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Power Quality Control using D-Stacom in 33KV Distribution Systems

J. DHANAPAL[1], S. SENTHIL[2]

[1]PG Scholar, Dept of EEE (EPS), SVCET, Chittoor, Andhrapradesh, India.

[2]Associate Professor, Dept of EEE, SVCET, Chittoor, Andhrapradesh, India.

Abstract: It has been observed that in recent years and predictably the coming years the power quality problems is a big issue in distribution system. There are different types of problems in power quality. These problems are power factor, reactive power compensation and harmonic distortion. A non-standard voltage, current or frequency results in failure or disoperation of the end consumers. These abundant problems that are faced in the distribution system cause an adverse effect on the economical aspect on both the power utility companies and the consumers as a whole. Due to rapid increase in utilization of power electronics, appliances for energy distribution and generation is in demand. Damping of low frequency electromechanical oscillations is very important for a safe system operation. In this paper we discuss the distribution static compensator (D- STATCOM) which can be dynamically controlled and will be used to mitigate the power quality problems that are faced in the distribution network through enhancement of harmonic distortion, voltage sags and low power factor. The D-STATCOM is parallel to the system and contains shunt capacitor that aids in the compensation and improvement of power factor and harmonic distortions. A current is injected in the system to rid of voltage sags. Due to its better response among other many more advantages the D-STATCOM has been chosen as the best fit for rectification of these problems.

Keywords: Variable Refrigerant Flow (VRF), Outdoor Air (OA), COP, ECM Motors.

I. INTRODUCTION

Now day's electrical power system is AC i.e. electric power is generated, transmitted and distributed in the form of alternating current. When the power is generated it possesses certain electrical properties that allow electrical system to function in their intended manner. But power travels long distances through wires. Due to various pieces of equipment's or due to any abnormal conditions in the network, the quality of the power changes and thus it becomes less suitable for any further application. In the early days of power transmission due to reactive power unbalances, the problems like voltage deviation during load changes and power transfer limitation were observed. Most of the AC loads are consuming reactive power due to presence of reactance. Power quality is getting poor due to heavy consumption of reactive power. The development in fast and reliable semiconductors devices (GTO and IGBT) allowed new power electronic configurations to be introduced to the tasks of power Transmission and load flow control.

II. DETERMINATION OF AC CONTROLLERS

Poor power quality may result either from transient conditions developing in the power circuit or from the installation of non-linear loads. Power quality is getting poor due to heavy consumption of reactive power. Due to the increasing use of loads sensitive to power quality, e.g. communications and medical equipment, variable speed drives, rectifiers, Uninterruptible Power Supplies(UPS), Personal computers (PC), Television (TV) sets etc., the issue of power quality has gained renewed interest over the last two decades. Nowadays, power quality is an even more complex problem than in the past because the new loads are not only sensitive to power quality but also responsible for affecting adversely the quality of power supply. Leading in recent years, flexible alternative current transmission systems (FACTS) devices are one of the most effective ways to improve power system operation controllability and power transfer limits. Through the modulation of bus voltage, phase shift between buses, and transmission line reactance, the FACTS devices can cause a substantial increase in power transfer limits during steady state. These devices are an addition to normally steady-state control of a power system but, due to their fast response, the FACTS can also be used for power system stability enhancement through improved damping of power swings. The real power flow with primary function of FACTS devices can be regulated to reduce the low frequency oscillation and enhance power system stability. Recently, several FACTS devices have been implemented and installed in practical power system

III. OPERATION OF D-STATCOM

D-STATCOM is a kind of custom power device which is used to regulate the system voltage and thereby protect the distribution system from power quality disturbances such as voltage sags, swells, voltage flicker and voltage unbalance. The main components of the D-STATCOM are the inverter using either GTO or IGBT, dc capacitor, coupling transformer and control system. It can be regarded as an active energy-exchanging device because it utilizes the passive energy storage component to realize the energy storing and exchanging and the switches to control the reactive power flow between different phases of a distribution system. The reactive power provided by the D-STATCOM is either capacitive or inductive depending on whether the magnitude of the D-STATCOM output voltage is larger or smaller than the magnitude of the system voltage. It is found that the UPQC in single-phase system effectively compensates the most common power quality issues, such as the load reactive power, load current harmonics, voltage harmonics, voltage sag, voltage swell and voltage flicker. Under distorted source voltage having total harmonics distortion (THD) of 14.1% with a non-linear load producing a distorted current (THD of 30.98%), the UPQC simultaneously compensates these harmonics resulting sinusoidal source current (THD of 3.77%) and load voltage (THD of 2.54%).

