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Cascaded Multilevel Inverter Based Statcom with PSO Technique

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ABSTRACT

The STATCOM (static synchronous compensator) is the shunt connected FACTS device which is connected to a line via voltage source converter. Use of the STATCOM device is a best solution to mitigate the problem of reactive power compensation. The STATCOM can be used to improve power factor, reactive power compensation. In this project the shunt operation of FACTS controller (STATCOM) is working under load compensation and during the fault condition in the ideal transmission line network is done. The dc-link voltages of the inverters are regulated. Here PI controller is used to regulate the STATCOM. The gain value of the PI controller is obtained using PSO technique. This project illustrates the usage of STATCOM for reactive power compensation & power factor improvement in power system by proper modeling of VSC based STATCOM using MATLAB/SIMULINK.

Index Terms: Cascaded multilevel inverter based STATCOM, Particle Swarm optimization, MATLAB.

1. INTRODUCTION

With the advent of FACTS technology, the parameters of the power system such as shunt impedance, series impedance including current, voltage and phase angle are controlled.The application of flexible ac transmission system FACTS controller, such as a STATCOM is increasing in power systems. This is due to their ability to stabilize the transmission system and to improve the power factor in distribution system.

The STATCOM is popularly accepted as a reliable reactive power controller. The device provide reactive power compensation, active power oscillation damping, flicker attenuation, voltage regulation etc. The major attributes of STATCOM are quick response time, optimum voltage platform, less space requirement, excellent dynamic characteristics and higher operational flexibility under various operating conditions.

The voltage source converter connected in shunt with the ac system provides a multifunctional topology which can be used for voltage regulation and compensation of reactive power, correction of power factor, elimination of current harmonics. Generally var compensation is achieved using multilevel inverters.

These inverters consist of a large no of dc source which is usually realized by capacitor. The control of individual dc-link voltage is difficult. Static var compensation by cascading conventional multilevel inverter based STATCOM is an attractive solution for reactive power compensation.

The STATCOM is shunt connected device which is used for compensation, either by injecting or absorbing reactive power. Several researchers contributed their research on reactive power compensation. In this paper the STATCOM is controlled by Particle Swarm Optimization method. The Particle Swarm Optimization method is mainly used for efficient operation of STATCOM.

In this topology, it consists of standard multilevel inverter based STATCOM connected in cascade through open end winding of a three phase transformer. The dc-link voltages of the inverters are regulated.

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Thus in this paper, a static var compensation scheme is proposed for a cascaded two-level inverter-based multilevel STATCOM. The dc-link voltages of the inverters are regulated. It is also implemented using MATLAB/SIMULINK.

2. CASCADED MULTILEVEL INVERTER BASED STATCOM

The STATCOM model considered in this paper Fig.1 shows the cascaded multilevel inverter based STATCOM. The inverters are connected on the low-voltage (LV) side of the transformer and the high-voltage (HV) side is connected to the grid. The dc-link voltages of the inverters are maintained constant.

3. CONTROL STRATEGY

The control block diagram is shown in Fig. 2. The unit signals sinωt and cosωt are generated from the PLL using three phase supply voltage (v_a, v_b, v_c). The converter currents (i'_a, i'_b, i'_c) are transformed to the synchronous rotating reference frame using the unit signals. The switching frequency ripple in the converter current components is eliminated using a low pass filter. The controller generates the reference voltages. The inverter supplies the desired reactive current and draws required active current to regulate total dc-link voltage $v^*_{dc1} + v^*_{dc2}$. The additional control is required to regulate individual dc-link voltages of the inverters.

4. PARTICLE SWARM OPTIMIZATION

Particle Swarm Optimization Algorithm is developed from swarm intelligence and is based on the research of bird and fish flock movement behavior. Particle Swarm optimization has two primary operators: Velocity update and Position update. During each generation each particle is accelerated toward the particles previous best position and the global best position. At each iteration a new velocity value for each particle is calculated based on its current velocity, the distance from its previous best position, and the distance from the global best position. The new velocity value is then used to calculate the next position of the particle in the search space. This process is then iterated for a set number of times, or until a minimum error is achieved.

