

Voltage dip mitigation in Radial distribution system using STATCOM

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Abstract- This paper presents the modeling and simulation results of Z-Source Inverter based Static Compensator (STATCOM). The IEEE ten bus system with and without STATCOM is modeled and simulated using the MATLAB/SIMULINK. The present work proposes Z-Source Inverter based STATCOM for the control of reactive power and hence to compensate the voltage dips in radial distribution systems. Z-Source inverter would ensure a constant DC voltage across the DC link during the process of voltage. The advantages of this system are reduced ripple, shoot through capability and reduced heating. Voltages at various load buses of IEEE ten bus radial distribution system, with and without STATCOM is studied and presented.

Index Terms- FACTS, Power quality, voltage dip, Static Synchronous Compensator (STATCOM), Z-Source Inverter (ZSI).

I. INTRODUCTION

Electrical power distribution network becomes more increasingly important and plays an essential role in power system planning. This type of power systems has a major function to serve distributed customer loads along a feeder line, therefore under competitive environment of electricity market service of electric energy must not be interrupted and at the same time there must provide reliable, stable and high quality of electric power. To complete this challenge, it requires careful design for power network planning. There exists many different ways to do so. However one might consider an additional device to be installed somewhere in the network. Such devices are capacitor shunt reactor, series reactors and automatic voltage regulators and/or recently developed dynamic voltage restorers, distribution STATCOM or combination of them. In developing countries like India, where the variation of power frequency and many such other determinants of power quality are themselves a serious question, it is very vital to take positive steps in this direction. The present work is to identify the prominent concern in this

area and hence the measures that can enhance the quality of power are recommended.

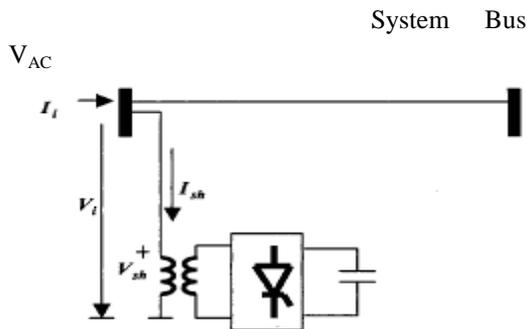
The main advantage of STATCOM compared to the traditional reactive power compensation devices are the ability of strongly regulation, low harmonic content and low loss without operational problems such as resonance. A STATCOM in association with a particular load can inject compensating current, so that the total demand meets the specification for utility connection. The STATCOM would play a more serious role in power system loadability, reactive power compensation, loss reduction, voltage regulation, voltage balancing and power quality and stability enhancement.

II. WORKING PRINCIPLE OF STATCOM

The principle of STATCOM operation is as follows: The AC voltage difference across the leakage reactance makes the power exchange between the STATCOM and the power system. The VSI voltage is compared with the AC bus voltage system, when the AC bus voltage magnitude is above that of the VSI magnitude; the AC system sees the STATCOM as inductance connected to its terminals. Otherwise if the VSI voltage magnitude is above that of the AC bus voltage magnitude, the AC system sees the STATCOM as capacitance connected to its terminals. If both AC system and VSI voltage magnitudes are equal, the reactive power exchange is zero. If the STATCOM has a DC source or energy storage device on its DC side, it can supply real power to the power system. This can be achieved by adjusting the phase angle of the STATCOM terminals and the phase angle of the AC power system. When phase angle of the AC power system leads the VSI phase angle, the STATCOM absorbs the real power from the AC system, if the phase angle of the AC power system lags the VSI

phase angle, the STATCOM supplies real power to AC system.

The Voltage Source Converter or Inverter (VSC or VSI) is the building block of a STATCOM and other FACTS devices. A very simple inverter produces a square voltage waveform as it switches the direct voltage source on and off. The basic objective of a VSI is to produce a sinusoidal AC voltage with minimal harmonic distortion from a DC voltage. Single-line diagram of STATCOM is shown in Fig1.



VSC

Fig.1 Single-line diagram of a STATCOM.

