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Dynamic Performance of 48-pulse STATCOM, SSSC and UPFC controller

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Abstract: The paper investigates the dynamic operation of both static synchronous compensator (STATCOM) and static synchronous series compensator (SSSC) based on a new full model comprising a 48- pulse gate turn off thyristor voltage source converter for combined reactive power compensation and voltage stabilization of the electrical grid net work. The complete digital simulation of the STATCOM and SSSC within the power system is performed in the MATLAB/ simulation environment using the power system block set (PSB).The STATCOM scheme and the electrical grid network are modelled by specific electrical blocks from the power system block set, while the control system is modelled using simulink.Two controllers for the STATCOM and SSSC are presented in this paper based on a decoupled with voltage and current control strategy. The performance of both STATCOM and SSSC schemes connected to the 500-kv grid are evaluated. The proposed to ensure the stable operation of the STATCOM under various load conditions. it is shown that phase-locked loop(PLL) inherent delay has a great effect on dynamic operation of SSSC and new auxiliary regulator is proposed to enhance the dynamic performance of the SSSC.the proposed control schemes are validated by digital simulation.

Keywords: *Phase-Locked Loop(PLL), auxiliary regulator, GateTurn-Off dynamic performance, static synchronous series compensator (SSSC), static synchronous compensator (STATCOM),voltage stabilization, 48-pulse converter.*

1. INTRODUCTION :

In the last decade, commercial availability of Gate Turn –Off (GTO) thyristor switching devices with high-power handling capability and the advancement of the other types of power –semiconductor devices such as IGBTs have led to the development of fast controllable reactive power sources utilizing new electronic switching and converter technology. These switching technologies additionally offer considerable advantages over existing methods in terms of space reductions and fast effective damping.

The GTO thyristors enable the design of the solid-state shunt reactive compensation and active filtering equipment based upon switching convertor technology. These power quality devices (PQ Devices) are power electronic converters connected in parallel or in series with transmission lines, and the operation is controlled by digital controllers. The interaction between these compensating devices and the grid network is preferably studied by digital simulation. Flexible alternating current transmission systems (FACTS) devices are usually used for fast dynamic control of voltage, impedance, and phase angle of high-voltage ac lines. FACTS devices provided strategic benefits for improved transmission system power flow management through better utilization of existing transmission assets, increased transmission system security and reliability as well as availability, increased dynamic and transient grid stability, and increased power quality for sensitive industries (e.g., computer chip manufacture). The advent of FACTS systems is giving rise to a new family of power electronic equipment for controlling and optimizing the dynamics equipment for controlling and optimizing the dynamic performance of power system, e.g., STATCOM, SSSC and UPFC. The use of voltage –source inverter (VSI) has been widely accepted as the next generation of flexible reactive power compensation to replace other conventional VAR compensation, such as the thyristor-switched capacitor (TSC) and thyristor controlled reactor (TCR). This paper deals witty a novel cascade multilevel converter model, which is a 48- pulse (three levels) source converter. The voltage source converter described in this paper is a harmonic neutralized, 48- pulse GTO converter.

It consists of four three phase, three-level inverters and four phase –shifting transformers. In the 48- pulse voltage source converter, the dc bus Vdc is connected to the four three-phase inverters. The four voltage generated by the inverters are applied to secondary windings of four zig-zag phase-shifting transformers connected in Y or Δ .The four transformer primary windings are connected in series, and the converter pulse patterns are phase shifted so that the four voltage fundamental components sum in Phase on the primary side

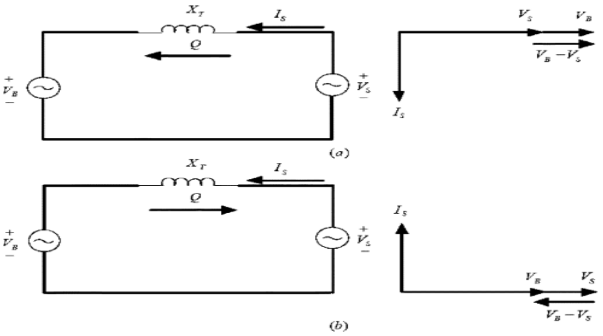


Fig.1.STATCOM operation (a) Induction operation.
(b)Capacitive operation

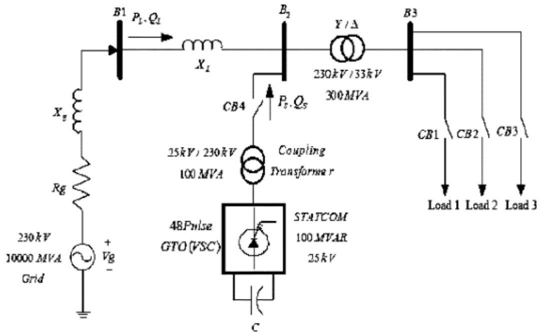


Fig.2.Sample three-bus study system with the STATCOM at bus B2

2. DYNAMIC PERFORMANCE OF THE STATCOM :

The basic STATCOM model consists of a step-down transformer with leakage reactance Xt, a three-phase GTO VSI, and a dc side capacitor. The ac voltage difference across this transformer leakage reactance produces reactive power exchange between the STATCOM and the power system at the point of interface. The voltage can be regulated to improve the voltage profile of the interconnected power system, which is the primary duty of the STATCOM. A secondary damping function can be added to the STATCOM for enhancing power system dynamic stability. The STATCOM's main function is to regulate key bus voltage magnitude by dynamically absorbing or generating reactive power to the ac grid network, like a thyristor static compensator. This reactive power transfer is done through the leakage reactance of the coupling transformer by using a secondary transformer voltage in phase with the primary voltage (network side). This voltage is provided by a voltage-source PWM inverter and is always in quadrature to the STATCOM current.

