Control of Power Flow in a Transmission line using SVC

Mr. Pankaj Kumar Gupta, Prof. Aziz Ahmad, Mr. Raj kumar Singh

Abstract— This dissertation deals with the control of active power flow, or load flow, in electric power systems. A 300-Mvar Static Var Compensator (SVC) regulates voltage on a 6000-MVA 735-kV system. The SVC consists of a 735kV/16-kV 333-MVA coupling transformer, one 109-Mvar thyristor-controlled reactor bank (TCR) and three 94-Mvar thyristor-switched capacitor banks (TSC1 TSC2 TSC3) connected on the secondary side of the transformer. Switching the TSCs in and out allows a discrete variation of the secondary reactive power from zero to 282 Mvar capacitive (at 16 kV) by steps of 94 Mvar, whereas phase control of the TCR allows a continuous variation from zero to 109 Mvar inductive. Taking into account the leakage reactance of the transformer (15%), the SVC equivalent susceptance seen from the primary side can be varied continuously from -1.04 pu/100 MVA (fully inductive) to +3.23 pu/100 Mvar (fully capacitive). The SVC controller monitors the primary voltage and sends appropriate pulses to the 24 thyristors (6 thyristors per three-phase bank) in order to obtain the susceptance required by the voltage regulator.

Index Terms- Control of active and reactive power flow, SVC, TCS, TCR, transmission line.

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1 INTRODUCTION

Today's power systems are highly complex and require careful design of new devices taking into consideration the already existing equipment, especially for transmission systems in new deregulated electricity markets. This is not an easy task considering that power engineers are severely limited by economic and environmental issues. Thus, of new concepts that emphasize a more efficient use of already existing power system resources without reduction in system stability and security. In the late 1980s, the Electric Power Research Institute (EPRI) introduced a new approach to solve the problem of designing and operating power systems; the proposed concept is known as Flexible AC Transmission Systems (FACTS) [1]. The two main objectives of FACTS are to increase the transmission capacity and control power flow over designated transmission routes.

A Flexible AC Transmission System incorporates power electronics and controllers to enhance controllability and increase transfer capability. This paper introduces the concept of a distributed static series compensator that uses multiple low-power single phase inverters that attach to the transmission conductor and dynamically control the impedance of the transmission line, allowing control of active power flow on the line.

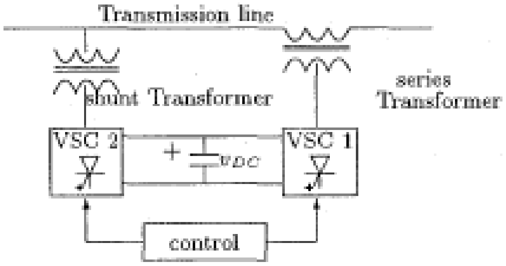

Fig 1. Power drwan/supply to branch

The DSSC inverters are self-powered by induction from the line itself, float electrically on the transmission conductors, and are controlled using wireless or power line communication techniques. Implementation of system level control uses a large number of DSSC modules controlled as a group to realize active control of power flow. The DSSC can be used to either increase or decrease the effective line impedance, allowing current to be "pushed" away from or "pulled" into a transmission line. The DSSC concept overcomes some of the most serious limitations of FACTS devices, and points the way to a new approach for achieving power flow control–the use of Distributed FACTS or D-FACTS devices.

Use Look under Mask to see how the TCR and TSC subsystems are built. . Each three-phase bank is connected in delta so that, during normal balanced operation, the zero-sequence tripplen harmonics (3rd, 9th...) remain trapped inside the delta, thus reducing harmonic injection into the power system.

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The power system is represented by an inductive equivalent (6000 MVA short circuit level) and a 200-MW load. The internal voltage of the equivalent can be varied by means of programmable source in order to observe the SVC dynamic response to changes in system voltage. Open the voltage source menu and look at the sequence of voltage steps which are programmed.

2 POWER FLOW CONTROL

Electric-power transmission is the bulk transfer of electrical energy, from generating power plants to electrical substations located near demand centers. This is distinct from the local wiring between high-voltage substations and customers, which is typically referred to as electric power distribution.