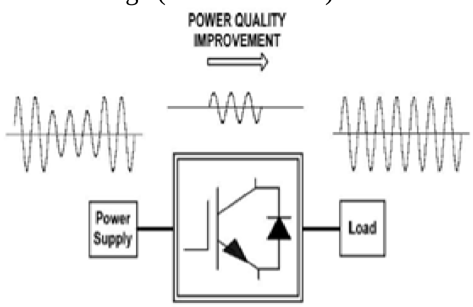

Figure1. DVR representation.

During standby operation, DVR neither absorbs nor delivers real power. However, when voltage sag/swell occurs in the system, DVR delivers/absorbs real power transiently to/from DC link. Many loads facilitated in industrial plants such as adjustable speed drives and process control equipment's are able to detect voltage faults as minimal as a few milliseconds. Due to the sensitivity of the loads, DVR is required to response in a very high speed (Chen et al 2004). Voltage unbalance – The voltages of a three-phase voltage source are not identical in magnitude or the phase differences between them are not 120 electrical degrees. Harmonics – Steady-state deviation in the voltage or current waveform from an ideal sine wave, which are sinusoidal voltages or currents having frequencies that are whole multiples of the frequency at which the supply system is designed to operate (50 Hz). The existing power quality improvement in distribution network using D-STATCOM is possible in a 25KV network. The figure below shows the existing 25KV distribution network.

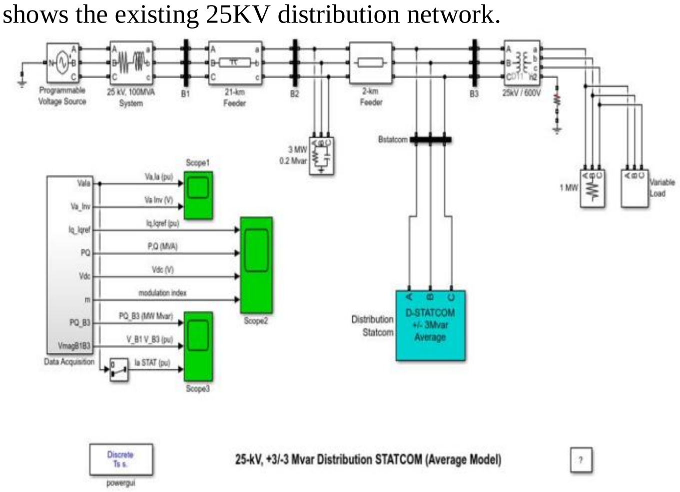

Fig2. Existing 25KV Distribution Network with Dstatcom.

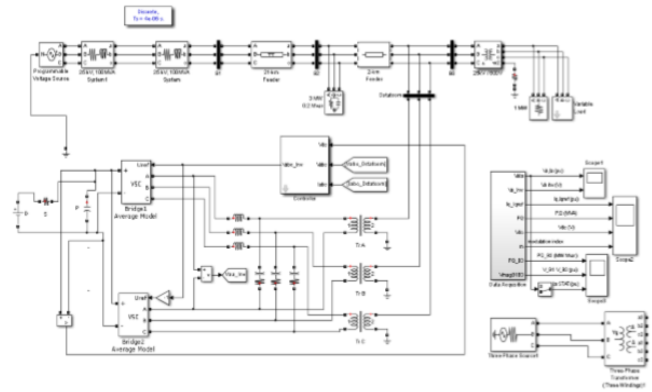

Figure3. Existing 25KV Distribution Network with DSTATCOM Showing connections

IV. IMPLEMENTATION OF 33KV D-STATCOM

From our problem statement we can be able to devise our proposed work. A design of a new 33KV network will have to be done. This network will be connected to a programmable voltage source and a coupling transformer rated at 33 KV, 130MVA. The voltage rating is increased in comparison to the existing 25KV network because we want to be able to distribute power over longer distances in comparison with the existing line network. The existing network can carry the rated voltage of 25KV over 21KM from B1 to B2 and also over a length of 2KM from B2 to B3. For the proposed work the rated voltage of 33KV, the voltage can be transmitted from a length of 21KM to 28KM over the feeder from B1 to B2. From B2 to B3 the voltage can be transmitted over a length of 2KM to approximately 2.7KM. From the existing 25KV network the DSTATCOM generates a reactive power of +2.7 MVAR to -2.8 MVAR or on average as indicated in the diagram the reactive power generated is from +3 MVAR to -3 MVAR.