III. IMPEDANCE SOURCE INVERTER(ZSI)

The circuit configuration of the Impedance Source Inverter(ZSI) with load is shown in Fig2. The newly proposed Z-source inverter has a unique feature that it can boost/buck the output voltage by introducing shoot through operation mode, which is forbidden in traditional voltage source inverters, with this unique feature, the Z-source inverter provides a cheaper, simpler, buck-boost inversion by single power conversion stage. The Z-Source Inverter circuit consists of a diode rectifier, DC link circuit, and an inverter bridge. The differences are that the DC link circuit is implemented by the Z-Source network (c_1 , c_2 , L_1 , and L_2) and small input capacitors (c_a , c_b , and c_c) are connected to the diode rectifier. Since Z-Source Inverter bridge can boost the DC capacitor (c_1 , and c_2) voltage to any value above the DC value of the rectifier, a desired output voltage is always obtainable regardless of line voltage. Using the 230V load system as an example, the DC capacitor voltage can be boosted to 350V or greater in order to produce 230V AC output regardless of the line voltage. Theoretically, the DC capacitor voltage can be boosted to any value above the inherent DC voltage(310-325V for a

230-V line) of the rectifier, by using the shoot through zero switching states. When a higher voltage is needed or during voltage sags. The capacitor voltage is, however, limited by the device voltage rating in practical use.

Modeling and simulation of distribution STATCOM is dealt by Giroux[3].solution to power quality problem is given by Mineski[4].Compensation of voltage sag is given by Haque[5].Harmonics study and comparison of ZSI with traditional Inverters is given by Justus[6].ZSI and Push-pull inverter based STATCOM given by N.Usha [7]-[11].

The authors are unaware of any literature dealing STATCOM using Z-Source Inverter based STATCOM for ten bus IEEE distribution system. This work gives voltage dip compensation in ten bus IEEE radial distribution system at various buses with ZSI based STATCOM.

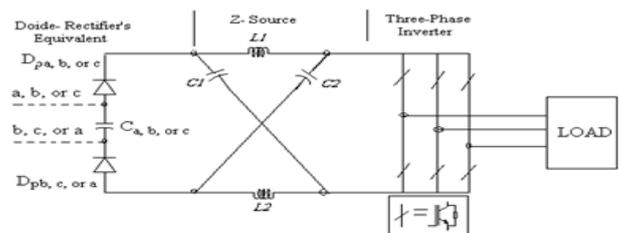


Fig.2 Main circuit configuration of Z-Source Inverter

IV.SIMULATION RESULTS

A ten-bus IEEE radial distribution system is considered for simulation studies. It is assumed that the three-phase radial distribution network is balanced and can be represented by their equivalent single line diagram as shown in Fig 3a.The 11KV,ten-bus IEEE radial distribution system is modeled and simulated using MATLAB/SIMULINK. The loads are distributed uniformly along the line section. All the loads are modeled as constant impedance loads. The SIMULINK model of PI controller, single-phase distribution line, single-phase load and single-phase source are shown in Fig 3b, Fig 3c, Fig 3d and Fig 3e respectively. The SIMULINK model of 11KV,ten-bus IEEE radial distribution system without and with STATCOM is shown in Fig3f and Fig3g respectively. In the radial system there are 9 load buses (from 2 to 10) and one source which is indicated by 1,hence there are 10 buses. In order to maintain the permissible level of

voltages at various load buses ,STATCOM is connected at each load bus in the distribution system. The load voltage is sensed and rectified using an uncontrolled rectifier. It is compared with reference voltage. The error is given to PI controller. The output of PI controller adjusts the pulse width to get the required voltage at the load. The STATCOM is connected to the system at $t=0.3\text{sec}$.The voltages at all load buses with and without STATCOMs are presented in the Table1

for base loading condition.From the Table1,it is clear that voltage dip at various load buses are compensated by connecting STATCOM at 2nd and 4th bus in the system for base loading condition. The loads at buses 8th and 9th are 20% overloaded and the corresponding voltages at all load buses with and without STATCOMs are presented in the Table2.From Table2 it is clear that the proposed STATCOM can also be used to compensate voltage dips for slightly overloading case.

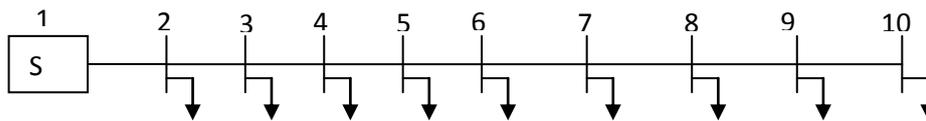


Fig3a single line diagram of 10-bus IEEE radial distribution system

(a)Simulink model of PI controller

Simulink model of PI controller is shown in Fig3b.The load voltage is fed to the summing point. This voltage is compared with reference voltage(set at 5v) and the error is fed to

PI controller(with $K_p=2$ and $K_i=0.5$). Output of the PI controller is given to pulse generator to produce the required pulse width. These pulses are given to the STATCOM to inject the voltage into the system for compensation.