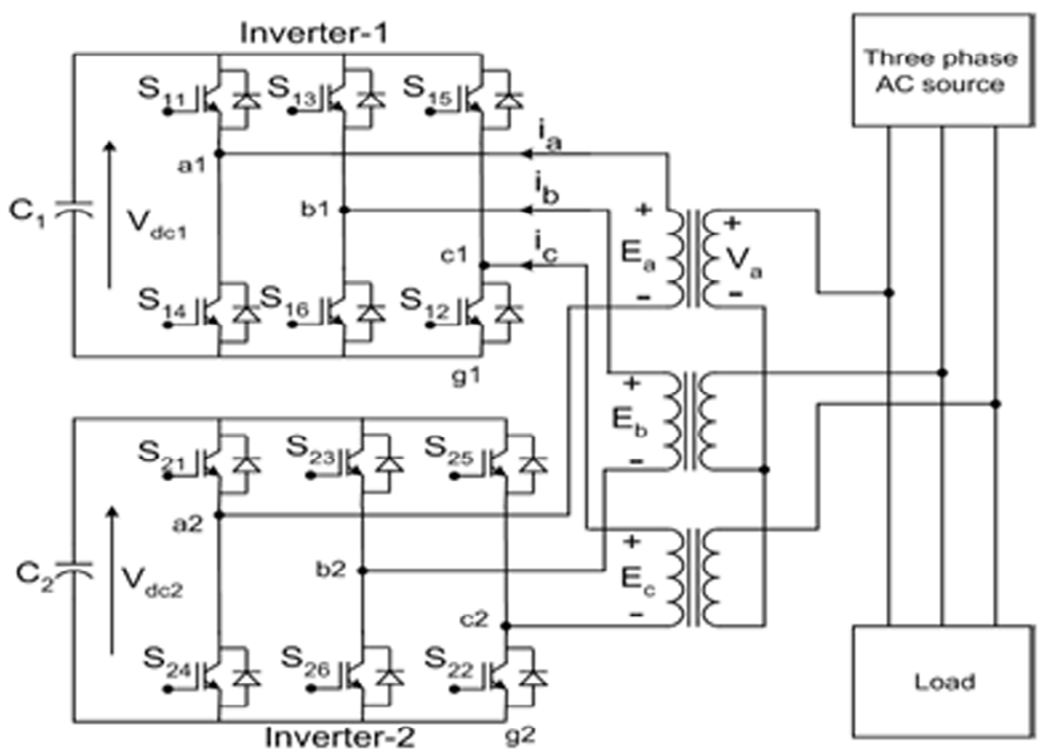

Figure 1: Cascaded multilevel inverter based STATCOM

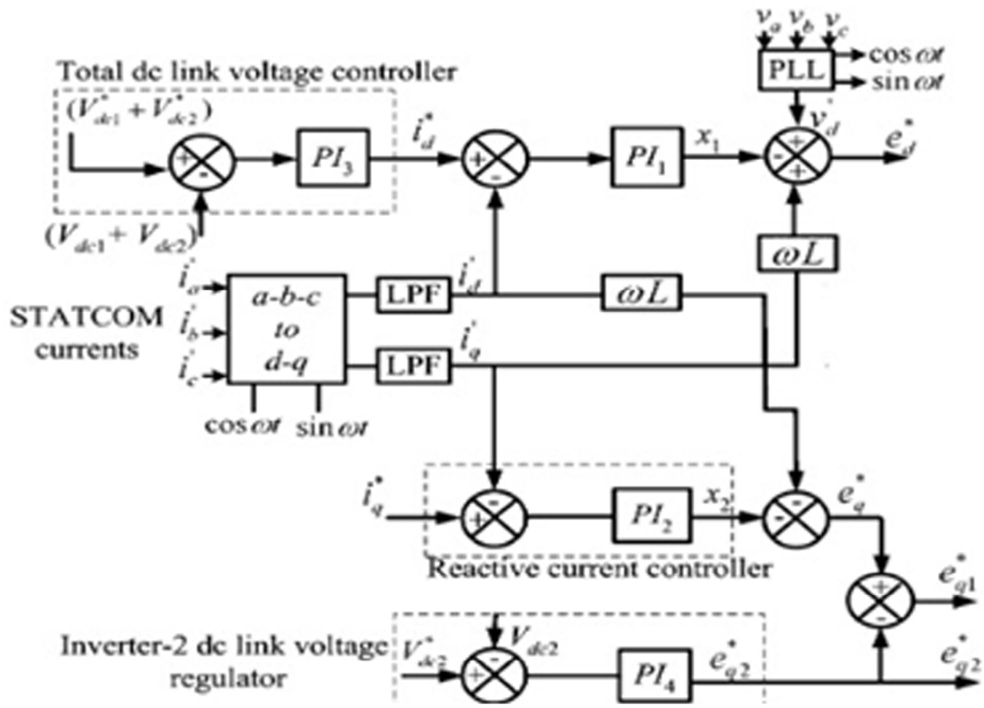

Figure 2: Control block diagram

$$V^{k+1}_{id} = V^{k}_{id} + C_1R_1^{k}(pbest^{k}_{id} - X^{k}_{id}) + C_2R_2^{k}(gbest^{k}_{d} - X^{k}_{id}) \quad (1)$$

$$X^{k+1}_{id} = X^{k}_{id} + V_{id} \quad (2)$$

In this equality, V^k_{id} and X^k_{id} stand for separately the speed of the particle “i” at its “k” times and the dimension quantity of its position; $pbest^k_{id}$ represents the d-dimension quantity of the individual “i” at its most optimist position at its “k” times. $gbest^k_d$ is the most optimist position. In order to avoid particle being far away from the searching space, the speed of the particle created at its each direction is confined between $-vd_{max}$, and $+vd_{max}$. If the number of vd_{max} is too big, the solution is far from the best, if the number of vd_{max} is too small, the solution will be the local optimum.C1 and C2 represent the speeding figure. They are used to regulate the length, when flying from one particle to another. Then, the most optimist individual particle of the whole swarm is selected.

5. ALGORITHAM

Step 1: Initialization-positions & velocities of particles are randomly generated.

Step 2: Velocity updation-Update the velocities of all particles at time k (current iteration) using the particles objective or fitness values.

$$V_l(k + 1) = WV_l(k) + C_1 \quad (3)$$

Step 3: Position updation-The Position of each particle is updated using its velocity vector as follows;

$$P_l(k + 1) = X_l + V_l(k + 1) \quad (4)$$

Step 4: memory updation-update, pi, best and $g_{i, best}$ when condition is met,

(i) $p_{i, best} = p_i$, if $f(p_i) > f(p_{i, best})$

(ii) $g_{i, best} = g_i$, if $f(g_i) > f(g_{i, best})$

Step 5: Stopping Criteria–The algorithm repeats steps 2 to 4 until certain stopping conditions are met, such as a pre-defined number of iterations. Once stopped, the algorithm reports the values of g_{best} and $f(g_{best})$as its solution.

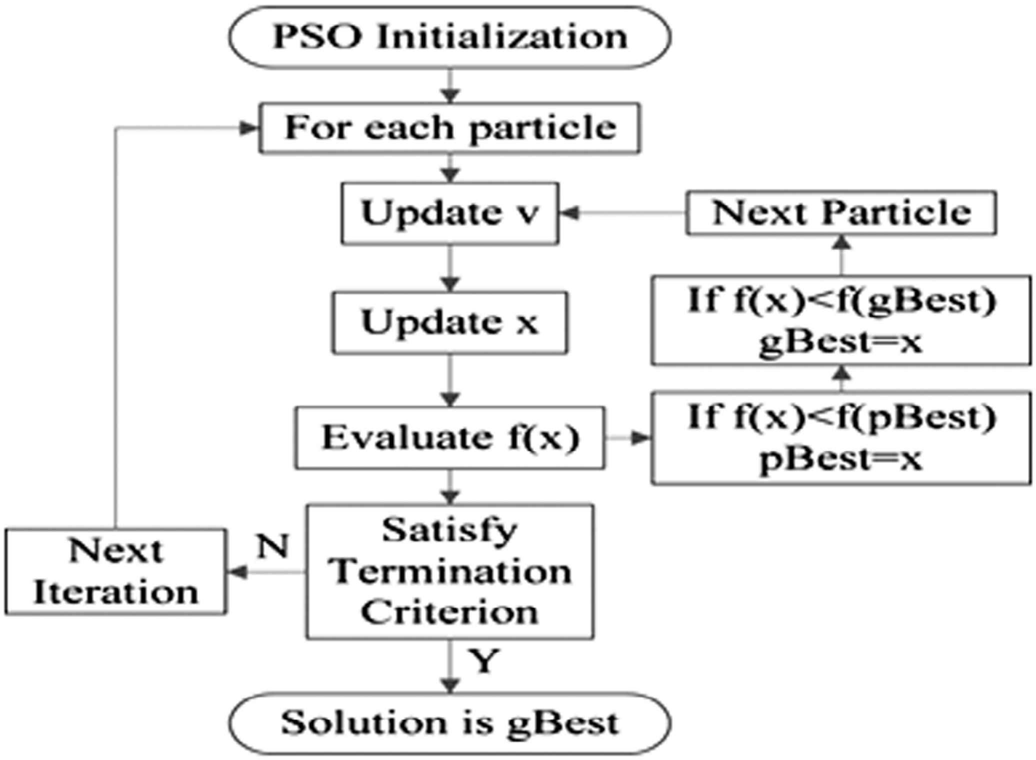

Figure 3: Flow chart for PSO algorithm

Using above pso algoritham the follwing Optimal gain values are obtained,

K_{p1} : 0.06434

K_{i1} : 0.071236

K_{p2} : 0.035154

K_{i2} : 0.05133

6. PROGRAMMING DETAILS

Table 1
Programming details

Content	*Data*
Population size	20
Parameters used	Kp1, Ki1, Kp2, Ki2, b best, gbest, Vdc1, Vdc2.
Maximum iteration	100
No. of execution times	20
Voltages	Vdc1 = 659, Vdc2 = 241

7. SIMULATION BLOCK DAIGRAM

The above block diagram consists of Cascaded two-level inverter based multilevel STATCOM using standard two-level inverters. To the low-voltage (LV) side of the transformer, inverters are connected and to the high-voltage (HV) side grid is connected. From the above diagram the power is transmitted from the AC source to the Load side through transmission line. Here the reactive power demand in the load side is compensated by using multilevel STATCOM. The multilevel STATCOM is controlled by using additional controller.