The STATCOM device operation can be illustrated by the phasor diagrams shown in Fig. 1. When the secondary voltage (VS) is lower than the grid system bus voltage (VB), the STATCOM acts like an inductance absorbing reactive power from the grid bus. When the secondary voltage (VS) is higher than the bus voltage (VB), the STATCOM acts like a capacitor generating reactive power to the grid bus. In steady-state operation and due to inverter losses, the bus voltage (VB) always leads the inverter ac voltage by a very small angle to supply the required small active power losses.

The voltage source-converter or inverter (VSC or VSI) scheme is the building block of any STATCOM device and other FACTS devices. A simple inverter produces a square voltage waveform as it switches the direct voltage source on and off. The basic objective of a good VSI-converter scheme is to produce a near sinusoidal ac voltage with minimal wave form distortion or excessive harmonics content. Three basic techniques can be used for reducing the harmonics produced by the converter switching. Harmonic neutralization using magnetic coupling (multi pulse converter configurations), harmonic reduction using multilevel converter configurations, and novel pulse-width modulation (PWM) switching techniques. The 24- and 48-pulse converters are obtained by combining two or four (12-pulse) VSI, respectively, with the specified phase shift between all converters. For high-power applications with low distortion, the best option is the 48-pulse converter, although using parallel filters tuned to the 23th–25th harmonics with a 24-pulse converter could also be adequately attentive in most applications, but the 48-pulse converter scheme can ensure minimum power quality problems and reduced harmonic resonance conditions on the interconnected grid network
.

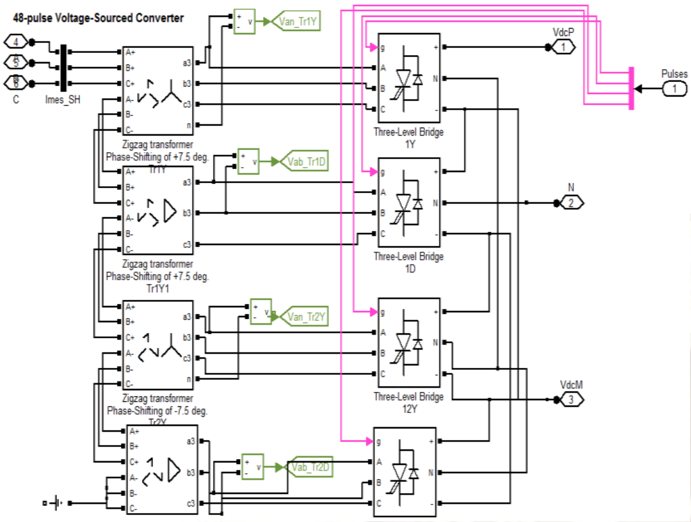
3. DIGITAL SIMULATION STATCOM MODEL:

A novel complete model using the 48-pulse digital simulation of the STATCOM within a power system is presented in this paper. The digital simulation is performed using the MATLAB/Simulink software environment and the Power System Block set (PSB). The basic building block of the STATCOM is the full 48-pulse converter-cascade implemented using the MATLAB/Simulink software it was shown in the Fig.2. The control process is based on a novel decoupled current control strategy using both the direct and quadrature current components of the STATCOM. The operation of the full STATCOM model is fully studied in both capacitive and inductive modes in a power transmission system and load excursion. The use of full 48–pulse STATCOM model is more accurate than existing low-order or functional models.

A. 48-PULSE VOLTAGE SOURCE GTO –CONVERTER :

Two 24-pulse GTO-converters, phase-shifted by 7.5 º from each other, can provide the full 48-pulse converter operation. Using a symmetrical shift criterion, the 7.5 º are provided in the following way: phase-shift winding with ---3.75º on the two coupling transformers of one 24-pulse converter and +3.75º on the other two transformers of the second 24-pulse converter. The firing pulses need a phase-shift of +3.75º, respectively.

The 48-pulse converter model comprises four identical 12-pulse GTO converters interlinked by four 12-pulse transformers with phase-shifted windings. Fig. 3 depicts the schematic diagram of the 48-pulse VS-GTO converter model. The transformer connections and the necessary firing-pulse logics to get this final 48-pulse operation are modeled.



