International Journal on Recent and Innovation Trends in Computing and Communication
Volume: 2 Issue: 4

ISSN: 2321-8169
824 – 827

Digital Simulation of 48 Pulse GTO Based Statcom and Reactive Power Compensation

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***Abstract*—** The static synchronous compensator (STATCOM) is a shunt device using power electronics to control power flow and improve transient stability and reactive power control on power grids. A dynamic model of a 100MVAR GTO based STATCOM consists of a 48 pulse seven level inverter and its control system.The simulating result shows that the STATCOM has fine dynamic response and can regulate transmission system voltage efficiency.

***Keyword\s** static synchronous compensator, 48 pulse three level inventor, dynamic response simulation*

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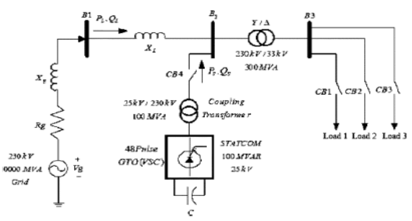
A. Introduction

The static synchronous compensator is a shunt device of the flexible AC transmission system family using power electronics to control power flow and improve transient stability on power grids. The statcom regulates voltage at its terminal by controlling the amount of reactive power capacitor injected into or absorbed from the power system, where the system voltage is low. The statcom generates reactive power when system voltage is high, it absorbs reactive power inductive. A novel complete using the 48 pulse digital simulation of the stat-com within a power system is presentated in this paper. The digital simulation is performed using the MATLAB/SIMULINK software and the power system block set (PSB).The basic building block of the statcom is the full 48 pulse .



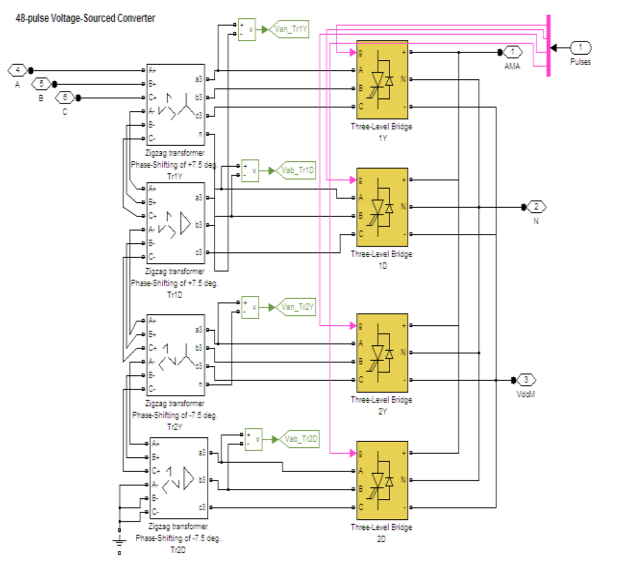


fig-2(48 pulse 3 level GTO based inverter)

B.48 Pulse 3 Level Inverter

The model of 48-Pulse three-level inverter is shown figure 3. It consists of four 3-phase 3-level inverters coupled with four phase shifting transformers introducing phase shift of ±7.5 degrees. Except for the 23rd and 25th harmonics, this transformer arrangement neutralizes all odd harmonics up to the 45th harmonic. Y and D transformer secondaries cancel harmonics 5+12n (5, 17, 29, 41,...) and

7+12n (7, 19,31,43,...). In addition, the 15° phase shift between the two groups of transformers (Tr1Y and Tr1D leading by 7.5°, Tr2Y andTr2D lagging by 7.5°) allows cancellation of harmonics 11+24n (11,35,...) and 13+24n (13, 37,...).Considering that all 3n harmonics are not transmitted by the transformers (delta and ungrounded Y), the first harmonics that are not canceled by the transformers are therefore the 23rd, 25th, 47th and 49th harmonics. By choosing the appropriate conduction angle for the three-level inverter (σ = 172.5°), the 23rd and 25th harmonics can be minimized. The first significant harmonics generated by the inverter will then be 47th and 49th.Using a bipolar DC voltage, the STATCOM thus generates a 48-step voltage approximating a sine wave[2,3].