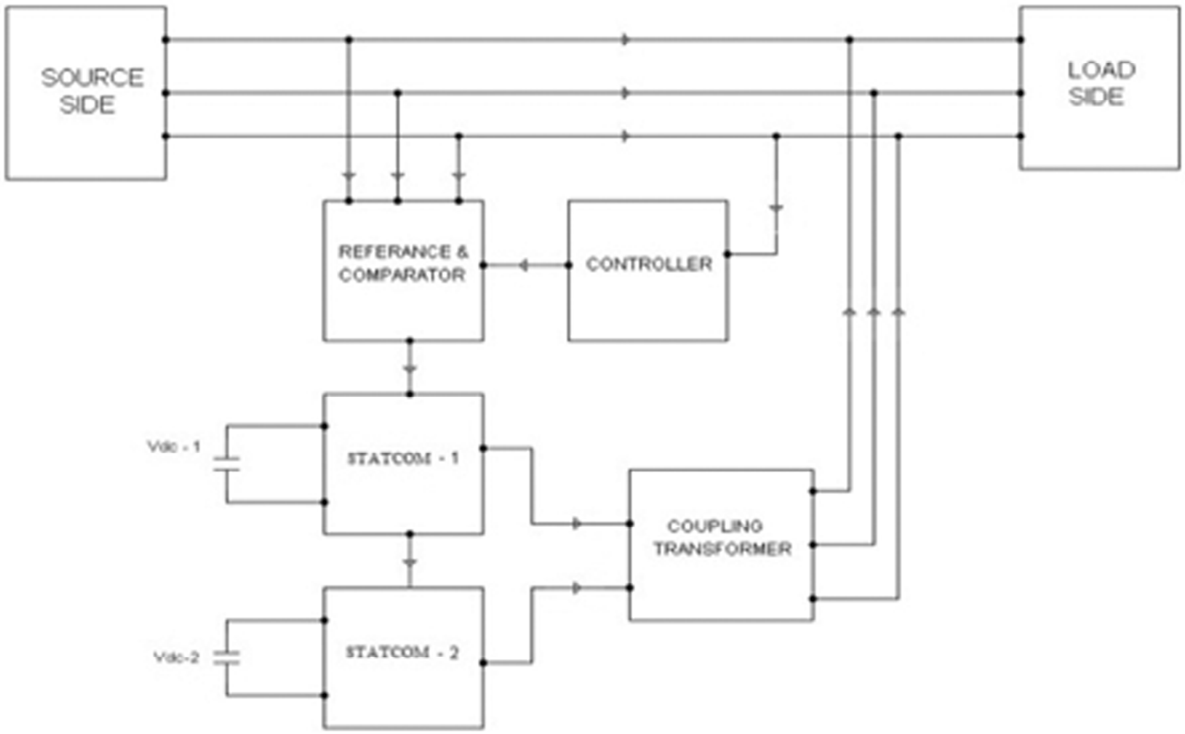

Figure 4: Block diagram of multilevel STATCOM

8. SIMULATION PARAMETERS

Table 2
Simulation parameters

Source voltages	380V(rms)
Switching frequencies	1200Hz
DC link capacitances C1, C2	6600µF
AC supply frequency, f	50Hz
Carrier frequency	1200Hz
Transformer ratings	11 KV/1200V
DC-link voltages(Vdc1, Vdc2)	659V,241V

9. CONTROLLER DAIGRAM

Fig. 5 shows the gain values of the PI controller is obtained using PSO technique. The best value (i.e) the gbest value which suits the system is obtained using the above SIMUATION diagram.

10. SIMULATION DIAGRAM

10.1. Reactive Power Compensation (With Statcom)

Fig. 6 shows the modeling of simple power system in MATLAB/Simulink using the active and the reactive power blocks available in simpower. The real and reactive power that flows, through the line are measured.

Fig. 7 & Fig. 8 show the source voltage & current, load voltage & current. The modeling is done by connecting a three phase source and RL load through a transmission line. Here the line voltage is maintained at 380V (rms value) and the frequency is 50Hz. The reactive power gets compensated using STATCOM WITHOUT STATCOM