Transmission lines, when interconnected with each other, become transmission networks. In the US, these are typically referred to as "power grids" or just "the grid." In the UK, the network is known as the "National Grid." North America has three major grids, the Western Interconnection, the Eastern Interconnection and the Electric Reliability Council of Texas (ERCOT) grid, often referred to as the Western System, the Eastern System and the Texas System.

Historically, transmission and distribution lines were owned by the same company, but starting in the 1990s, many countries have liberalized the regulation of the electricity market in ways that have led to the separation of the electricity transmission business from the distribution business.[1]

Most transmission lines use high-voltage three-phase alternating current (AC), although single phase AC is sometimes used in railway electrification systems. High-voltage direct-current (HVDC) technology is used for greater efficiency in very long distances (typically hundreds of miles (kilometers), or in submarine power cables (typically longer than 30 miles (50 km). HVDC links are also used to stabilize against control problems in large power distribution networks where sudden new loads or blackouts in one part of a network can otherwise result in synchronization problems and cascading failures.

Electricity is transmitted at high voltages (110 kV or above) to reduce the energy lost in long-distance transmission. Power is usually transmitted through overhead power lines. Underground power transmission has a significantly higher cost and greater operational limitations but is sometimes used in urban areas or sensitive locations.

A key limitation in the distribution of electric power is that, with minor exceptions, electrical energy cannot be stored, and therefore must be generated as needed. A sophisticated control system is required to ensure electric generation very closely matches the demand. If the demand for power exceeds the supply, generation plants and transmission equipment can shut down which, in the worst cases, can lead to a major regional blackout.

3 OPERATING PRINCIPLE

Run the simulation and observe waveforms on the SVC scope block. The SVC is in voltage control mode and its reference voltage is set to Vref=1.0 pu. The voltage droop of the regulator is 0.01 pu/100 VA (0.03 pu/300MVA). Therefore when the SVC operating point changes from fully capacitive (+300 Mvar) to fully inductive (-100 Mvar) the SVC voltage varies between 1-0.03=0.97 pu and 1+0.01=1.01 pu.

Initially the source voltage is set at 1.004 pu, resulting in a 1.0 pu voltage at SVC terminals when the SVC is out of service. As the reference voltage Vref is set to 1.0 pu, the SVC is initially floating (zero current). This operating point is obtained with TSC1 in servive and TCR almost at full conduction (alpha=96 degrees). At t=0.1s voltage is suddenly increased to 1.025 pu. The SVC reacts by absorbing reactive power (Q=-95 Mvar) in order to bring the voltage back to 1.01 pu. The 95% settling time is approximately 135 ms. At this point all TSCs are out of service and the TCR is almost at full conduction (alpha = 94 degrees) . At t=0.4 s the source voltage is suddenly lowered to 0.93 pu. The SVC reacts by generating 256 Mvar of reactive power, thus increasing the voltage to 0.974 pu. At this point the three TSCs are in service and the TCR absorbs approximately 40% of its nominal reactive power (alpha =120 degrees). Observe on the last trace of the scope how the TSCs are sequentially switched on and off. Each time a TSC is switched on the TCR alpha angle changes suddenly from 180 degrees (no conduction) to 90 degrees (full conduction). Finally, at t=0.7 s the voltage is increased to 1.0 pu and the SVC reactive power is reduced to zero.

4 CONTROL STRATEGY

Each time a TSC is switched off a voltage remains trapped across the TSC capacitors. If you look at the 'TSC1 Misfiring' scope inside the "Signals and Scope" subsystem you can observe the TSC1 voltage (first trace) and the TSC1 current (second trace) for branch AB. The voltage across the positive thyristor (thyristor conducting the positive current) is shown on the 3rd trace and the pulses sent to this thyristor are shown on the 4th trace. Notice that the positive thyristor is fired at maximum negative TSC voltage, when the valve voltage is minimum. If by mistake the firing pulse is not sent at the right time, very large overcurrents can be observed in the TSC valves.