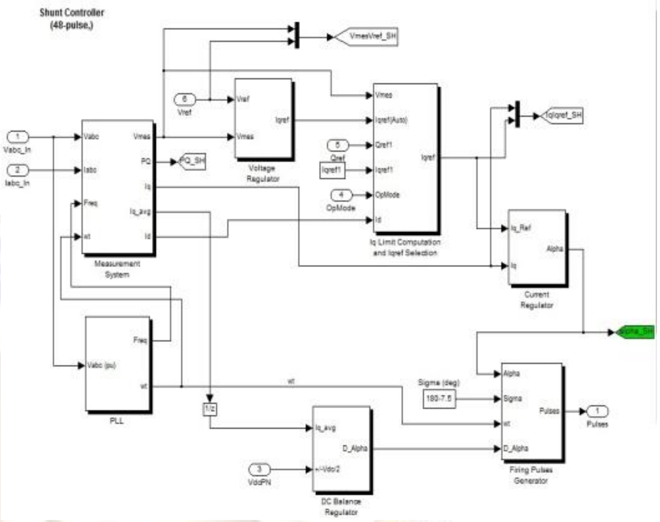


Fig.3. Forty-eight-pulse GTO's voltage source converter. Fig.4. 48-pusle generation block

The 48-pulse converter can be used in high-voltage high-power applications without the need for any ac filters due to its very low harmonic distortion content on the ac side. The output voltage have normal harmonics n=48± 1 , where r=0,1,2,……, i.e., 47th ,49th,95th ,97th ,…. , with typical magnitudes (1/47th ,1/49th , 1/95th ,1/97th ,….), respectively, with respect to the fundamental; on the dc side, the lower circulating dc current harmonic content is the 48th.

The phase-shift pattern on each four 12-pulse converter cascade is as follows.

1st 12-Pulse Converter: It is shown in the equation at the bottom of the page. The resultant output voltage generated by the first 12-pulse converter is

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PST: +7.5° Necessary to eliminate the 24 -pulse harmonics

$\upsilon_{ab12}(t)_1 = 2[V_{ab1}\sin(\omega t+30^\circ) + V_{ab11}\sin(11\omega t+195^\circ) + V_{ab13}\sin(13\omega t+225^\circ) + V_{ab23}\sin(23\omega t+60^\circ) + V_{ab25}\sin(25\omega t+120^\circ)+\ldots\ldots]$. ------------------- (1)

+3.75 ° Necessary to eliminate the 48 -pulse harmonics

Total +11.25° winding turn rate 1: tan (11.25 °) Drive:- 7.5 ° Necessary to eliminate the 24-pulse harmonics

−3.75° Necessary to eliminate the 48 -pulse harmonics.

Total −11.25°

Total +3.75° *2nd 12-Pulse Converter:* It is shown in the second equation at the bottom of the previous page. The resultant output voltage generated by the second 12-pulse converter is

$\upsilon_{ab12}(t)_2 = 2[V_{ab1}\sin(\omega t+30^\circ)\ V_{ab11}\sin(11\omega t+15^\circ) + V_{ab13}\sin(13\omega t+75^\circ) + V_{ab23}\sin(23\omega t+60^\circ) + V_{ab25}\sin(25\omega t+120^\circ)+\ldots\ldots]$. -------------------(2)

3rd 12-Pulse Converter: It is shown in the first equation at the bottom of the page. The resultant output voltage generated by the third 12-pulse converter is

$\upsilon_{ab12}(t)_3 = 2[V_{ab1}\sin(\omega t+30^\circ) + V_{ab11}\sin(11\omega t+285^\circ) + V_{ab13}\sin(13\omega t+345^\circ) + V_{ab23}\sin(23\omega t+240^\circ) + V_{ab25}\sin(25\omega t+300^\circ)+\ldots\ldots]$. ------------------- (3)

4th 12-Pulse Converter: It is shown in the second equation at the bottom of the page. The resultant output voltage generated by the fourth 12-pulse converter is

$\upsilon_{ab12}(t)_3 = 2[V_{ab1}\sin(\omega t+30^\circ) + V_{ab11}\sin(11\omega t+105^\circ) + V_{ab13}\sin(13\omega t+165^\circ) + V_{ab23}\sin(23\omega t+240^\circ) + V_{ab25}\sin(25\omega t+300^\circ)+\ldots\ldots]$. -------------------(4)

These four identical 12-pulse converter provide shifted ac output voltages, described by (1)–(4), are added in series on the secondary windings of the transformers. The net 48-pulse ac total output voltage is given by

$\upsilon_{ab48}(t)= \upsilon_{ab12}(t)_1+\upsilon_{ab12}(t)_2+ \upsilon_{ab12}(t)_3+ \upsilon_{ab12}(t)_4$ _________(5)

$\upsilon_{ab48}(t)= 8[V_{ab1}\sin(\omega t+30^\circ) + V_{ab47}\sin(47\omega t+150^\circ) + V_{ab49}\sin(49\omega t+210^\circ) + V_{ab95}\sin(95\omega t+330^\circ) + V_{ab97}\sin(97\omega t+30^\circ)+\ldots\ldots]$. __________________(6)

The line-to-neutral 48-pulse ac output voltage from the STATCOM model is expressed by

$\upsilon_{ab48}(t) = 8/\sqrt{3} \sum_{n=1}^{\infty} V_{abn} \sin(n\omega t + 18.75^\circ n - 18.75^\circ i)$__________(7)

n=(48±1), r=0,1,2…..