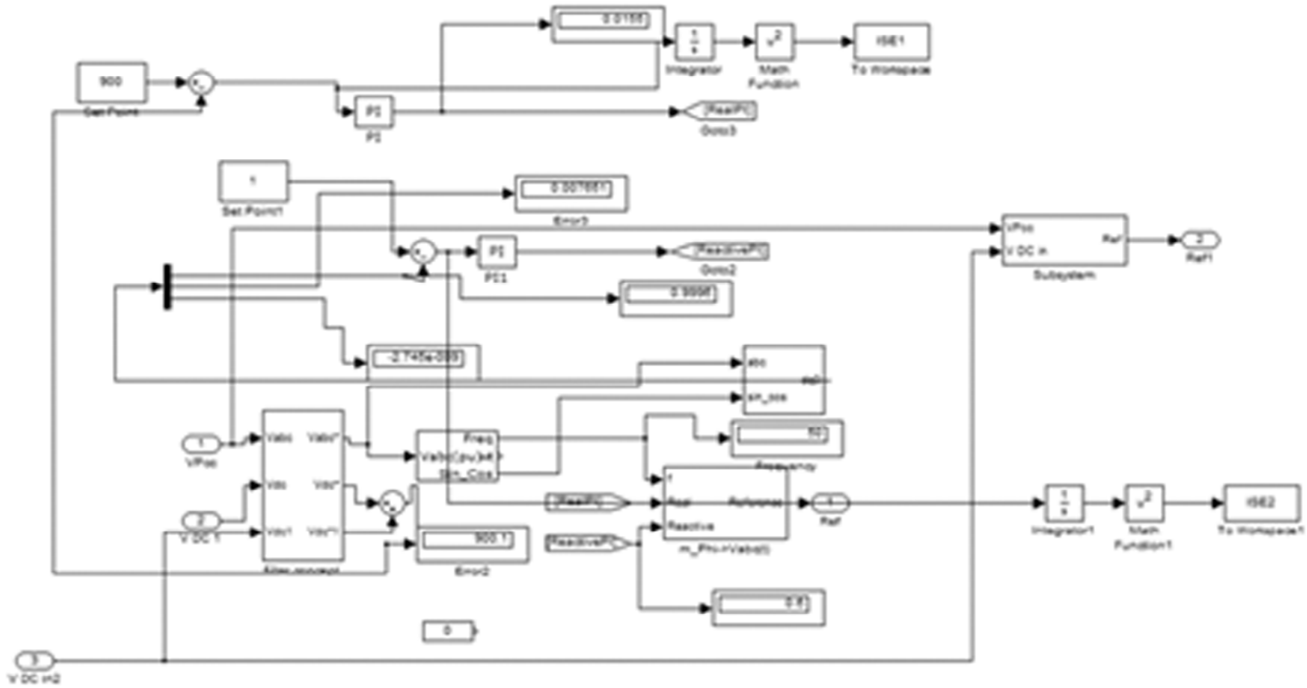

Figure 5: PSO based PI controller

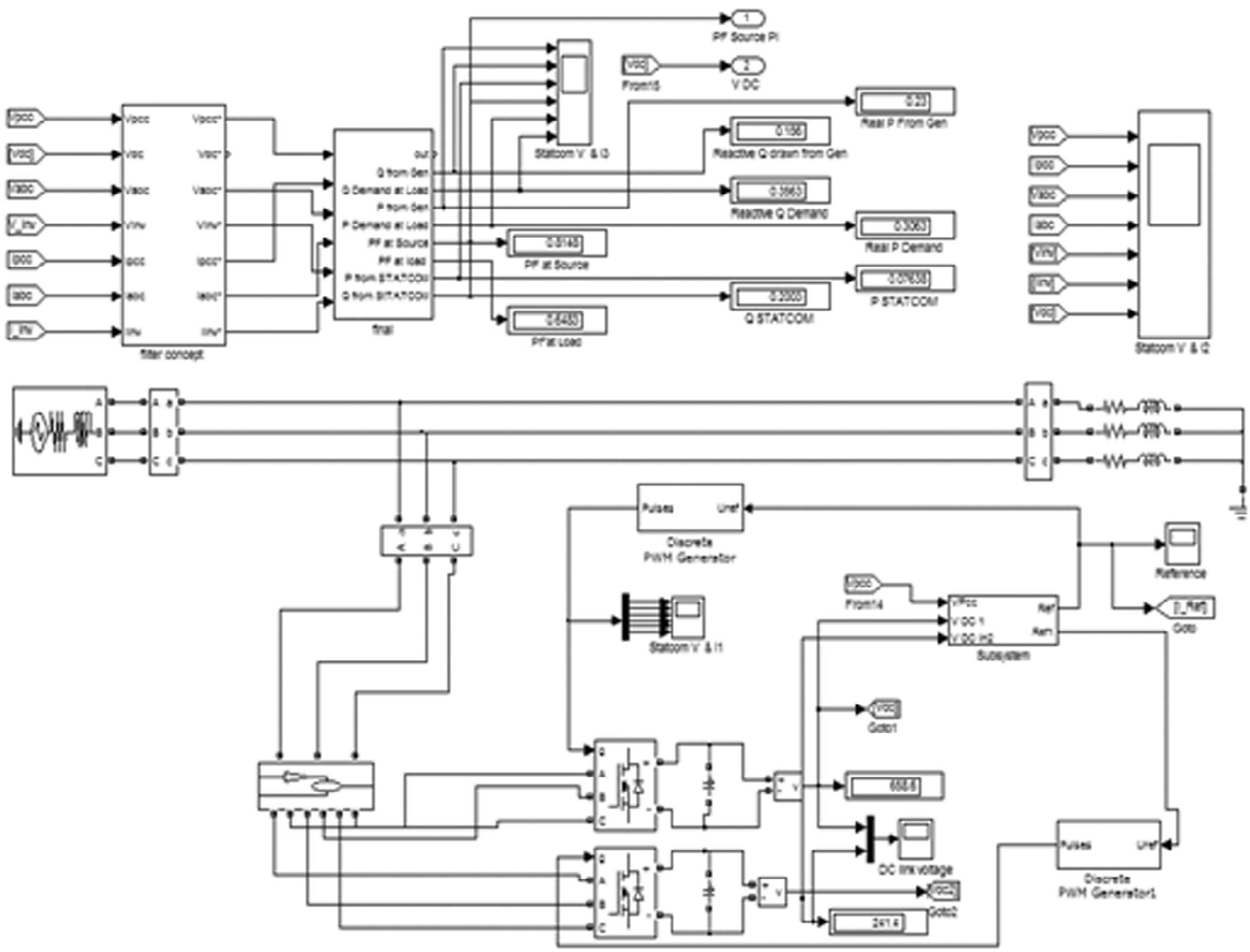

Figure 6: Simulation diagram of simple power system with STATCOM

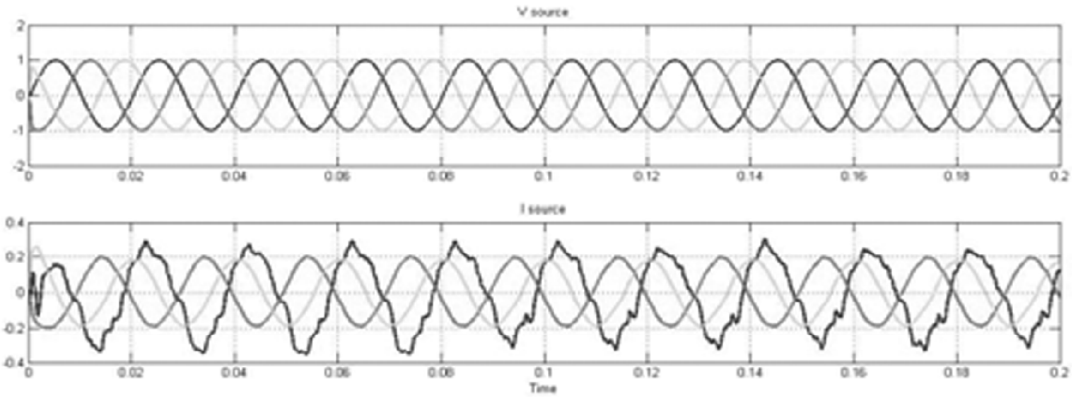

Figure 7: Source voltage & current waveform

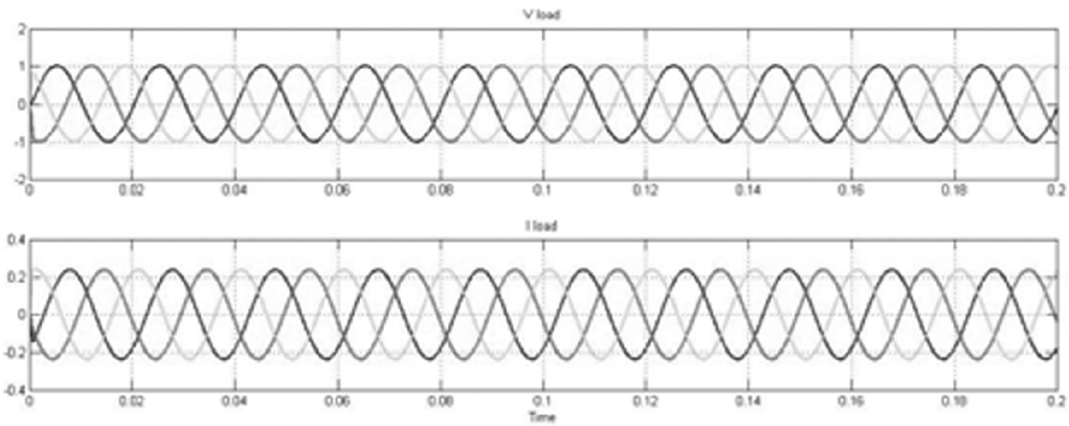

Figure 8: Load voltage & current waveform

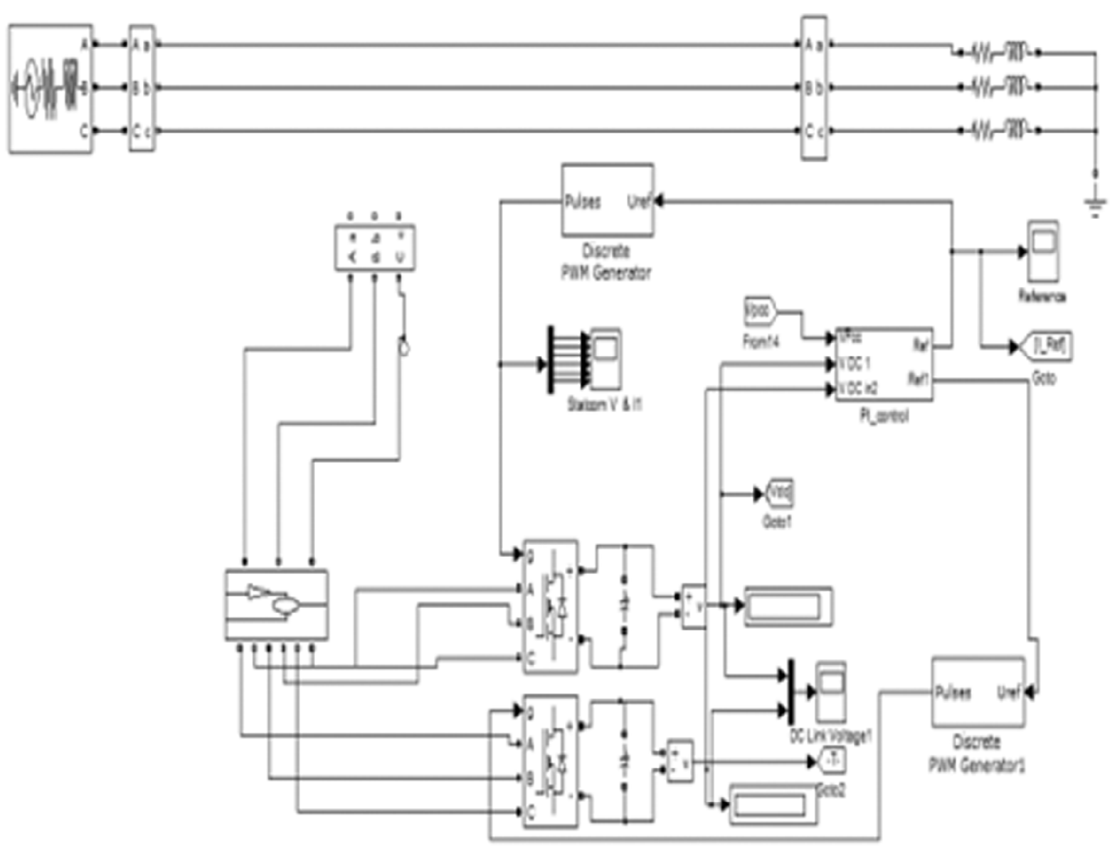

Figure 9: Simulation diagram of simple power system without STATCOM

Fig. 9 shows the simulation diagram of power system without STATCOM .Here the STATCOM is not connected to the system so it cannot maintain the dc link voltage as constant under the real & reactive power compensation, load compensation and 3 fault condition.

Fig .10 shows the real power and reactive power flows through the source to load side. Here the transmission system losses gets increased and power transmission capability of the system gets reduced because of not using the STATCOM device. Here the STATCOM not supplying the real and reactive power to the load demand.

Table.3 shows the real and reactive power generation from source, load and STATCOM

Under without STATCOM Condition the Real and Reactive power generation from STATCOM is 0, so the real & reactive power demands at load that cannot be compensated.