C. STATCOM CONTROL SYSTEM

The model of STATCOM Control System is shown figure 4.Its task is to increase or decrease the capacitor DC voltage, so that the generated AC voltage has the correct amplitude for the required reactive power. The control system must also keep the AC generated voltage in phase with the system voltage at the STATCOM connection bus to generate transformer and inverter losses).The control system uses the following modules: 1) PLL (phase locked loop) it synchronizes GTO pulses to the system voltage and provides a reference angle to the measurement system. 2) Measurement System it computes the positive sequence. components of the STATCOM voltage and current, using phase-to-dq transformation and a running-window averaging. 3) Voltage regulation it is performed by two PI regulators: from the measured voltage Vrms and the reference voltage Vref, the Voltage Regulator block (outer loop computes the reactive current reference Iqref used by the current regulator block (inner loop). The output of the current regulator is the α angle which is the phase shift of the inverter voltage with respect to the system voltage. This angle stays

very close to zero except during short periods of time, as explained below. A voltage droop is incorporated in the voltage regulation to obtain a V-I characteristics with a slope (0.03 pu/100 MVA in this case). Therefore, when the STATCOM operating point

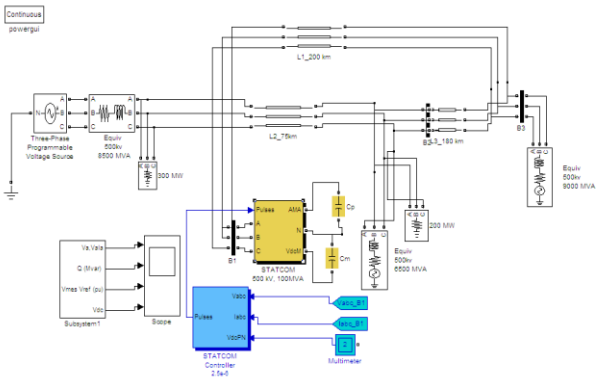


fig-3(STATCOM control system)

1st 12 pulse converter :-_ It is shown in the equation at the bottom of the page.The resultant output voltage genarated by the 1st 12 pulse converter is

$Vab_{12}(t)_1$ = 2 [Vab_1 sin(wt + 30^0) + Vab_{11}sin(11wt + 195^0) + Vab_{13}sin(13wt + 255^0) + Vab_{23}sin(23wt + 60^0) + Vab_{25}sin(25wt + 120^0) +…………….]

PST : + 7.5^0
+ 3.75^0
Total + 11.25^0
Driver : -7.5^0 -24 pulse harmonics
- 3.75^0 -48 pulse harmonics
Total - 11.25^0
PST : - 7.5^0 -24 pulse harmonics
+ 3.75^0 -48 pulse harmonics
Total - 3.25^0
Driver : +7.5^0
- 3.75^0
Total - 11.25^0
\

<u>2nd 12 pulse converter :-</u>

$Vab_{12}(t)_2$ = 2 [Vab_1 sin(wt + 30^0) + Vab_{11}sin(11wt + 15^0) + Vab_{13}sin(13wt + 75^0) + Vab_{23}sin(23wt + 60^0) + Vab_{25}sin(25wt + 120^0) +…………….]

<u>3rd 12 pulse converter :-</u>

Equtation at the bottom of the page

$Vab_{12}(t)_3$ = 2 [Vab_1 sin(wt + 30^0) + Vab_{11}sin(11wt + 285^0) + Vab_{13}sin(13wt + 345^0) + Vab_{23}sin(23wt + 240^0) + Vab_{25}sin(25wt + 360^0) +…………….]

<u>4th 12 pulse converter :-</u>

$Vab_{12}(t)_4$ = 2 [Vab_1 sin(wt + 30^0) + Vab_{11}sin(11wt + 105^0) + Vab_{13}sin(13wt + 165^0) +

$Vab_{23}\sin(23wt + 240^0) + Vab_{25}\sin(25wt + 300^0)$ +……………]

These four identical 12 pulse converter provide shifted ac output voltage , described by (1) –(4) Are added in series on the secondary windings of the transformer, the ret 48 pulse converter output voltage is given by

$Vab_{48}(t) = Vab_{12}(t)_1 + Vab_{12}(t)_2 + Vab_{12}(t)_3 + Vab_{12}(t)_4 +$ ……………………………(5)