Voltages υ ab48(t) and υ cn48(t)have a similar near sinusoidal shape with a phase shifting of 120 and 240 , respectively, from phase a υ an48(t) . Fig. 4 depicts the net resultant 48-pulse line-to-line output voltage of the 48-pulse GTO-Converter control scheme. .

B. CURRENT CONTROL MODE OPERATION :

The new decoupled control system is based on a full d-q decoupled current control strategy using both direct and quadrature current components of the STATCOM ac current. The decoupled control system is implemented phase locked loop (PLL) synchronizes as shown in Fig. 8. A on the positive sequence component of the three phase terminal voltage at

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PST: −7.5° Necessary to eliminate the 24 -pulse harmonics

−3.75 ° Necessary to eliminate the 48 -pulse harmonics

Total −11.25° winding turn rate 1: tan(11.25 °) Drive: +7.5 ° Necessary to eliminate the 24-pulse harmonics

+3.75° Necessary to eliminate the 48 -pulse harmonics. Total +11.25° interface Bus 2. The output of the PLL is the angle (θ) that used to measure the direct axis and quadrature axis component of the ac three-phase voltage and current. To enhance the dynamic performance of the full 48-pulse STATCOM device model, a supplementary regulator loop is added using the dc capacitor voltage. The dc side capacitor voltage charge is chosen as the rate of the variation of this dc voltage. Thus, for a fixed selected short time interval Δt, the variation in the Vdc magnitude is measured, and any rapid change in this dc voltage is measured and if this ΔVdcchange is greater than a specified threshold k , the supplementary loop is activated. The main concept is to detect any rapid variation in the dc capacitor voltage.

The strategy of a supplementary damping regulator is to correct the phase angle of the STATCOM device voltage $\theta *$, with respect to the positive or negative sign of this variation. If $\Delta Vdc > 0$, the dc capacitor is charging very fast. This happens when the STATCOM converter voltage lag behind the ac system voltage; in this way, the converter absorbs a small amount of real power from the ac system to compensate for any internal losses and keep the capacitor voltage at the desired level. The same technique can be used to increase or decrease the capacitor voltage and, thus, the amplitude of the converter output voltage to control the Var generation or absorption. This supplementary loop reduces ripple content in charging or discharging the capacitorand improves fast controllability of the STATCOM.

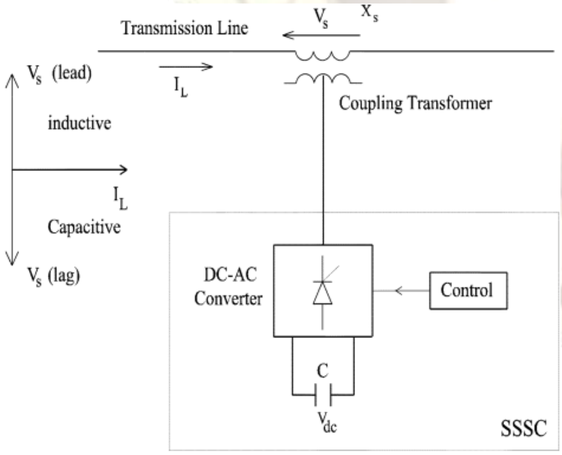


Fig.5 Sample study system with SSSC

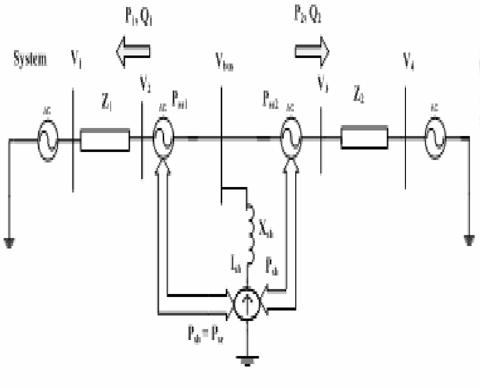


Fig.6 Proposed method block of UPFC

DYNAMIC PERFORMANCE OF THE SSSC:

The dynamic performance control strategy for the SSSC is also validated in both capacitive and inductive operating modes when the system is subjected to severe disturbances of switching electric loads contingencies. The SSSC device is one of the most important FACTS devices for power transmission line series compensation. It is a power electronic-based synchronous voltage generator (SVG) that generates almost three-phase sinusoidal ac voltages, from a dc source/capacitor bank with voltage in

quadrature with the reference line current. The SSSC converter blocks are connected in series with the transmission line by a series coupling transformer. The SSSC device can provide either capacitive or inductive voltage compensation,
If the SSSC-AC voltage Vs lags the line current IL by 90°, a capacitive series voltage compensation is obtained in the transmission line, and if Vs * leads IL by 90, an inductive series voltage compensation is achieved. By controlling the level of the boost/buck voltage transmission line, the amount of series compensation voltage can be fully adjusted. The equivalent injected series voltage Vs is almost in quadrature with the reference transmission line current. A small part of this injected voltage Vs *, which is in phase with transmission line current, supplies the required losses in the inverter bridge and coupling transformer. Most of the injected voltage Vs * is in full quadrature with the reference transmission line current and, hence, emulates an equivalent inductive or capacitive reactance in series with the transmission line.