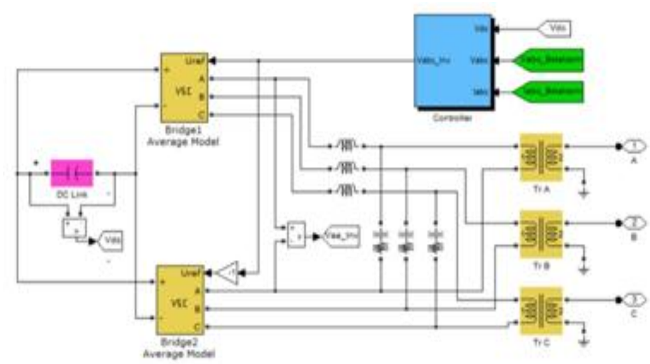

Figure4. Dstatcom Model.

This reactive power is generated in order to compensate for the voltage fluctuations in the system thus voltage increase or voltage decrease making sure that the power factor is 1 P.U or at least close to unity. In the proposed 33KV distribution network however, the reactive power generated has to change as well meeting the requirements of the new designed parameters. For the proposed system or work the DSTATCOM will be generating a reactive power of +3.6 MVAR to -3.7 MVAR. The average reactive power generated for the proposed network in comparison to the existing 25KV network is +3.96 MVAR to -3.96 MVAR. At this rating when the DSTATCOM generates the reactive power the voltage fluctuations in the proposed 33KV network can be smoothly mitigated. The figures below show the DSTATCOM and the proposed 33KV network.

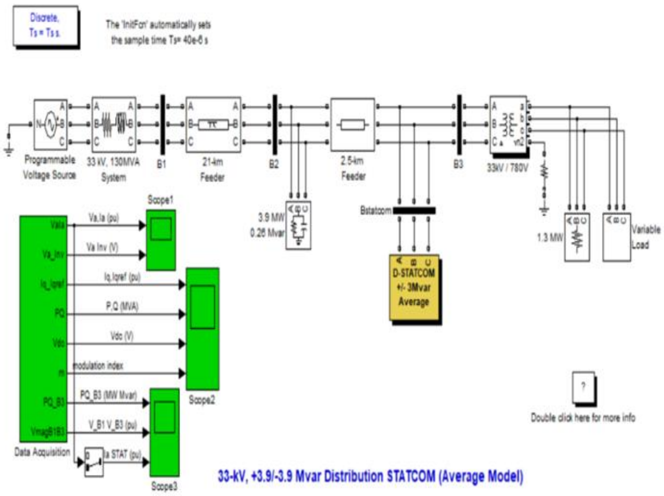

Figure5. Proposed 33KV Distribution Network with DSTATCOM.

V. PROPOSED MODEL

In this paper from our problem statement we want to implement the DSTATCOM for power quality improval in a 33KV distribution network. The existing network operates at 25KV now has the disadvantage that it's used for a limited range of distance. In this paper we show that we can increase the length of the distribution network that's increasing its distribution capacity to various areas. In this new model of 33KV we will be able to see that the length has been extended and power quality is still maintained at an optimum maintain low power losses and also making sure that there is high economic benefits both for the power utility and the consumers.In this chapter we will discuss how this system is implemented to achieve this goal and the various devices software and hardware that are used in this model network. Simulation shall be done to observe if we have achieved the new model efficiently.

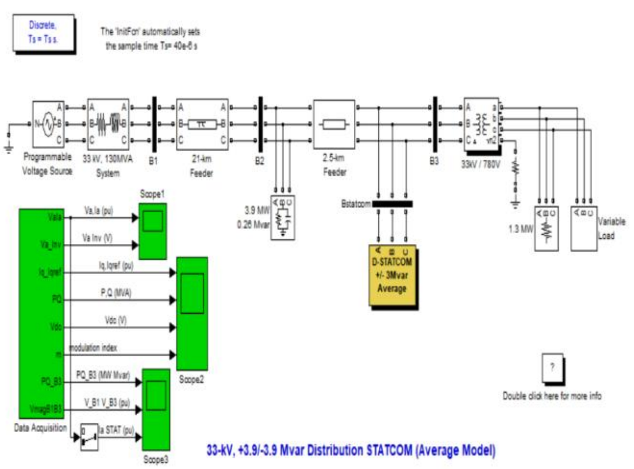

Figure6. 33 KV Simulation Circuit.

