Experimental Verification of STATCOM for Power Quality Improvement

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Abstract*: This paper aims in presenting the importance of presence of STATCOM for enhancement of power quality of existing transmission network. STATCOM is used for controlling various transmission parameters such as shunt impedance, line voltage, current, active and reactive power, oscillation damping etc. Experimental controlled reading of STATCOM is obtained with the help of lab model for various parameters. Controlling is done with the help of IGBT based converters through DSP kit (for controlling firing angle of converters).This paper also presents a lab prototype of STATCOM.*

Keywords: STATCOM, VAR, VSC, VFCT, FACTS, DSP.

1. Introduction

With the increase in load demand, we have to increase the generation & require proper channel to transfer electrical power from generating end to receiving end which is highly efficient in nature (i.e. transmission line). But when we try to add one or more number of generator to the existing transmission network then system suffers from large number of problems such as reduction in power , voltage dip, interruption , over voltage etc which can cause ill effect to the power system quality. It is necessary to maintain or enhance the quality of the network in order to get efficient power flow. Adding large number of generating to the existing transmission makes it more and more complex. Hence designing of such system is really a hectic job or we have to redesign the whole system by selecting the proper filter rating, power system stabilizer etc. We can use the traditional controller also for controlling power flow of this lines but frequent tuning is again a problem. Hence to overcome from above mention problem, we can use the fast acting power electronics controllers called FACTS devices. In late 1980's, Electric power research institute introduce the new technology called Flexible AC Transmission Technology and the controller used for controlling power flow is known as FACTS devices. Deregulated environment is again one of the major causes of making line network more and more bulky. The AC system cannot be preferable for long transmission of power because of high transmission losses but by using this technology we can able to transfer the AC power for long distance.

2. STATCOM

2.1 Reactive Power Compensation Principle

Generally in linear circuit, the reactive power is defined as the ac component of instantaneous power with frequency equal to 100/120 Hz in a 50 or 60 Hz system. The reactive power generated by ac source is stored in the form of reactance in capacitor or reactor during a quarter of a cycle and in next quarter of cycle it is send back to power source.

So the reactive power oscillate between the ac source and capacitor or reactor and also between them at a frequency equal to two times the rated value(50/60Hz).For this reason it can be compensated using VAR compensator or generator, avoiding circulation between load(inductive or capacitive) and source. Thereby improving the voltage stability of power system. Reactive power compensation can be implemented with VAR compensation connected in series or parallel. Here we consider reactive power compensation by using shunt compensation.
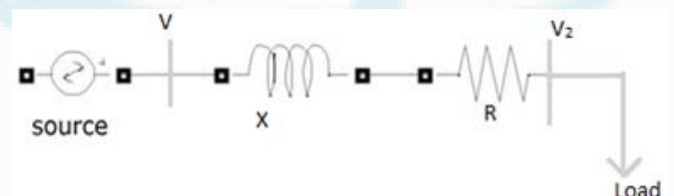

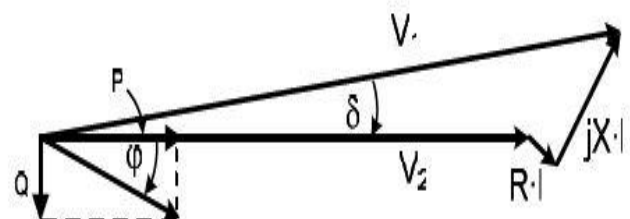**Figure 1:** Line diagram of transmission line model

Figure 2: Phasor diagram of transmission line model

2.2 Shunt Compensation

The principles and theoretical effect of shunt reactive power compensation in a basic ac system comprising of source, power line and load. For system without compensation, the phase angle of current has been related to load giving active power in phase with load voltages. Since load assumed inductive it requires reactive power for proper operation and hence source must supply it which increases the current through source side via power line. If reactive power is supplied near load, the line current may be reduced which

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results in reduced power loss and improves the voltage regulation at load terminals. This can be done using current source, voltage source or with a capacitor. Current source device is used to compensate reactive components of load current which improves the voltage regulation of system and reactive current components from source is also reduced. If lad needs loading compensation then inductor is required. A current source/voltage source can be required for inductive shunt compensation. The main advantage using this voltage or current source, VAR generator is that reactive power generated is independent of voltage at point of connection.