DIGITAL SIMULATION MODEL OF SSSC:

A complete digital simulation study using the full 48-pulse GTO-SSSC device model for a sample test power system is presented in this paper. The digital simulation is performed in the MATLAB/Simulink software environment using the PSB. The basic building block of the SSSC device is the same cascade of converters forming the 48-pulse GTO converter whose complete digital simulation model was implemented using MATLAB/Simulink. This new full SSSC device compensator can be more accurate in providing fully controllable compensating voltage over a specified identical capacitive and inductive range, independently of the magnitude of the line current, and better represent realistic improved power quality reduced harmonics.

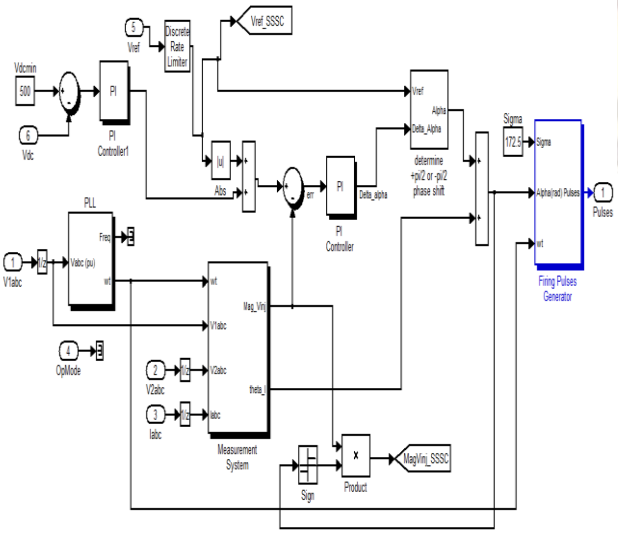
A. POWER SYSTEM DESRIPTION:

The test system is a simple power system 500-kV network grid equipped with the SSSC and its novel controller, which connected in series with the transmission system. Modeling the SSSC compensator, including the power network and its controller in MATLAB/Simulink environment, requires using “electric blocks” from the power system blockset and control blocks from thr Simulink library. A ±70 Mvar SSSC device is connected to the 500-kV grid network. Fig. 5 shows the single line diagram that represents the SSSC and the 500/33-kV grid network.

The feeding network is represented by an its equivalent Thevenin (bus B1) where the voltage source is a 500 kV with 10 000 MVA short circuit level with a resistance of 0.1 p.u. and an equivalent reactance of 0.3 p.u. followed by the 500-kV radial transmission system connected to bus B2. The full system parameters are given in appendix. The SSSC FACTS device consists mainly of the 48–pulse GTO-voltage source converter model that is connected in series with the transmission line at Bus B1 by the coupling transformer T1. The dc link voltage Vdc is provided by capacitor C, which is charged with an active power taken directly from the ac network. The novel full 48-pulse GTO-VSC model results in less harmonic distortion than other 6-, 12-, and 24-pulse converters or functional models usually used to represent SSSC device operation.

B. *Control Scheme for the 48-pulse SSSC*

The control system for the SSSC device is shown in Fig. 7. The basic synchronization signal is the phase angle θ of the transmission line current. The SSSC equivalent impedance Xs is measured as the ratio of the q-axis voltage of the SSSC device Veq to the magnitude of transmission line current I_L . This equivalent inserted or equivalent (positive/negative) impedance is then compared with the reference level of the compensation impedance (SX_L).