VI. WORKING PRINCIPLE OF D-STATCOM

D-STATCOM is a shunt connected devices which is used to regulate the voltage either by generating or observing reactive power. Among of the various distribution FACTS controllers, Distribution Static Compensator (DSTATCOM) is an important shunt compensator which has the capability to solve power quality problems faced by distribution systems. DSTATCOM has effectively replaced s Static VAR Compensator (SVC), as it takes large response time in addition it is connected with the passive filter banks and capable steady state reactive power compensation. A DSTATCOM is a Voltage Source Inverter (VSI) based FACTS controller sharing similar concepts with a STATCOM used at transmission level. Moreover SVCs which have been largely used in arc welding plants for voltage flicker mitigation have been replaced by DSTATCOMs because SVCs exhibit limited reduction of instantaneous flicker level. In this system a three phase input voltage of 220KV per phase is applied using three single phase supply in Simulink Matlab. During this test, the variable load will be kept constant and you will observe the dynamic response of a D-STATCOM to step changes in source voltage. Check that the modulation of the Variable Load is not in service (Modulation Timing [Ton Toff]=[0.151]*100>Simulation Stop time).

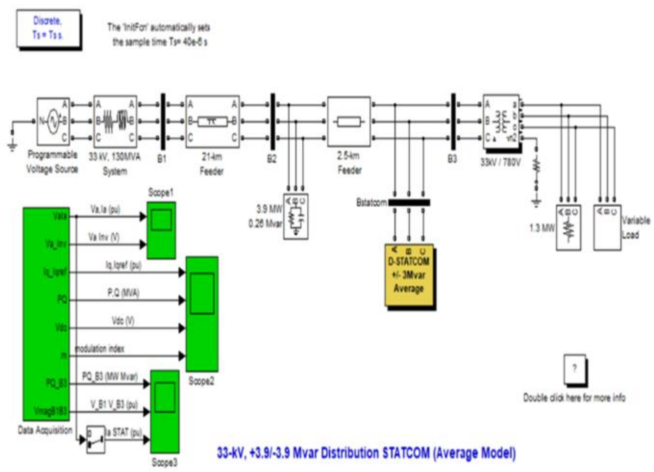

Figure7. Distribution Network.

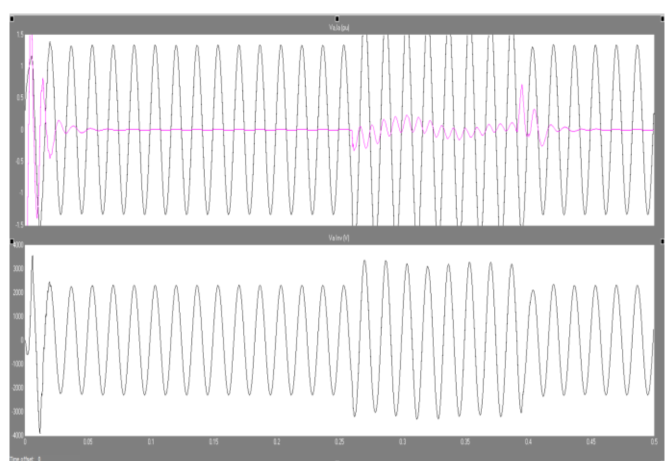

Figure8. Phase A voltage and current waveforms.

The Programmable Voltage Source block is used to modulate the internal voltage of the 33-kV equivalent. The voltage is first programmed at 1.077 PU in order to keep the D-STATCOM initially floating (B3 voltage=1 PU and reference voltage Vref=1 PU). Three steps are programmed at 0.2 s, 0.3 s, and 0.4 s to successively increase the source voltage by 6%, decrease it by 6% and bring it back to its initial value (1.077 PU).

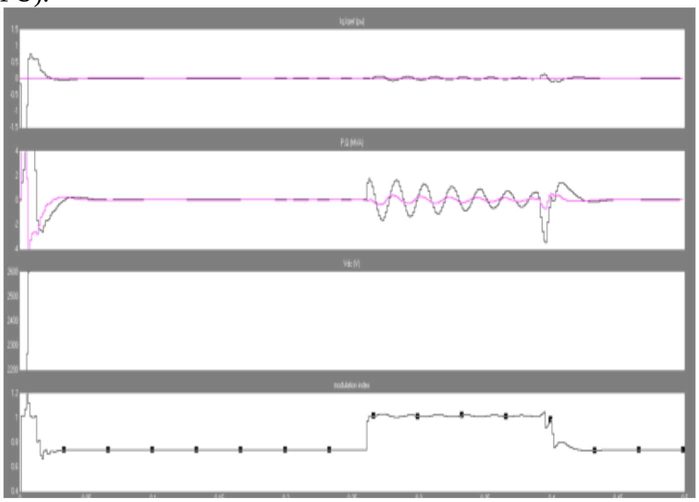

Figure9. Control signal.