2.3 Function of STATCOM

The STATCOM is a regulating device which can be used to regulate the flow of reactive power in the system independent of other system parameters. STATCOM has no long term energy support on the dc side and it cannot exchange real power with the ac system. In the transmission systems, STATCOMs primarily handle only fundamental reactive power exchange and provide voltage support to buses by modulating bus voltages during dynamic disturbances in order to provide better transient characteristics, improve the transient stability margins and to damp out the system oscillations due to these disturbances. The STATCOM consists of a three phase inverter (generally a PWM inverter) using IGBTs, which is the intelligent power module. D.C capacitor which provides the D.C voltage for the inverter, a link reactor which links the inverter output to the a.c supply side, filter components to filter out the high frequency components due to the PWM inverter. From the d.c. side capacitor, a three phase voltage is generated by the voltage source converter. This is synchronized with the a.c supply. The link inductor links this voltage to the a.c supply side.

2.4 Shunt Controllers

Shunt controller is a variable impedance, variable source ac combination of both. All type of shunt controller inject current into system at point of connection. As long as injected current is in phase quadrature with line, shunt controllers only supplies variable reactive power. Any of these phase relationship will get involved for handling real power as well. Static synchronous compensator, STATCOM is one among the type of shunt FACTS controllers.

This paper gives the method of controlling active and reactive power of transmission line when STATCOM is connected at the sending end. This type of controlling can be done with the help of PWM technique by using STATCOM voltage converter and this controlled signal is given to the converter so as to control the parameter of transmission line and provide reactive power compensation. The shunt controller compare Vdc measured and Vdcref and produce error which is given to PI controller, in order to produce the required shift as shown below:
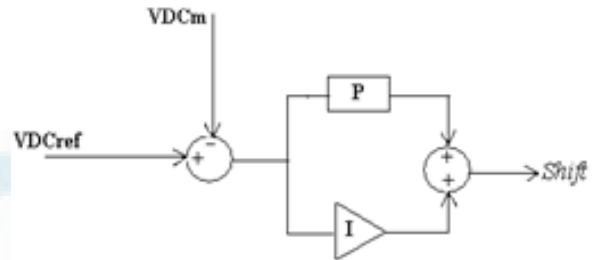

Figure 3: STATCOM DC voltage controller

3. Lab Prototype

3.1 Lab Prototype Specification

VSC based facts controller trainer model: VFCT-100

The main parts of experimental panel are:

1. Transmission line simulator module
2. Voltage Source Converter (VSC)
3. Transformer with LC Filter
4. Digital Meters and Load Setup

1. Transmission Line Simulator Module
- L=24mh/ph
- R=8 ohm/phase
- Input Voltage=3phase,415V
- Input Current=4A per phase
- Length=200km

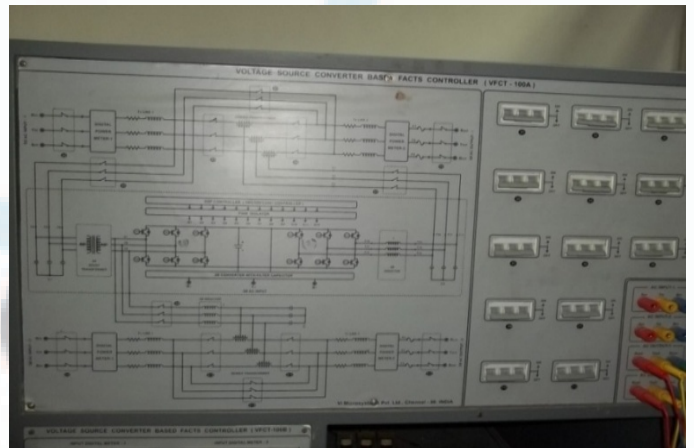Figure 4 drawn below Shows transmitter line simulator module.

Figure 4: Transmission line simulator module

3.2 Voltage Source Converter (VSC)

It consists of two no's of IGBT base converter along with 1 no of DSP kit for controlling firing angle of signals. It consists of following:

1. IGBT based Power Module - 02 No's
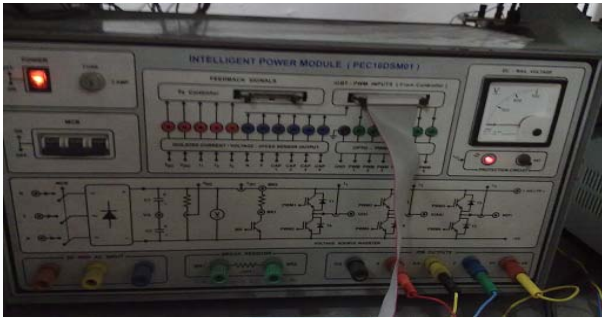2. TMS320F2407 based DSP Controller - 01 No.