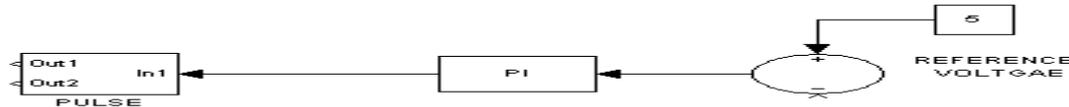


Fig3b simulink model of PI controller

(b)SIMULINK model of single-phase distribution line:

Using SIMULIK 1-Phase Series RLC Branch block (C value set to ∞) and 1-Phase

Parallel RLC Branch block (R and L values set to infinity) with V, I and PQ measurement blocks develop distribution line as shown in Fig3c

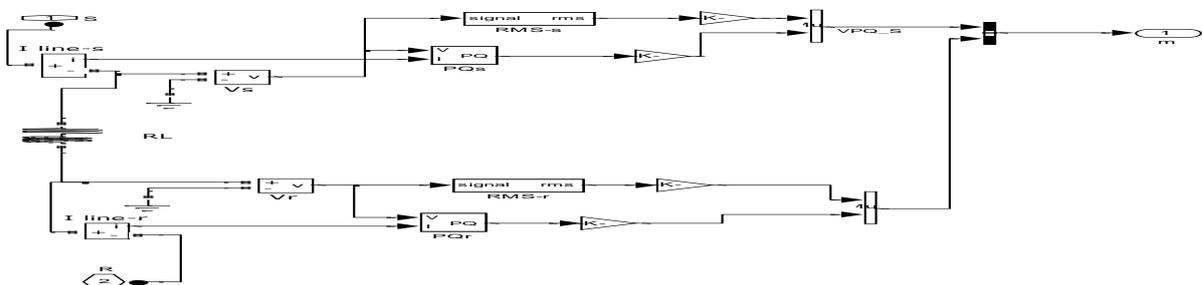


Fig3c SIMULINK model of Single-phase distribution line

(c) SIMULINK model of single-phase RL Load:

Using SIMULIK 1-Phase Parallel RLC Load block with V, I and PQ measurement blocks the model is developed as shown in Fig3d. It exhibits constant impedance at the specified

frequency. The load active and reactive powers are proportional to the square of the applied voltage. Capacitive VAR Q_C value is set to 0 for getting 1-Phase RL load.

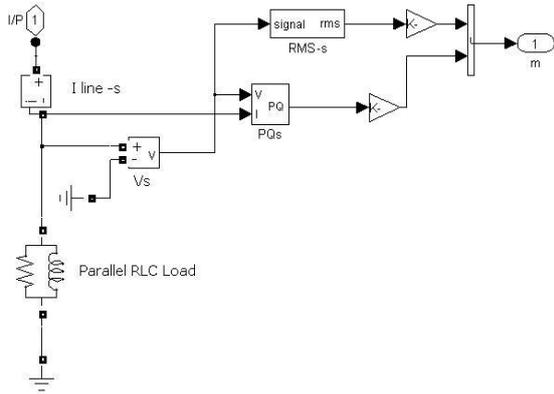


Fig3d SIMULINK model of Single-phase RL load
(d) SIMULINK model of a single phase source:

Using SIMULIK 1-Phase AC source, 1-Phase Series RLC Branch block (R value set very low value $1e-12$, L value set zero and C value set to ∞) and 1-Phase Parallel V, I and PQ measurement blocks develops single phase source model as shown in Fig3e. Here very low value of resistance is connected in series to avoid convergence problem.

