuevo Vallarta substation for its unmanned characteristics, the operation record also give the positive evidence of these functional mode. The bird view of the whole SVC is shown as below:

Fig 13 SVC of Nuevo Vallarta Substation

BIBLIOGRAPHY

[1]   R.Mohan Mathur, Rajiv K.Varma, THYRISTOR-BASED FACTS CONTROLLERS FOR ELECTRICAL TRANSMISSION SYSTEMS, vol. I. New York: Wiley-IEEE Press Wiley, 2002, p. 117,p. 130, p. 203.

[2]   IEEE Power & Energy Society, "IEEE Draft Guide for Static Var Compensator Field Tests" (IEEE Standard 1303-2011, June. 2011).

[3]   IEEE Power & Energy Society, "IEEE Guide for the Functional Specification of Transmission Static Var Compensators" (IEEE Standard 1301-2011, June. 2011).

[4]   Xin Huang, Lei Zhang, "The Design of Control and Protection System of 900 MVAr SVC in Holeta Substation in Ethiopia" (IEEE PES Power Africa Conference 148, July 2016 pages 223-227)