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Figure 5: Intelligent Power Module

- 600V, 20A 3phase IGBT based Inverter Bridge for both the VSC.
- 1200V, 25A Uncontrolled rectifier with capacitor of 440 micro farad for both the VSC.
- Input Voltage: 3 Phase, 415V.
- Outputs of IGBTs in DIPM terminated at banana sockets,
- Hall sensors provided to sense dc links voltage, dc link current & the DIPM output currents, 6 high side and 6 low side high speed opto coupler to isolate gating signals to DIPM.
- Independent onboard power supplies to all channels.
- Optically isolated fault output DIPM.
- Build in control power supply.
- Test point on the front panel to monitor/measure the voltage and current as well as control power supply.
- DC voltmeter to measure the dc link voltage.
- Protection for short circuit, over current, earth fault, over voltage, under voltage and over temperature provided.
- Output AC: variable frequency and voltage
- FRC connector provided to interfaceTMS320F2407A DSP trainer with DIPM.
- 1 no. of 1KVA auto transformer for VSC input voltage.

Here we are using two VSC's back to back operation via common dc link. The capacitor terminals of VSC 1 and 2 are available on left side of module. If we want to form the UPFC then we have to short these two VSC capacitor terminals

3.3 TMS320F2407A Based DSP Trainer (MICRO-2407A)

Figure 6: DSP Trainer TMS320F2407

- In this DSP controller the program has been fixed. The PWM outputs are given to two VSC's. We can vary the

pulse by using increment and decrement keys provided in this unit. We have separate pulses for each unit. The processor is running at 25ns instruction cycle time.
- Input:230V AC
- Output:5V/3.0A,12V/150Ma

3.5 Transformer with LC Filter

- 1 No. of 3 phase 1 KVA transformer acts as shunt transformer with capacitor filter provided for STATCOM applications.

(a)

(b)

Figure7: (a) Digital Meters **(b)** 3 phase RLC Load

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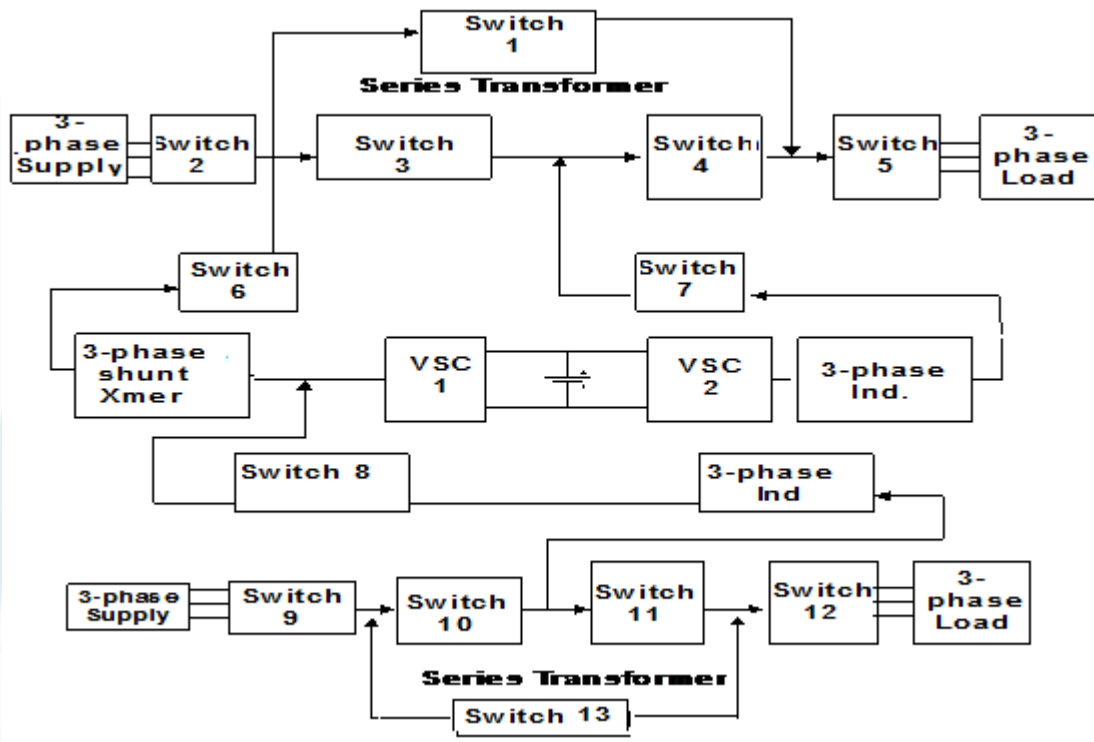
3.6 Block Diagram of Prototype
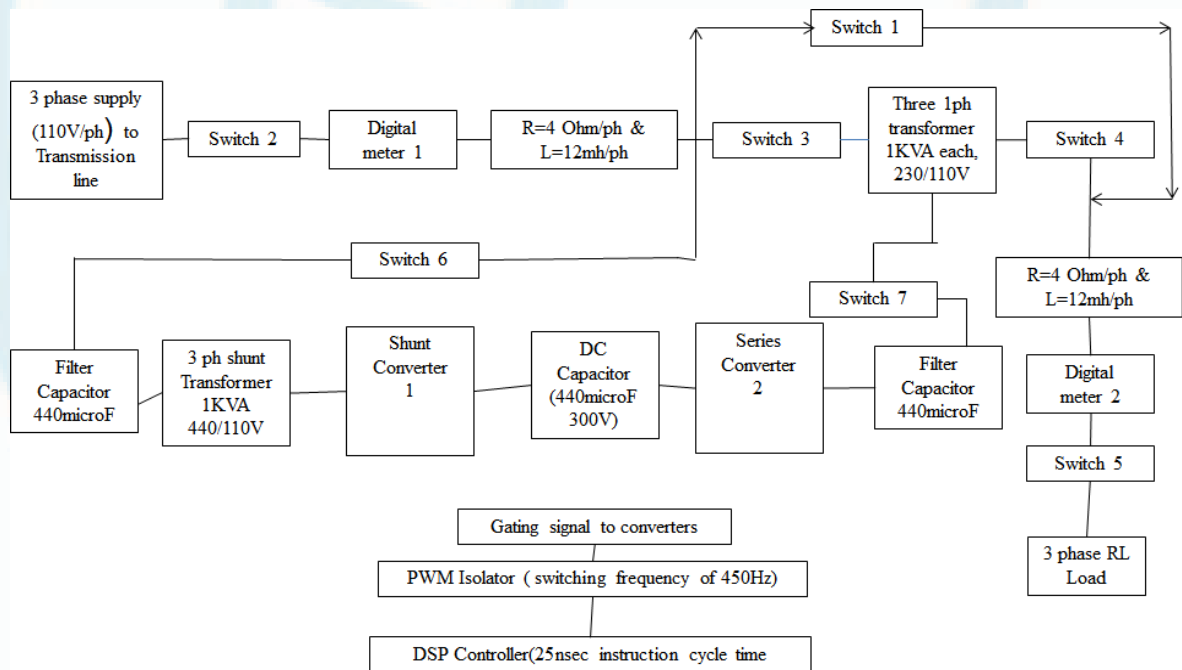