Under with STATCOM Condition the real & reactive power demands at load that can be compensated by using the FACTS devices like STATCOM.

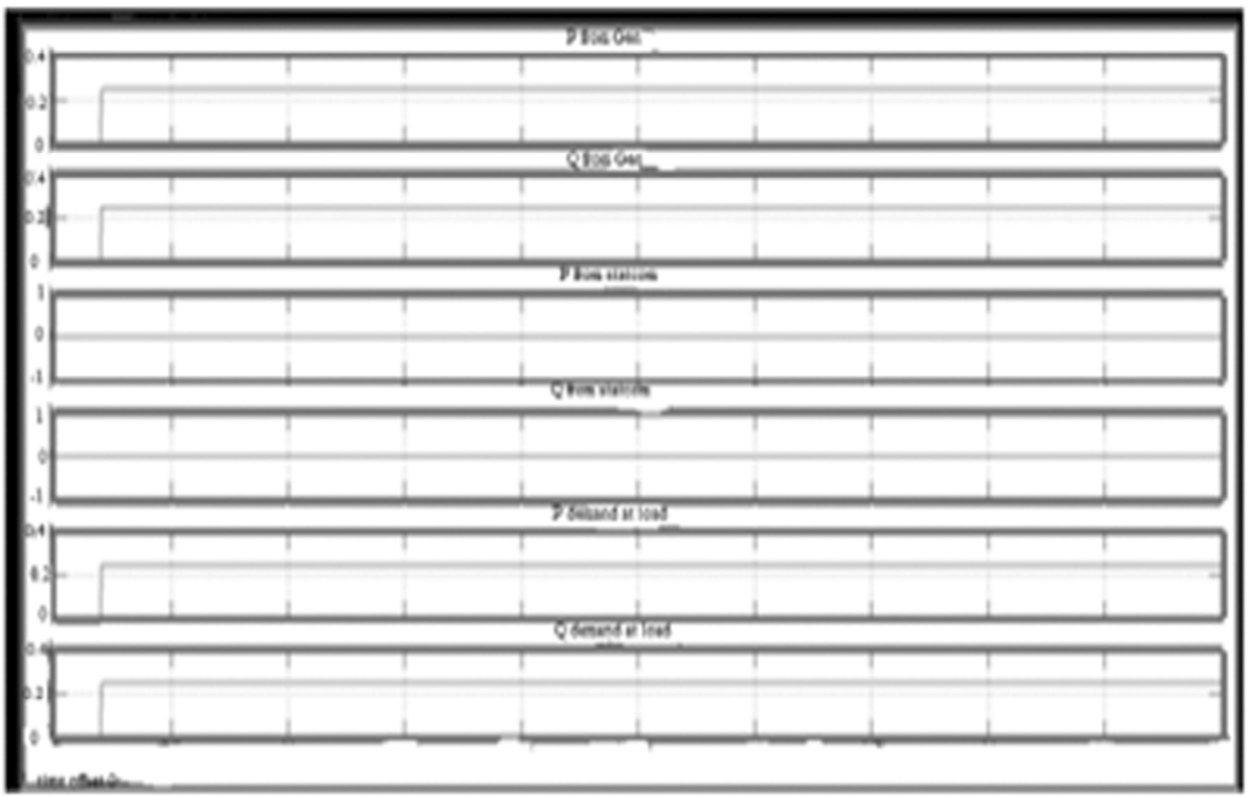

Figure 10: Simulation result of simple power system without STATCOM

Table 3
P&Q Demand under Reactive Power Condition

S. No	*Power*	*Without Statcom (pu)*	*With Statcom (pu)*
1	P from Generation	0.2494	0.1706
2	Q from STATCOM	0	0.07916
3	P Demand at load	0.2494	0.2498
4	Q from Generation	0.2494	0.0717
5	Q from STATCOM	0	0.1781
6	Q Demand at load	0.2494	0.2498

10.2. Under Fault Condition

In this case, a three phase fault is created at t = 0.4ms (transition time = [0.03 0.08]). The fault is cleared after t = 0.08sec. In this fault condition the dc link voltage of the inverter 1 & inverter 2($V_{dc}1$ = 659V, Vdc2 = 241V) is maintained at constant value by using the PI controller.

Fig. 13 shows the source voltage and source current waveform & Fig. 14 shows the load voltage & load current under fault condition at transition time t = [0.03 0.08]. At time t = 0.03s the fault is created then at time = 0.08s the fault is cleared. During this fault condition the controller maintained the capacitor voltage $V_{dc}1$ = 659V, $V_{dc}2$ = 241V as constant under three phase fault condition.

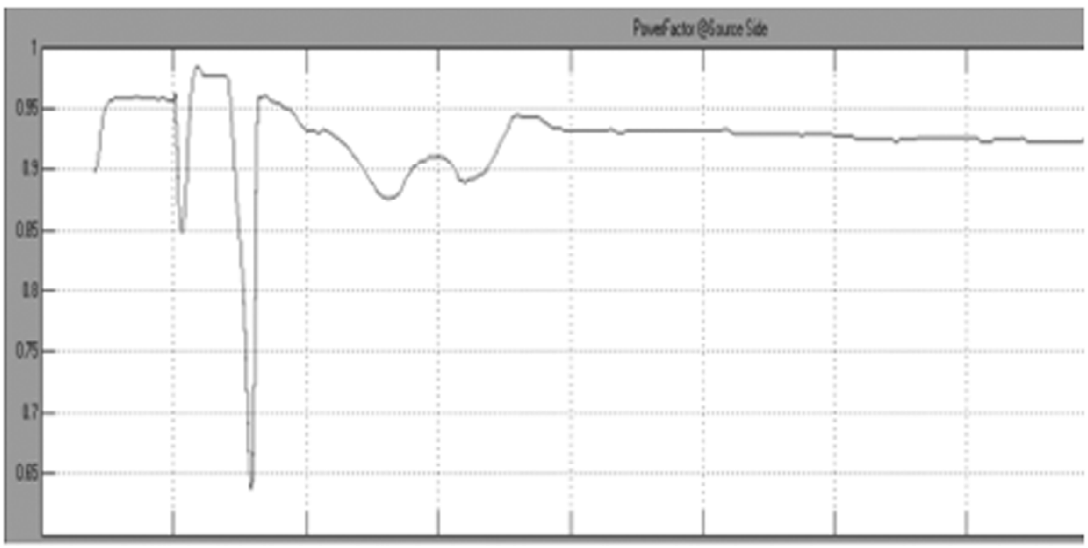

Figure 11: Shows the source side power factor

With Statcom (3 Fault Condition)