Look inside the SVC Controller block how a misfiring can be simulated on TSC1. A Timer block and a OR block are used to add pulses to the normal pulses coming from the Firing Unit. Open the Timer block menu and remove the 100 multiplication factor. The timer is now programmed to send a misfiring pulse lasting one sample time at time t= 0.121 s. Restart simulation. Observe that the misfiring pulse is sent when the valve voltage is maximum positive immediately after the TSC has blocked. This thyristor misfiring produces a large thyristor over current (18 kA or 6.5 times the nominal peak current). Also, immediately after the thyristor has blocked, the thyristor voltage reaches 85 kV (3.8 times the nominal peak voltage). In order to prevent such overcurrents and overvoltage's, thyristor valves are normally protected by metal oxide arresters (not simulated here).

5 SIMULATION AND DESIGN

Simlulink design is shown here in four different modules.

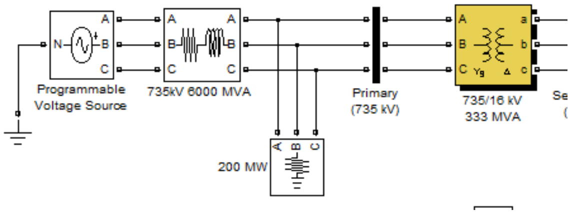

Fig 2: Input power supply and connections of load.

Digital Simulation of SVC: For simulating SVC in power system, simple two-bus system connected by transmission line is used for simulation. The system data and line data is given in diagram.

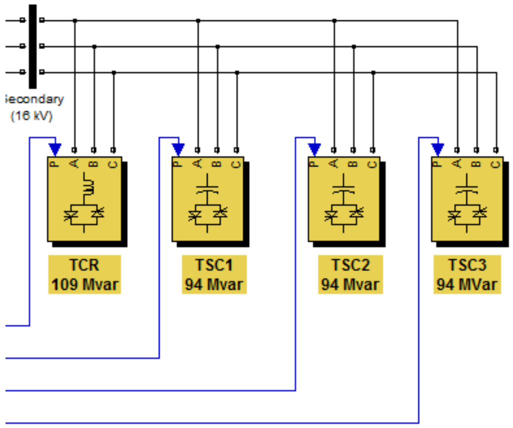

Fig 3: Schematic of TCR and TSC

The system consists of 230 kV, 50 Hz generators. Sending end operated at 63 degrees and receiving end generator operated at 0 degrees power angle. The measuring and plotting icons are connected at various sections with suitable time constants and scaled for smooth measurement.

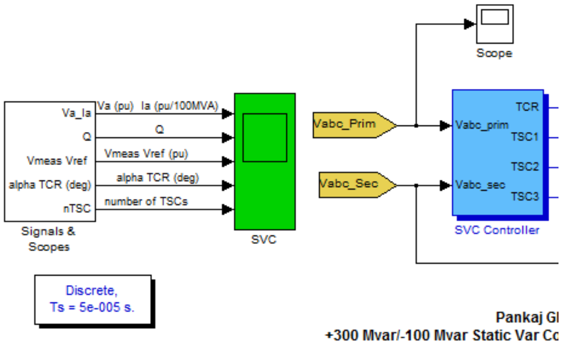

Fig 4: Connections of scope and input parameters

5 RESULT

Each three-phase bank is connected in delta so that, during normal balanced operation, the zero-sequence triple n harmonics (3rd, 9th...) remain trapped inside the delta, thus reducing harmonic injection into the power system. The power system is represented by an inductive equivalent (6000 MVA short circuit level) and a 200-MW load. The internal voltage of the equivalent can be varied by means of programmable source in order to observe the SVC dynamic response to changes in system voltage.

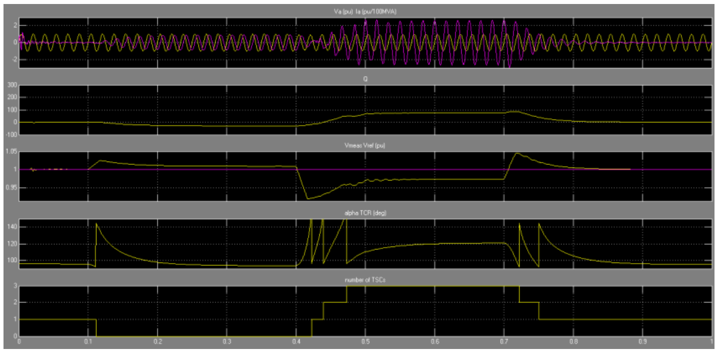

Fig 5: Output of V-I and number of TCS used.

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