Figure 8: General block diagram

Figure 9: Detailed block diagram with specification for STATCOM

4. Working of Prototype as STATCOM

This panel consists of various elements such as voltage source converter, transmission line, DSP kit, shunt transformer, switches, filters etc. There are 13 switches as shown in above fig. 8 for forming different devices. Switch on the three phase supply for auto transformer and single phase supply for VFCT 100 model .Now vary the auto transformer voltage gradually to 230V from input source.

After setting the input voltage, switch on MCB 2.The input digital meters shows the input voltages and currents(R, Y, B) respectively. Add some load and switch on 3, 4 MCBs. The input/output meters show the sending end, receiving end voltages and currents. The receiving end voltage is lower than sending end voltage because of transmission line losses. Next switch on the voltage source converter (VSC1) and press reset switch of converter, thereafter switch on MCB 6 ,after that switch on the DSP kit 2407 processor. Vary the voltage from 0% to 90% by using the push button of DSP

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kit. Hence, producing the controlled output pulse to VSC. The VSC phase angle is adjusted by changing the toggle switch selection and the push button for lagging or leading the injected voltage. If we want to take readings without STATCOM switch on supply of switch 1, Switch 2, switch 5 and load. Take the readings for various parameters such as sending and receiving end voltage, current, dc link voltage, firing angle etc. For taking readings with STATCOM switch on S4, S5, S6 and switch off S1 and then take the readings.DSP is used as a controller to generate PWM output for VSC. In actual Power System with very high MVA rating PWM technique is not prevalent due to high switching losses. PWM output of DSP is shown below in fig 10.
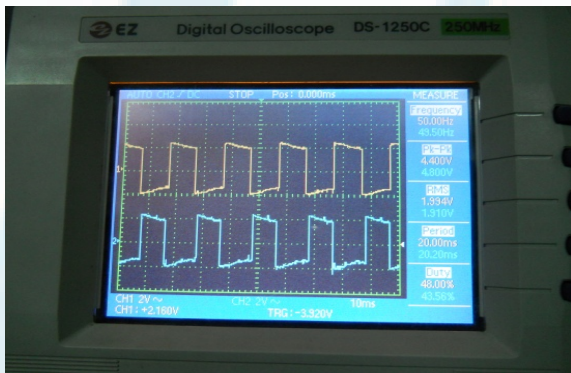