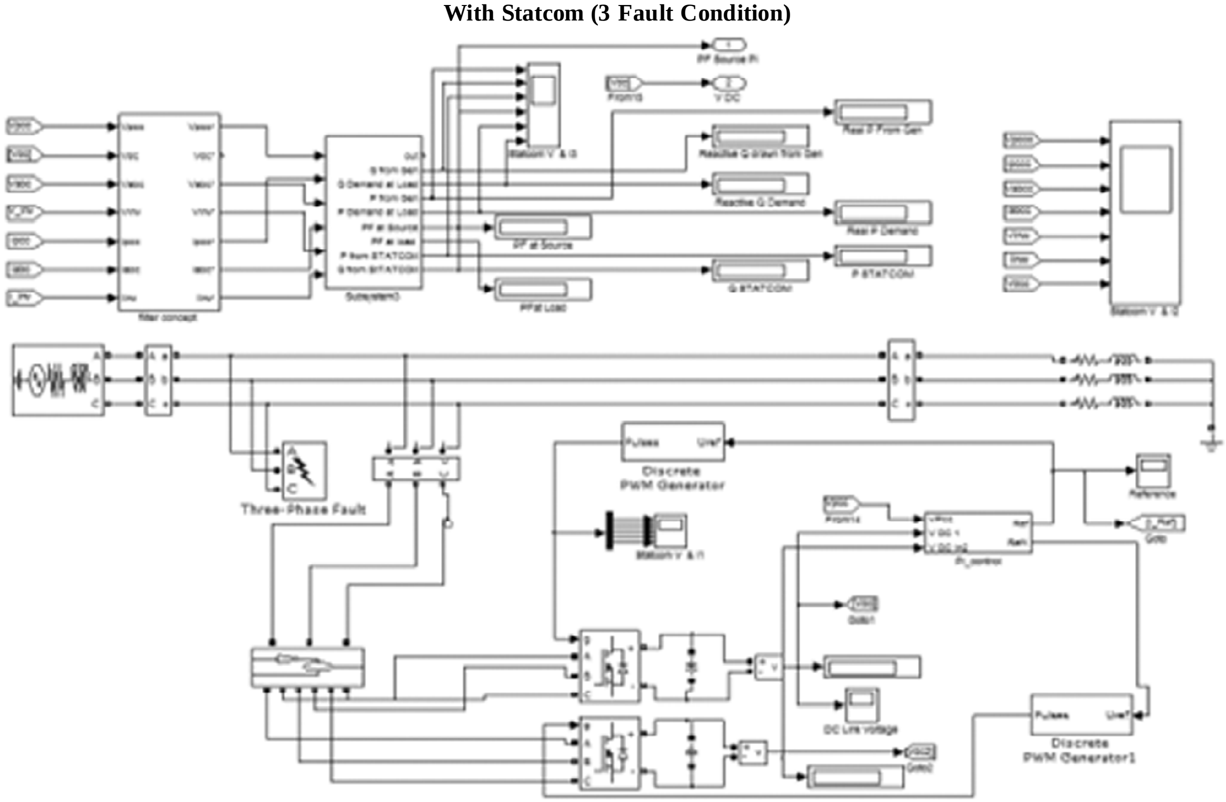

Figure 12: Simulation diagram of simple power system with STATCOM (under 3 fault condition)