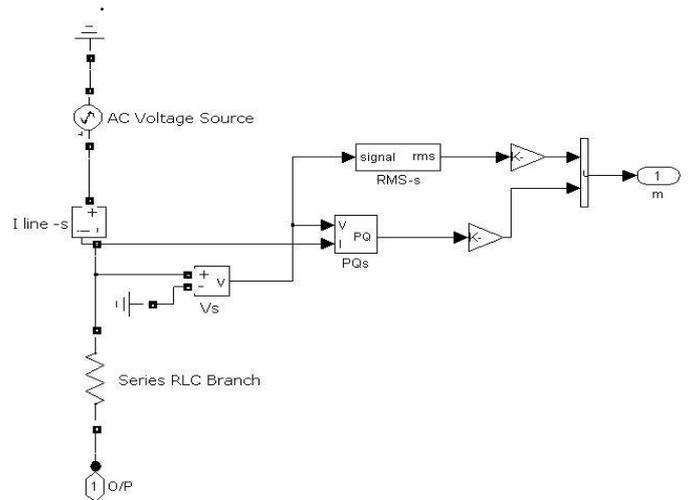


Fig3e SIMULINK model of a single phase source

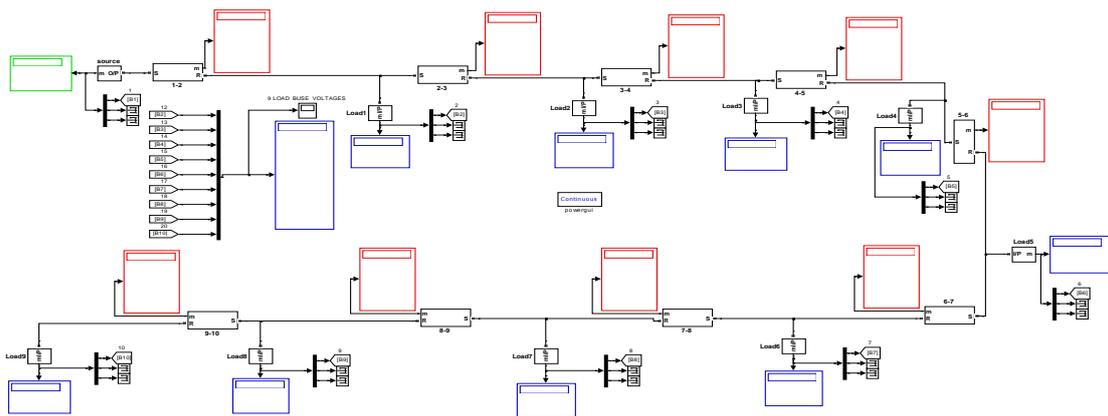


Fig3f SIMULINK model of 10-bus IEEE radial distribution system without STATCOM

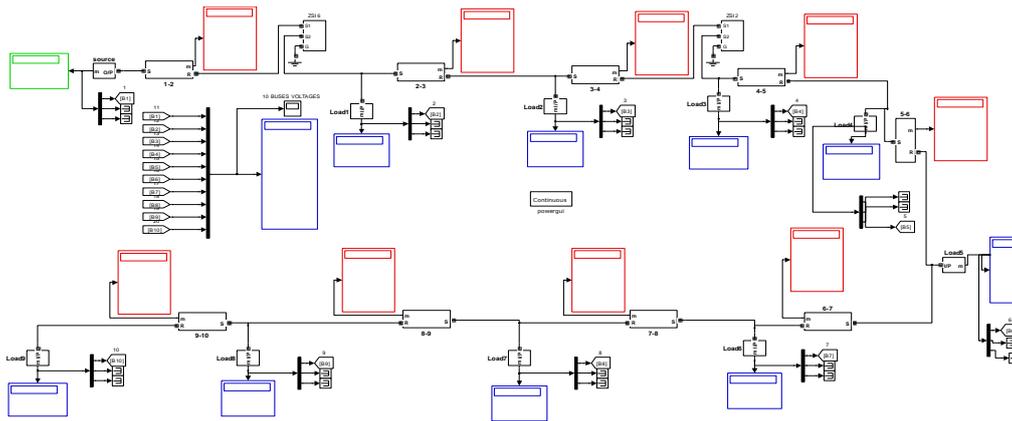


Fig3g SIMULINK model of 10-bus IEEE radial distribution system with STATCOMs

Table1 Summary of Voltages at all loads with and without STATCOMs for base loading

Load	Load Voltage without STATCOM(in pu)	Load Voltage with STATCOMs (in pu)
1	0.9376	0.9908
2	0.8851	0.8975
3	0.7251	0.8929
4	0.6384	0.7860
5	0.4956	0.6099
6	0.4561	0.5612
7	0.3923	0.4826
8	0.301	0.3702
9	0.2434	0.2995

Table2 Summary of Voltages at all loads with and without STATCOMs for 20%overloading

Load	Load Voltage without STATCOM(in pu)	Load Voltage with STATCOMs (in pu)
1	0.9372	0.9933
2	0.8843	0.8981
3	0.7230	0.8999

4	0.6355	0.7908
5	0.4899	0.6093
6	0.4488	0.5581
7	0.3816	0.4745
8	0.2811	0.3495
9	0.2189	0.2721

V.CONCLUSION

This work presents the possibility of using Z-Source Inverter based STATCOM system. The ten-bus IEEE radial distribution system is modeled and simulated using MATLAB/SIMULINK and results are presented. The simulation results of ten-bus IEEE radial distribution system with and without STATCOM is presented. Simulation studies were done using single phase model of balanced three phase system. It is found that the load voltage is improved by connecting STATCOM. The proposed method is capable of compensating the voltages for slightly overloading. The simulation results are in line with the predictions. This system has improved reliability and power quality. The scope for future work is simulation can also be done using PSCAD or PSIM. The simulation studies can be extended to IEEE 33-bus,69-bus radial distribution system with and without tie-lines. Testing can also be done on extremely large real time power systems.

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