**Figure 10:** PWM pulse from DSP

5.Prototype Result

The STATCOM unit has been checked with the conventional mode of operations and STATCOM mode of operations. The readings were taken from transmission line sending end voltage, receiving end voltage and line current for conventional mode of operation which is tabulated in Table 1.The transmission line voltage drop is shown in the waveform Fig 11(a).While checking the STATCOM mode of operations, the amplitude and phase angle of the voltage source converter was adjusted with respect to the transmission line voltage which is tabulated in Table 2.Here V_{dc} is DC line voltage of voltage source converter. The compensation mode is shown in fig 11(b).In the compensation mode of operation, the receiving end voltage have been improved by adjusting the amplitude and phase sequence of the injected voltage in the voltage source converter with the help of digital signal processing unit, So we can finalize the line drop of transmission line have been reduced by the compensation (STATCOM) mode of operations.

Table 1: Reading without STATCOM

Sr.	Vs	Vr	Line Current
1	230	217	0.41
2	230	213	0.55
3	230	207	0.6
4	230	202	0.74
5	230	197	0.85
6	230	194	1.05
7	230	192	1.26
8	230	189	1.47
9	230	186	1.74
10	230	184	1.91
11	230	180	2.29

Table 2: Reading with STATCOM

S. No	Vs	Vr	Line current	Theta 2 (STATCOM)	Vdc
1	230	223	0.39	20LG	120.0
2	230	223	0.42	33LG	125.5
3	230	223	0.55	34LG	124.5
4	230	223	0.57	36LG	117.7
5	230	223	0.59	36LG	115.2
6	230	223	0.62	36LG	124.2
7	230	223	0.65	37LG	119.6
8	230	223	0.72	38LG	114.9
9	230	223	0.85	39LG	114.0
10	230	223	0.99	39LG	113.2
11	230	224	1.30	40LG	120.9
12	230	224	1.40	40LG	117.3
13	230	224	1.52	40LG	111.4
14	230	224	1.55	40LG	107.8
15	230	224	1.63	41LG	126.5
16	230	224	1.72	41LG	117.5
17	230	224	1.85	41LG	109.4
18	230	225	1.96	41LG	113.6
19	230	226	2.22	41LG	123.2
20	230	226	2.37	41LG	123.6
21	230	228	2.58	41LG	124.3
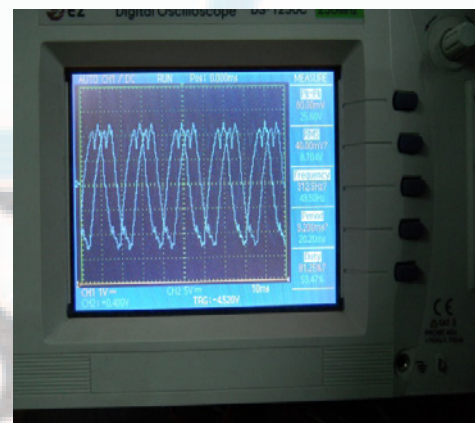
(a)
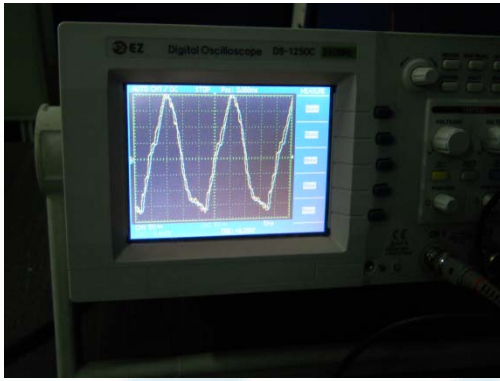
(b)

Figure11: Waveform Observed (a) without STATCOM (b) with STATCOM

6. Conclusion

The conclusion was drawn by observing results in the presence of STATCOM, where power transfer of existing system was observed better. The work is carried on hardware (prototype) through the STATCOM device. When we connect STATCOM in the system, it increases the receiving end voltage which concludes that, it gives efficient operation with low transmission losses by controlling firing angle of IGBT based converter through DSP kit. The transmission network is formed with the help of RLC network. When firing the converters at different angles, the prototype gives best performance result, showing that the receiving end voltage was improved in the hardware model. Through the result of comparison it proves that, there is enhancement in power transfer capability of existing system with and without STATCOM.

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