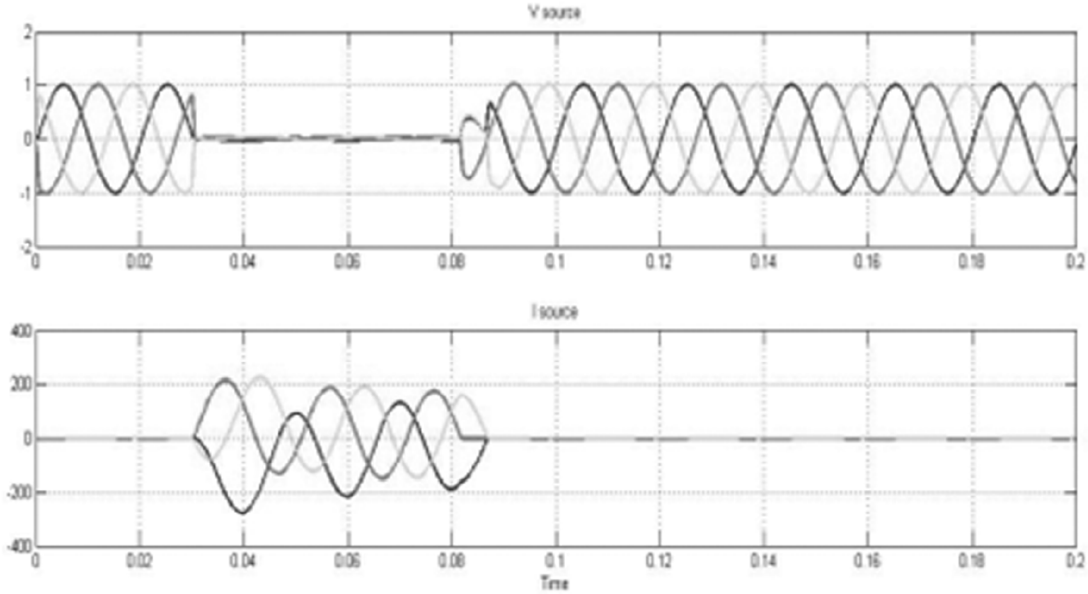

Figure 13: Source voltage & current waveform

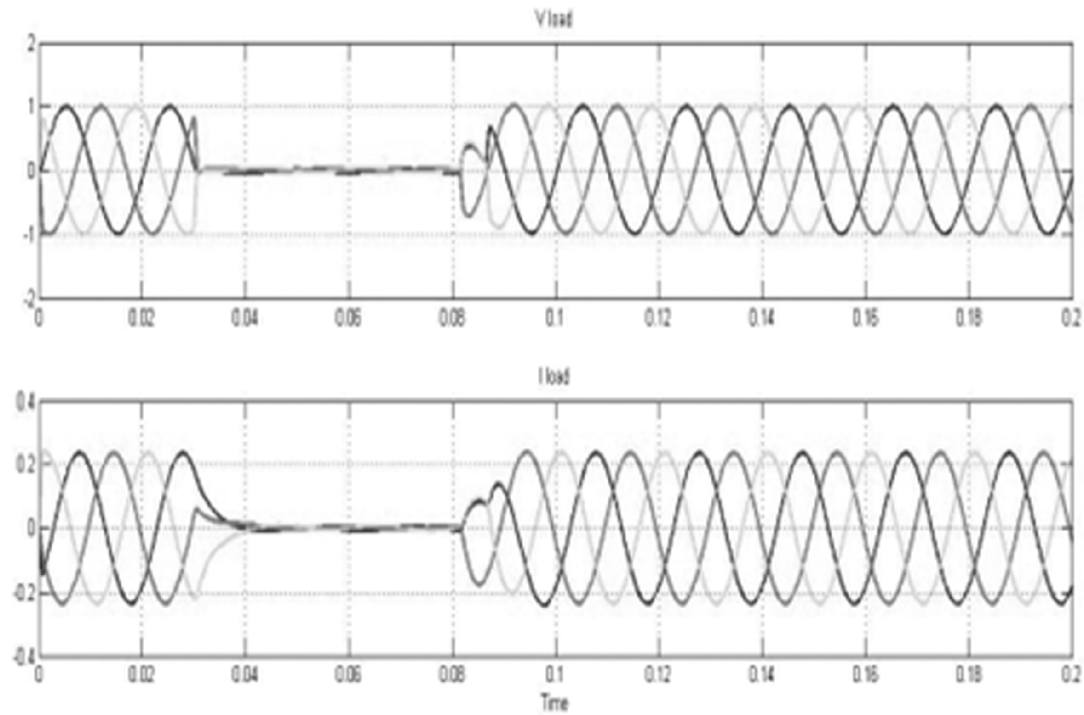

Figure 14: Load voltage & current waveform

Table 4
P & Q Demand under 3 Fault Condition

S. No	*Power*	*Without Statcom (pu)*	*With Statcom (pu)*
1	P from Generation	0.2495	0.3005
2	Q from STATCOM	0	-0.0506
3	P Demand at load	0.2494	0.2499
4	Q from Generation	0.2494	0.01532
5	Q from STATCOM	0	0.2346
6	Q Demand at load	0.2494	0.2499

10.3. Load Compensation

By using breaker the over load is added. Here the line voltage s is maintained at 380V (rms value) and the frequency is 50Hz. The reactive power gets compensated using STATCOM Here the STATCOM provides reactive power during the load compensation.

Fig. 16 & Fig. 17 show the source voltage & current and load voltage & current. In this case the transition time Ts = [0.1 0.15] the load is decreased (10MW), here the reactive power that can be compensated & capacitor voltages $V_{dc}1 = 658.1V$ & $V_{dc}2 = 241.8V$ are maintained as constant by using the PI controller.

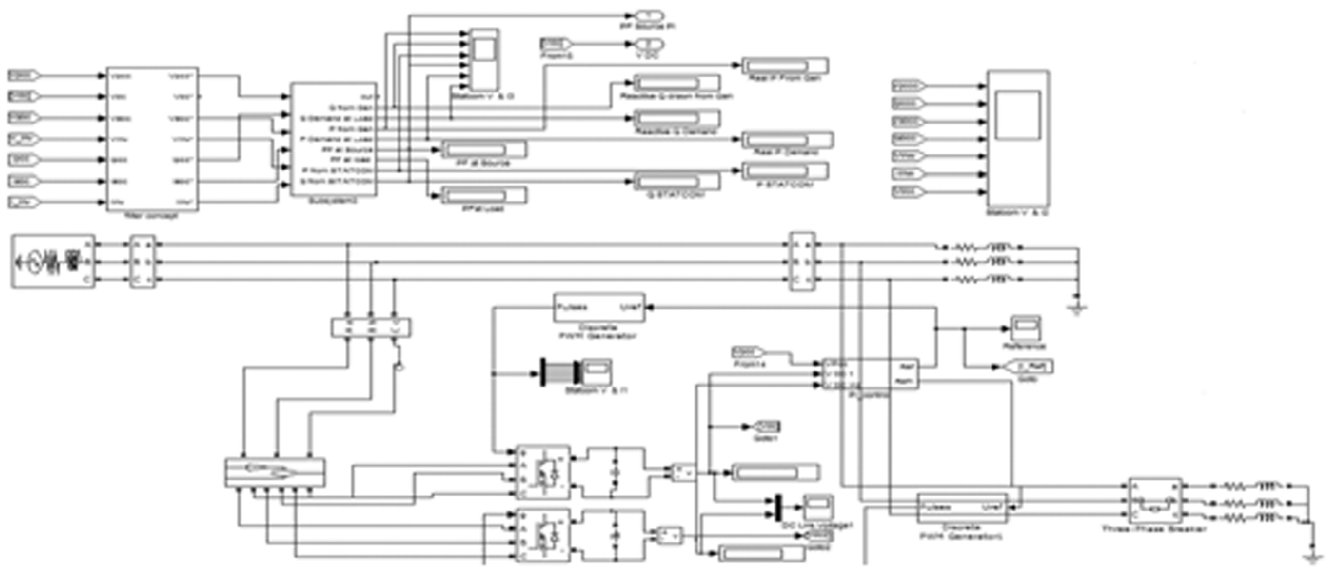

Figure 15: Simulation diagram of simple power system with STATCOM (under Load compensation)