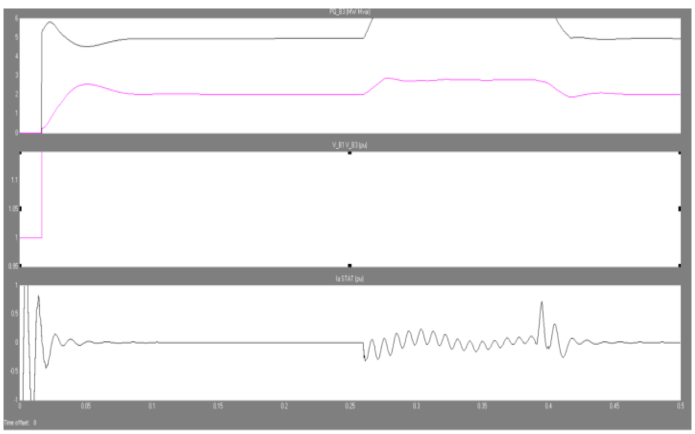

Figure10. Variations of Power factor and Reactive Power.

Observe on Scope1 the phase A voltage and current waveforms of the D-STATCOM as well as controller signals on Scope2. After a transient lasting approximately 0.15 sec., the steady state is reached. Initially, the source voltage is such that the D-STATCOM is inactive. It does not absorb nor provide reactive power to the network. At t = 0.2 s, the source voltage is increased by 6%. The D-STATCOM compensates for this voltage increase by absorbing reactive power from the network (Q=+3.9 Mvar on trace 2 of Scope2). At t = 0.3 s, the source voltage is decreased by 6% from the value corresponding to Q=0. The D-STATCOM must generate reactive power to maintain a 1 pu voltage (Q changes from +3.9MVAR to -4.0 MVAR). Note that when the D-STATCOM changes from inductive to capacitive operation, the modulation index of the PWM inverter is increased from 0.56 to 0.9 (trace 4 of Scope2) which corresponds to a proportional increase in inverter voltage. Reversing of reactive power is very fast, about one cycle, as observed on D-STATCOM current (magenta signal on trace 1 of Scope1). During this test, voltage of the Programmable Voltage Source will be kept constant and you will enable modulation of the Variable Load so that you can observe how the D-STATCOM can mitigate voltage flicker.

In the Programmable Voltage Source block menu, change the "Time Variation of" parameter to "None". In the Variable Load block menu, set the Modulation Timing parameter to [Ton Toff] = [0.15 1] (remove the 100 multiplication factor). Finally, in the D-STATCOM Controller, change the "Mode of operation" parameter to "Q regulation, and make sure that the reactive power reference value Qref (2nd line of parameters) is set to zero. In this mode, the D-STATCOM is floating and performs no voltage correction. Run the simulation and observe on Scope3 variations of P and Q at bus B3 (1st trace) as well as voltages at buses B1 and B3 (trace 2). Without D-STATCOM, B3 voltage varies between 0.96 pu and 1.04 pu (+/- 4% variation). Now, in the D-STATCOM Controller, change the "Mode of operation" parameter back to "Voltage regulation" and restart simulation. Observe on Scope 3 that voltage fluctuation at bus B3 is now reduced to +/- 0.7 %. The D-STATCOM compensates voltage by injecting a reactive current modulated at 5 Hz (trace 3 of Scope3) and varying between 0.6 pu capacitive when voltage is low and 0.6 pu inductive when voltage is high.

VII. CONCLUSION

There are many types of equipment available for improving the power quality in electrical power transmission systems. However, the nature and type of the load in the electrical power distribution system pollutes the power system at the customer end. It is important for motivating researchers in solving power quality problems using custom power devices. The custom power devices like DVR, DSTATCOM, and UPQC enhance the power quality in the distribution system. This research work focused on the design and validation of various DSTATCOM controllers for voltage regulation, reactive power compensation, power factor improvement and unbalanced load compensation. The paper mainly focused on various power quality improvements using different control algorithms for the DSTATCOM. The PI controlled SPWM or the PI controlled SVPWM techniques in the DSTATCOM regulates the bus voltage at the point of common coupling (PCC). Voltage fluctuation problems occur in a power system when the power system is not able to meet the reactive power demand during faults or at heavy loading. Dynamic compensation of the reactive power is an effective solution for maintaining the power quality and mitigating the effects due to the voltage fluctuations. The performances of the SPWM and the SVPWM algorithms have been studied for reactive power compensation for dynamic load variations. In a three-phase system, voltage or current unbalance is a major power quality issue to be solved. The unbalanced system is controlled through a balanced set of sequence components. The phase sequence based HCC is used to compensate the unbalanced system. The unbalanced delta connected three-phase load requires the negative sequence current in addition to the positive sequence current from the source, which affects other loads in the system.

VIII. REFERENCES

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