Power Quality Improvement using DSTATCOM for Small Isolated Alternator feeding Distribution System

Sunil Kr. Singh
PG Research scholar
Oriental Institute of Science and Technology
Bhopal (M.P.), India.
Sunilkrsingh001@yahoo.com

Dr. Deepika Masand
Department of Electrical Engg.
Oriental Institute of Science and Technology
Bhopal (M.P.), India.
deepikajai@rediffmail.com

*Abstract –*This paper demonstrates a perfect controlled DSTATCOM model with a small isolated distribution system to improve power quality of the system in which a linear/nonlinear three-phase load is fed by a small alternator. A hysteresis rule based carrier-less PWM current controller is used to control the DSTATCOM. Three leg IGBT based PWM-VSI is used as VSC with a capacitor in its parallel working as DSTATCOM. Two PI controllers are used. Any dip in voltages due to sudden load change/dynamic conditions of the system is improved by this DSTATCOM model presented in this paper. Voltage regulation, power factor correction and load balancing is obtained in this system. The work has been carried out in MATLAB environment using Simulink and Simpowersystem toolboxes. The proposed DSTATCOM model is very effective to enhance the power quality of an isolated distribution system feeding power to crucial equipments in remote areas.

Keywords- **DSTATCOM, hysteresis controller, VSC, isolated system, power quality.**

I. INTRODUCTION

Continuously increasing requirement of isolated distribution system in remote areas where grid supply is not readily available attracted researchers' attention towards the power quality of isolated distribution systems. Electric power systems on ships, off-shore plants, diesel electric supplied trains, aircrafts and islands are some examples of isolated systems. The nature of isolated systems introduces problems different from that of grid connected system. Isolated systems are more susceptible to currents and voltage variations because of their relatively low inertia and short circuit levels as compared to the rather stiff large power systems. Some power Quality problems introduces in isolated distribution system like power factor, voltage dips, unbalancing are overcome by Distribution Static Compensator(DSTATCOM) model introduces in this paper. Due to high source impedance of DG set three-phase voltages unbalanced and distorted at Point of Common Coupling (PCC). DG sets are loaded with linear/nonlinear balanced and unbalanced loads such as power supplies in telecommunication and medical equipments. Harmonics and unbalanced currents flowing through the generator and all other factors mentioned above lead to the increased fuel consumption and reduced life of DG sets, which results into an increased cost of the system. Load variations, disturbances and unbalances produce higher level of power quality deviations in these systems [3-6]. One effective solution is to use custom power devices [3-4], DSTATCOM is one of the best suitable low voltage custom power devices for these systems to compensate reactive power and improve power quality. In the past, attempts have been made on electric power quality problems and many solutions have been suggested to improve power quality in electric distribution system [2, 7]. In this paper power quality improvement is done using DSTATCOM connected to a small three-phase three-wire distribution system.

II. SYSTEM DESCRIPTION

Fig.1 shows the basic diagram of DSTATCOM for compensating reactive power to a small isolated alternator feeding distribution system supplying power to a linear balanced/unbalanced load. VSC working as a DSTATCOM connected in parallel with the system in which a three-phase synchronous generator driven by a diesel engine is considered
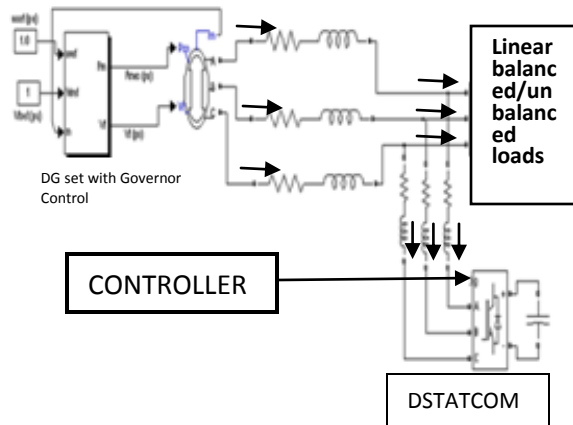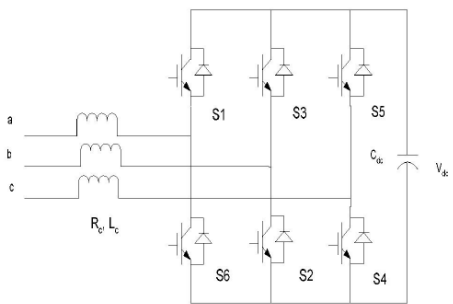
Fig.1 (a) Schematic diagram of System

Fig.1 (b) DSTATCOM model

Fig.1 Basic model of DSTATCOM connected to small isolated alternator feeding distribution system.

to fed power to the load. A capacitor is connected in parallel with VSI to obtain a self supporting DC bus to maintain the system voltage constant, using voltage of the capacitor.VSI consists of IGBT switches fired by gate pulses generated through the hysteresis controller. The system considered here consists of linear R-L load. A 42.5 KVA, 50 Hz small alternator is considered here feeding the load. Controller block in fig.1 is a hysteresis rule based generates six gate pulses to fire six IGBT switches of VSI Bridge. DSTATCOM is connected in shunt with distribution system and injects current at point of common coupling (PCC) to compensate reactive power, improve power factor, regulate voltage, and reduce harmonics at PCC.. Excitation system chosen here is the standard IEEE Type-model taken from machine library.