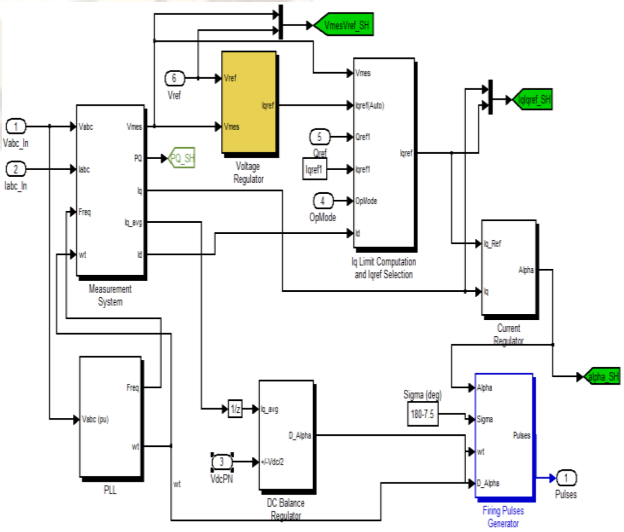


Fig.7.a Control scheme of sssc **Fig.7.b.Control scheme of statcom**

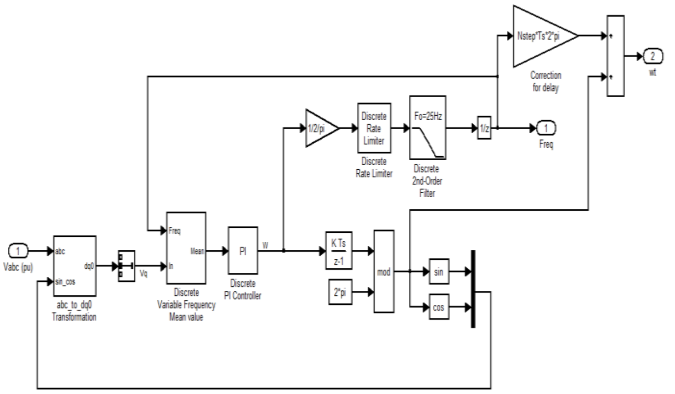


Fig.8 Block design of PLL

A proportional plus integral PI controller generates the required small phase displacement angle $\Delta\propto$ of few degrees electric, in order to charge or discharge the dc capacitor (C), while a positive $\Delta\propto$ discharges the dc side capacitor. When Xref is negative Vc lags I_L by 90 (Capacitive Compensation) and when Vc leads I_L by 90 and $\Delta\propto$ (inductive compensation). The final output of the control system is the desired phase angle $\theta^* = \pm\frac{\pi}{2} \pm \Delta\propto + \theta$ of the SSSC device output voltage

RESULTS OF SIMULATION:

Various Control Methods Of STATCOM and SSSC:

A combination of SHUNT controller and SERIES controller action is works as a unified power flow controller (UPFC) is used to control the power flow in a 500 kV transmission system. The SSSC and STATCOM located at the left end of the 75-km line L2, between the 500 kV buses B1 and B2, is used to control the active and reactive powers flowing through bus B2 while controlling voltage at bus B1. It consists of two 100-MVA, three-level, 48-pulse GTO-based converters, one connected in shunt at bus B1 and one connected in series between buses B1 and B2. The shunt and series converters can exchange power through a DC bus. The series converter can inject a maximum of 10% of nominal line-to-ground voltage (28.87 kV) in series with line L2.
This pair of converters can be operated in three modes:
Unified Power Flow Controller (UPFC) mode, when the shunt and series converters are interconnected through the DC bus. When the disconnect switches between the DC buses of the shunt and series converter are opened, two additional modes are available: Shunt converter operating as a Static Synchronous Compensator (STATCOM) controlling voltage at bus B1Series converter operating as a Static Synchronous Series Capacitor (SSSC) controlling injected voltage, while keeping injected voltage in quadrature with current.
. The principle of operation of the harmonic neutralized converters is explained in entitled “Three-phase 48-pulse GTO converter”. This power 48pulse gto converter is accessible in the Power simulation. When the two converters are operated in UPFC mode, the shunt converter operates as a STATCOM and series Converter SSSC
.

Power control in UPFC mode:

The GUI allows you to choose the operation mode (combined SSSC and STATCOM, STATCOM or SSSC) as well as the Pref/Qref reference powers and/or Vref reference voltage settings . Also, in order to observe the dynamic response of the control system, the GUI allows you to specify a step change of any reference value at a specific time. The reference active and reactive powers are specified in the last two lines of the GUI menu. Initially, Pref= +8.7 pu/100MVA (+870 MW) and Qref=-0.6 pu/100MVA (-60 Mvar). At t=0.25 sec Pref is changed to +10 pu (+1000MW). Then, at t=0.5 sec, Qref is changed to +0.7 pu (+70 Mvar). The reference voltage of the shunt converter (specified in the 2nd line of the GUI) will be kept constant at Vref=1 pu during the whole simulation (Step Time=0.3*100> Simulation stop time (0.8 sec). When the UPFC is in power control mode, the changes in STATCOM reference reactive power and in SSSC injected voltage (specified respectively in 1st and 3rd line ‘
Run the simulation for 0.8 sec. Observe on traces 1 and 2 of the scope the variations of P and Q. After a transient period lasting approximately 0.15 sec, the steady state is reached (P=+8.7 pu; Q=-0.6 pu). Then P and Q are ramped to the new settings (P=+10 pu Q=+0.7 pu). Observe on traces 3 and 4 the resulting changes in P Q on the three transmission lines. The performance of the shunt and series converters can be observed respectively on the STATCOM and SSSC scopes. If you zoom on the first trace of the STATCOM scope, you can observe the 48-step voltage waveform Vs generated on the secondary side of the shunt converter transformers (yellow trace) superimposed with the primary voltage Vp (magenta) and the primary current Ip (cyan). The dc bus

voltage (trace 2) varies in the 19kV-21kV range. If you zoom on the first trace of the SSSC scope, you can observe the injected voltage waveforms Vinj measured between buses B1 and B2. Var control in STATCOM mode as shown in below fig.9
operation mode to “STATCOM (Var Control): the STATCOM references values (1st line of parameters, [T1 T2 Q1 Q2]) are set to [0.3 0.5 +0.8 -0.8]. In this mode, the STATCOM is operated as a variable source of reactive power. Initially, Q is set to zero, then at T1=0.3 sec Q is increased to +0.8 pu (STATCOM absorbing reactive power) and at T2=0.5 sec, Q is reversed to -0.8 pu (STATCOM generating reactive power).