$Vab_{48}(t) = 8/\sqrt{3}[Vab_1 \sin(wt + 30^0) + Vab_{47}\sin(47wt + 150^0) + Vab_{49}\sin(49wt + 210^0) + Vab_{95}\sin(95wt + 330^0) + Vab_{97}\sin(97wt + 30^0)$ +……………]…………………………..(6)

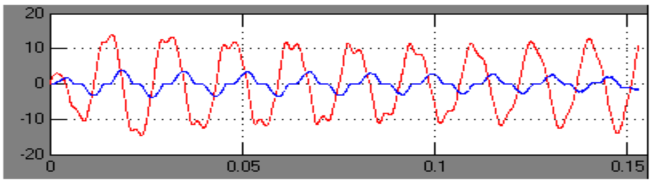


fig-4 (Va, VaIa)

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

$Vab_{48}(t) = 8/\sqrt{3} \quad Vab_n\sin(nwt + 18.75^0 n - 18.75^0 n)$

$n = (48r \pm 1)$,

$r = 0,1,2$……………………………….(7)

phase shifting of 120^0 and 240^0

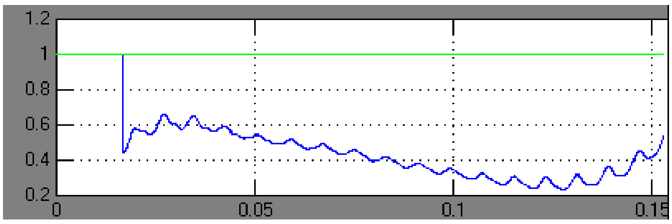


fig-5 (Q MVAR)

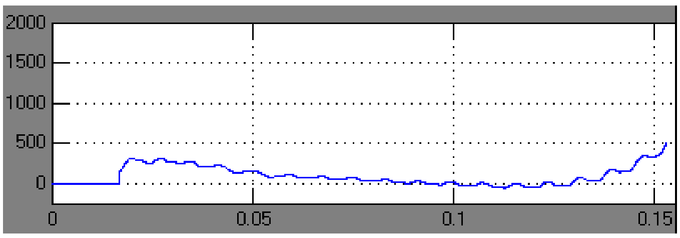


fig-6 (Vmes, Vref (pu)

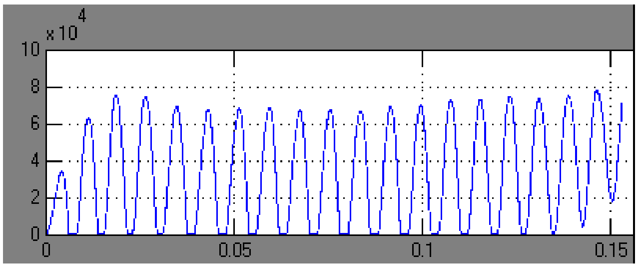


Fig-7 (Vdc)

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D. SIMULATING

Open the programmable voltage source menu and look at the sequence of voltage steps that are programmed. Also, open the STATCOM Controller dialog box and verify that the STATCOM is in voltage regulation mode with a reference voltage of 1.0pu. Run the simulation and observe waveforms on the STATCOM scope block. Initially the programmable voltage source is set at 1.0491pu, resulting in a 1.0pu voltage at bus B1 when the STATCOM is out of service. As the reference voltage Vref is set to 1.0 pu, the STATCOM is initially floating (zero current).The DC voltage is 19.3kV. These waveforms are reproduced is shown figure 5. □□At t=0.1s, voltage is suddenly decreased by 4.5% (0.955pu of nominal voltage). The STATCOM reacts by generating reactive power (Q=+70Mvar) to keep

voltage at 0.979pu. The 95% settling time is approximately 47 ms. At this point the DC voltage has increased to 20.4kV. □□at t=0.2s the source voltage is increased to1.045pu of its nominal value. The STATCOM reacts by changing its operating point from capacitive to inductive to keep voltage at 1.021pu. At this point the STATCOM

absorbs 72Mvar and the DC voltage has been lowered to 18.2kV. Observe on the first trace showing the STATCOM primary voltage and current that the current is changing from capacitive to inductive in approximately one cycle.

□□at t=0.3s the source voltage in set back to its nominal value and the STATCOM operating point comesback to zero Mvar.

E. 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

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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 behavior, 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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