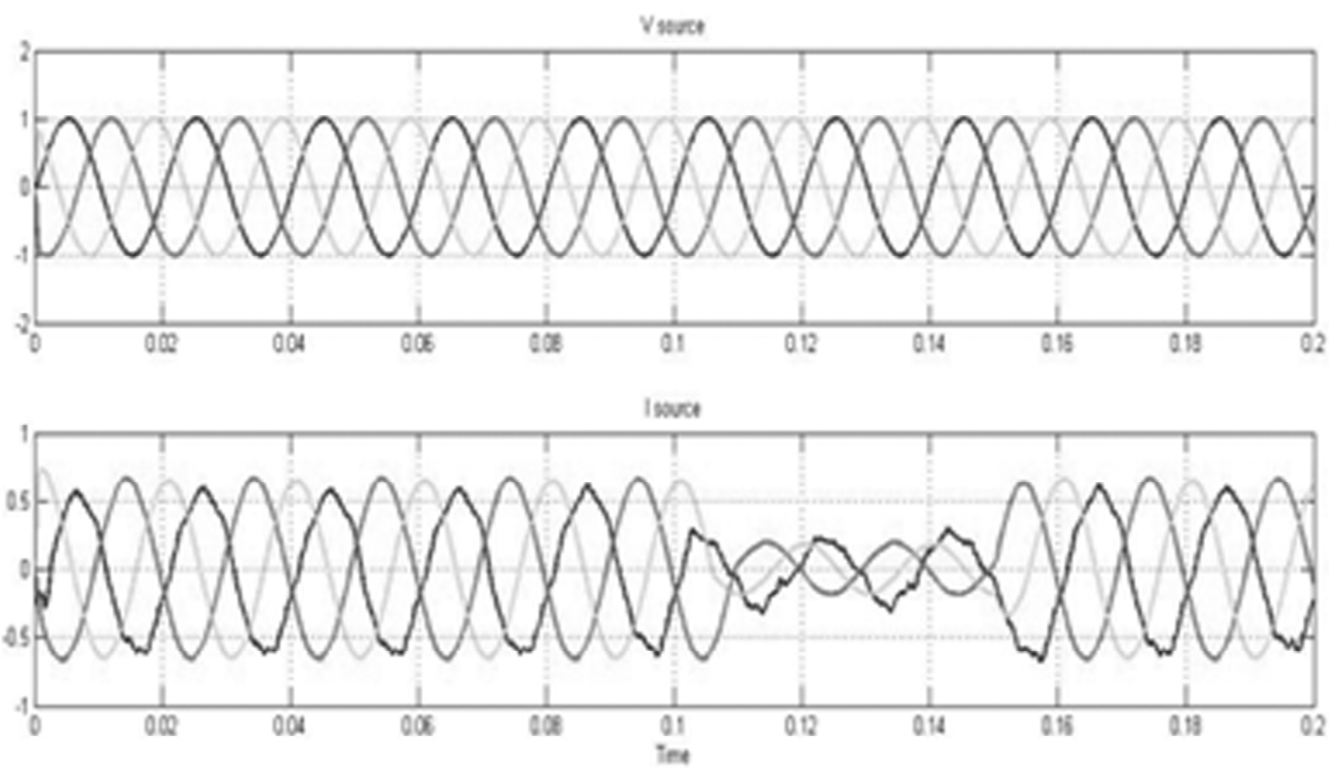

Figure 16: Source voltage & current waveform

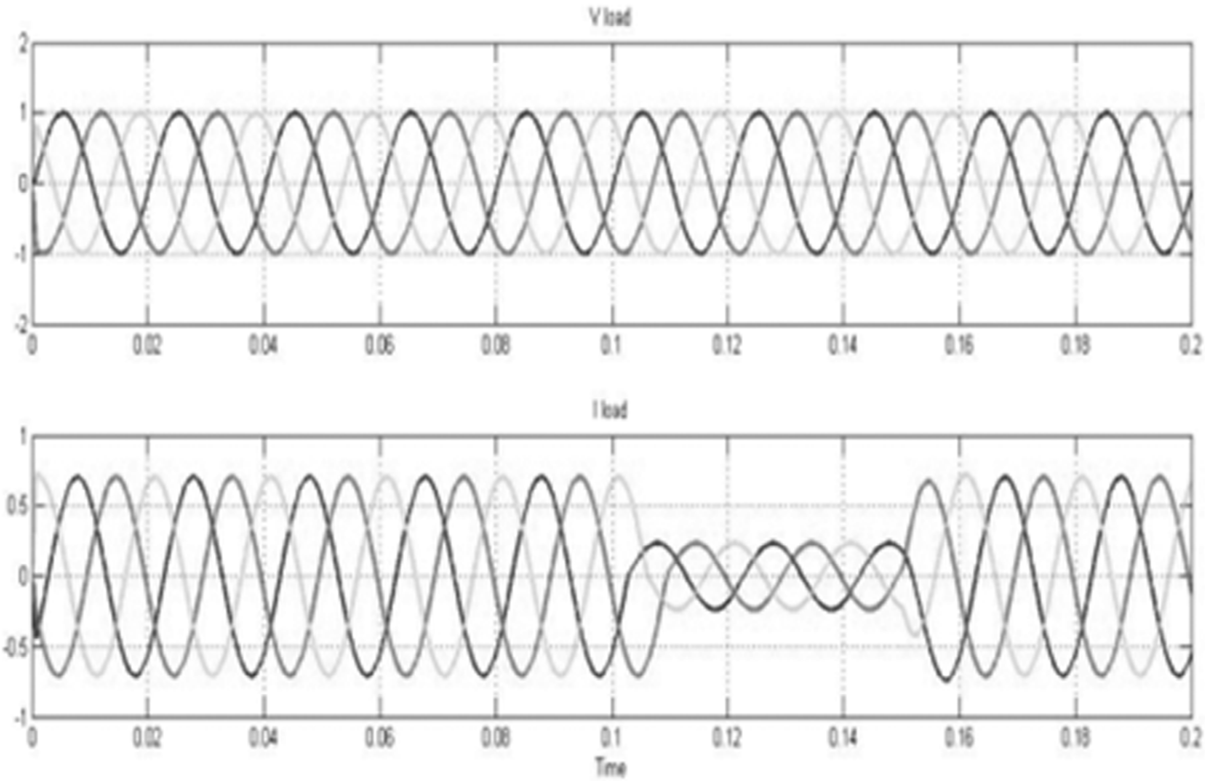

Figure 17: Load voltage & current waveform

Table 5
P&Q Demand under Load Compensation

S. No	*Power*	*Without Statcom (pu)*	*With Statcom (pu)*
1	P from generation	0.7451	0.75
2	Q from STATCOM	0	-0.00376
3	P Demand at load	0.7451	0.7463
4	Q from Generation	0.745	0.5422
5	Q from STATCOM	0	0.2041
6	Q Demand at load	0.745	0.7463

10.4. Maintenance of Dc link voltage

The dc link voltage of the capacitors that can be maintained at constant level ($V_{dc}1$ = 659V, $V_{dc}2$ = 241V)

Fig.18 shows the maintenance of the DC link voltage of the inverter at constant Value under Reactive power control, under fault condition, under Load compensation.

Table 6
Capacitor voltages of two inverters for different cases

S. No	*Conditions*	*Capacitor Voltages*	
		$V_{dc1(Volt)}$	$V_{dc2(Volt)}$
1	Reactive Power Control	658.6	241.5
2	Under Fault Condition	658.6	241.5
3	Load Compensation	658.6	241.5

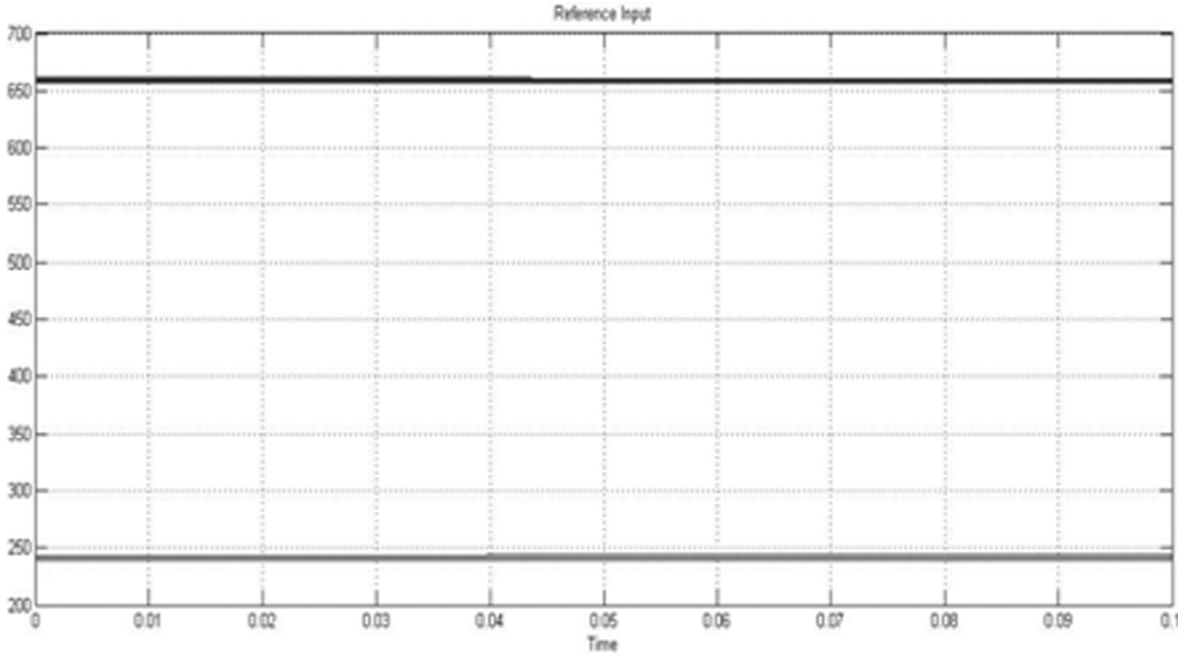

Figure 18: Dc link voltage of two inverters

11. CONCLUSION

DC link voltage balance is one of the major problem in cascaded inverter based multilevel STATCOM. In this paper, the DC link voltage of the inverter is maintained at constant value. In the ideal transmission line, reactive power compensation is provided by the STATCOM. PI controller is designed using PSO technique to get better optimization. The power factor is improved for this kind of optimization. The STATCOM provides the reactive power compensation during the fault condition and load compensation. So that transmission losses get reduced and power transfer capability of the system is improved.

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