Run the simulation and observe on the STATCOM scope the dynamic response of the STATCOM. Zoom on the first trace around t=0.5 sec when Q is changed from +0.8 pu to -0.8 pu. When Q=+0.8 pu, the current flowing into the STATCOM (cyan trace) is lagging voltage (magenta trace), indicating that STATCOM is absorbing reactive power. When Qref is changed from +0.8 to -0.8, the current phase shift with respect to voltage changes from 90 degrees lagging to 90 degrees leading within one cycle. This control of reactive power is obtained by varying the magnitude of the secondary voltage Vs generated by the shunt converter while keeping it in phase with the bus B1 voltage Vp. This change of Vs magnitude is performed by controlling the dc bus voltage. When Q is changing from +0.8 pu to -0.8 pu, Vdc (trace 3) increases from 17.5 kV to 21 kV show in Fig.10. Series voltage injection in SSSC mode: the SSSC references values (3rd line of parameters) [Vinj_Initial Vinj_Final Step Time]) are set to [0.0 0.08 0.3].

The initial voltage is set to 0 pu, then at t=0.3 sec it will be ramped to 0.8 pu. Run the simulation and observe on the SSSC scope the impact of injected voltage on P and Q flowing in the 3 transmission lines. Contrary to the UPFC mode, in SSCC mode the series inverter operates with a constant conduction angle (Sigma= 172.5 degrees). The magnitude of the injected voltage is controlled by varying the dc voltage which is proportional to Vinj (3rd trace). Also, observe the waveforms of injected voltages (1st trace) and currents flowing through the SSSC (2nd trace). Voltages and currents stay in quadrature so that the SSSC operates as a variable inductance or capacitance. The applied parameters in simulation of both SSSC and STATCOM are table 1 in appendix. It is modelled and analyzed by Matlab/Simulink.

Fig.9 illustrates real and active power flow control in dynamic condition and injected series voltage, crossing current at two sides of transmission line. at first, the transmitted power in transmission line, after a transient period lasting approximately 0.1 sec, the steady state is reached (=+8.7 PU; =-0.6 PU). or = +8.7−j0.7 (PU). The reference active and reactive powers are specified in the last two lines. Initially, = +8.7 PU/100MVA (+870 MW) and =-0.6 PU/100MVA (-60 MVAR). At t=0.7sec is changed to +10 PU (+1000MW) and is changed 48 - Pulse GTO Centre SSC an STATCOM 111 to +0.7 PU (+70 MVAR), Then and are increased in form of ramp to the new settings (=+10PU, =+0.7 PU).