III. CONTROL TECHNIQUES

The control system/scheme is the heart of the complete DSTATCOM system presented here to control DSTATCOM. Indirect current control scheme [10] is used and three-phase reference source currents are computed using dc bus voltage and three-phase ac voltages. A DSTATCOM considered here is a controlled reactive source which includes a Voltage Source Converter (VSC) and a DC link capacitor connected in shunt, capable of generating and /or absorbing reactive power.
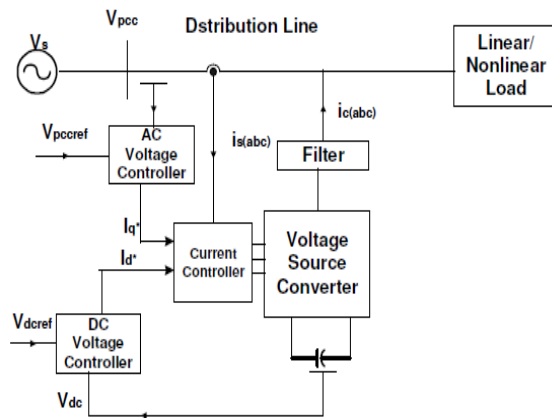

Fig. 2 Controllers of DSTATCOM

The controller as shown in Fig. 2 comprises of an outer loop consisting of ac and dc voltage controllers and an inner current controller. Three phase ac supply voltages and dc link voltages are sensed and converted into their per unit values and fed to two PI controllers, the outputs of which decide the amplitude of the reference reactive and active current to be generated by the DSTATCOM. The AC voltage loop is activated in order to achieve voltage regulation. The current Iq* is the output of a PI controller, the input to which is the deviation of the PCC voltage Vpcc as compared to a reference Vpcc_ref. The current Iq* is assigned zero during unity power factor operation and harmonic mitigation.

The DC voltage loop is responsible for keeping constant the dc voltage through a small active power exchange with the ac network compensating the active power losses in the filter and the inverter. The output of this PI controller is Id*, input to which is the deviation of Vdc from Vdc_ref. The current Id* is responsible for unity power factor and harmonic mitigation operation in a DSTATCOM.

IV. MODELING AND SIMULATION OF DSTATCOM SYSTEM

As discussed in the operation in the control scheme that control principle is based on extraction of in-phase and quadrature components of reference supply currents. In-phase components of reference supply current are obtained using PI controller realized over the average value of dc bus voltage Vdc of the DSTATCOM and reference dc voltage $V_{dc\_ref.}$ The error signal generated by the PI controller is processed with the in-phase unit current templates to compute the instantaneous values of in-phase component of reference source currents. Power factor correction is done using this PI controller. Quadrature components of reference supply currents are computed using another PI controller realized over the amplitude of ac supply voltage using quadrature unit

current tempelates. Reference supply currents are computed by adding in-phase and quadrature components of source currents as [8].

$$Isa\_ref \ = \ isa\_in\text{-}phase + isa\_qr$$

$$Isb\_ref \ = \ isb\_in\text{-}phase + isb\_qr$$

$$Isc\_ref \ = \ isc\_in\text{-}phase + isc\_qr \tag{1}$$

A hysteresis PWM current controller is employed over the reference supply and sensed supply currents to generate gate pulses of IGBTs of the DSTATCOM. Fig.3 shows the MATLAB model of the isolated alternator feeding linear load at 0.8 power factor lagging.
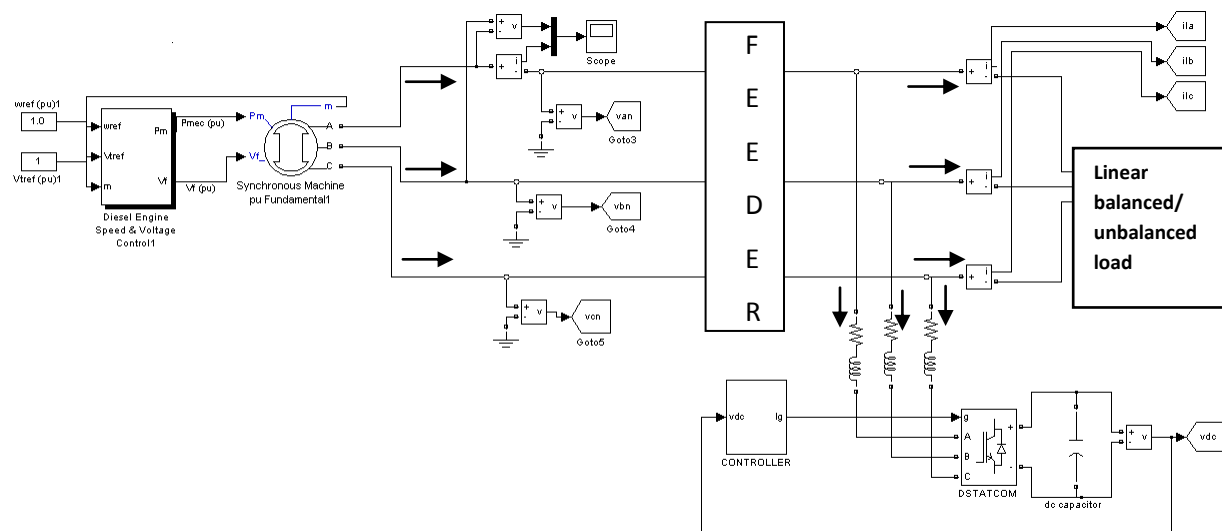