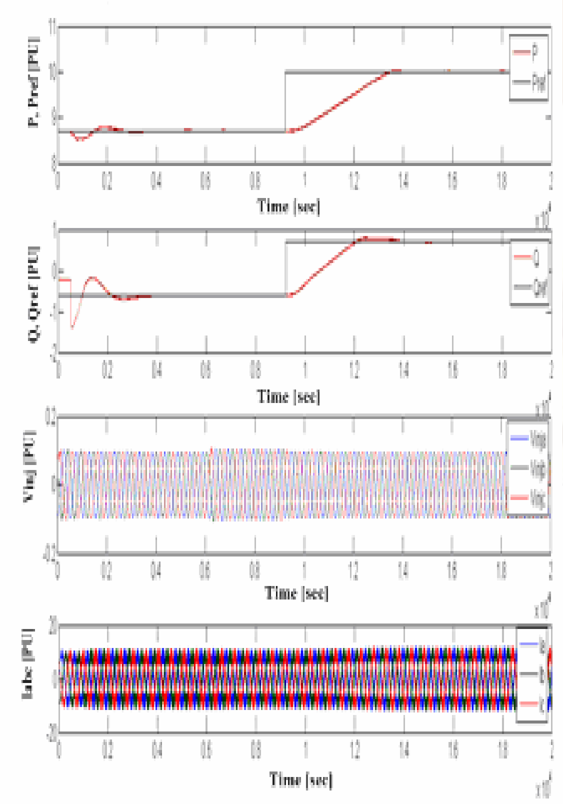


Fig.9. Wave form of SSSC and STATCOM

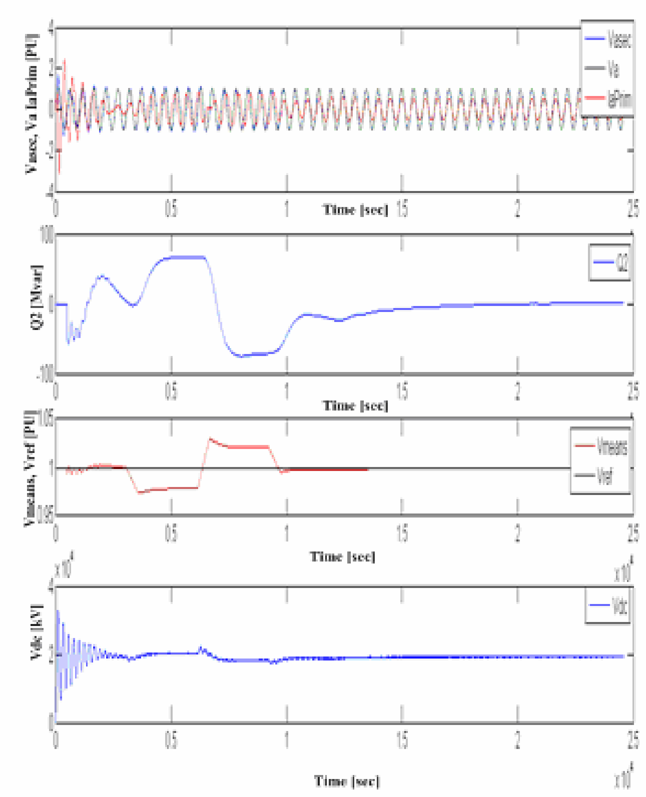


Fig.10.Wave form of STATCOM and SSC

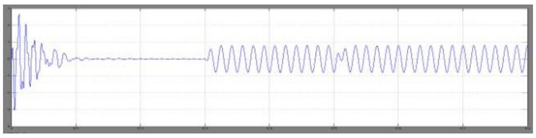


Fig.11. Current injection in STATCOM

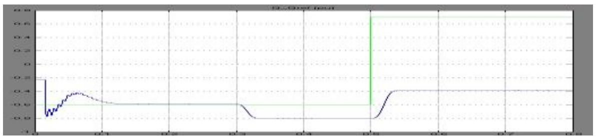


Fig.12. DC voltage at SSSC & STATCOM

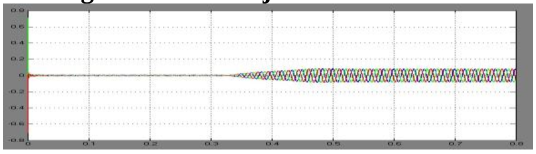


Fig.13. Series voltage injection in SSSC

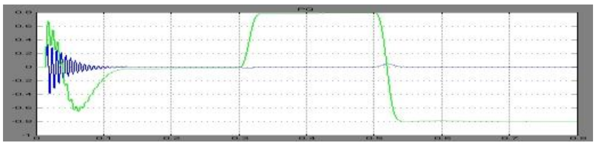


Fig.14. PQ on shunt STATCOM

Fig.9, 10, 11, 12,13shows regulation of voltage, injected reactive power flow and common DC-link voltage in dynamic condition in transmission line, around time of t=2 sec when Q is changed from +0.8 PU to - 0.8 PU. When Q=+0.8 PU, the current flowing into the STATCOM is lagging voltage indicating that STATCOM is absorbing reactive power. When is varied from +0.8 to -0.8, the current phase shift with respect to voltage changes from 90 degrees lagging to 90 degrees leading during one cycle.

This control of reactive power is achieved by changing the magnitude of the secondary voltage generated by the shunt converter while keeping it in phase with the bus of transmission line, this change of magnitude is performed by controlling the dc bus voltage as shown in Fig.14. WhenQischangingfrom+0.8PUto-0.8PU, increasesfrom17.5KVto21KV.10

CONCLUSION:

The paper presents a novel full 48-pulse GTO voltage source converter of STATCOM and SSSC FACTS devices. These full descriptive digital models are validated for voltage stabilization reactive compensation and dynamically power flow control using three novel decoupled current control strategies. The control strategies implement decoupled current control and auxiliary tracking control based on a pulse width modulation switching technique to ensure fast controllability, minimum oscillatory behaviour, and minimum inherent phase locked loop time delay as well as system instability reduced impact due to a weak interconnected ac system

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APPENDIX:

The system parameters are:100MVA
Grid:
— Rated Voltage: 500kV
— Short Circuit Capacity: 3000 MVA
— Reactance, : 0.3 pu
— Resistance, : 0.1 pu.
Transmission Line:
— Reactance, : 0.2 pu (500 KV, 300 MVA)
Power Transformer :(Y/Δ)
— Rated Voltage: kV 500/33kV
— Rated Power: 300 MVA
— Leakage Reactance: 0.01 p.u.
STATCOM:
— Type of valves: GTO
— Number of pulses: 48
— Nominal ac voltage: 25 kV
— Nominal dc voltage: 2 kV
— Rated power: ±100 MVAR
— GTO’s Forward Resistance: 1 mΩ
Capacitor Bank (dc):
— Total Capacitance: 10 mF
— Rated dc Voltage: 2 kV
Coupling Transformer: (Y/Y)
— Rated Voltage:25/500 kV
— Rated Power: 100 MVA
— Resistance: 0.001 pu
— Leakage Reactance: 0.08 pu.
The system parameters of ar $(MVA_{base} = 100)$ *Transmission Line:*
— Reactance, X_l : 0.25 pu (500 kV, 300 MVA)
— Resistance, R_l : 0.05 pu.
Power Transformer: (Y/Δ)
— Rated Voltage: 500/33kV
— Rated Power: 300 MVA
— Leakage Reactance: 0.01 pu.
SSSC:
— Type of Valves: GTO
— Number of Pulses: 48
— Nominal ac Voltage: 6.6 kV
— Nominal dc Voltage: 1 kV