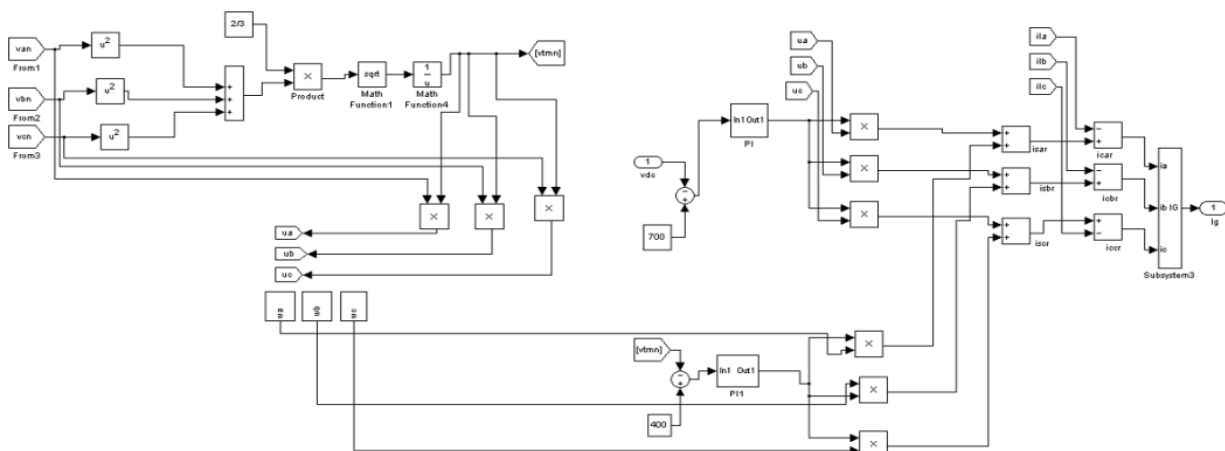Fig.3 MATLAB based complete model DTATCOM system

Fig.4 MATLAB based model of control technique

For controlling the DSTATCOM gate pulse is generated with a hysteresis PWM current controller. This Gate pulse is given to IGBTs of the DSTATCOM. Hysteresis PWM current controller is employed over the reference supply currents and sensed supply currents to generate gating pulses, figure 4. Figure4 shows the reference current extraction technique.

V. RESULT ANALYSIS

The performance of DSTATCOM is studied for model described here to demonstrate the improved power quality of a small isolated alternator system. Performance of DSTATCOM has been discussed for balanced and unbalanced linear loads. Linear loads are R-L load delta connected. Unbalancing of load is obtained by switching off one phase of the load.

Unbalancing of load unbalances the load currents causes distortion of voltages at PCC. DSTATCOM removes the unbalancing of currents and improves the voltage distortion. Voltage regulation is obtained by using PI controller realized over ac supply voltage obtained. These results are shown here in figure 5.

A. Power Factor Correction

In power factor improvement by DSTATCOM PI controller is used, which is realized over the dc link voltage. In this small distribution system a linear load of 25kW at 0.8 power factor lagging. Reference voltage is 700V to regulate dc link voltage at this value. PI controller is operated in power factor correction mode; it is observed that supply voltage and supply currents are in phase as shown in waveform 1 of fig.5
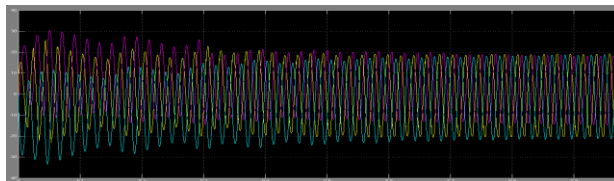
1.supply voltage and currents
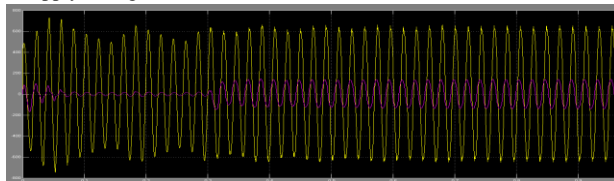
3.dc bus voltage
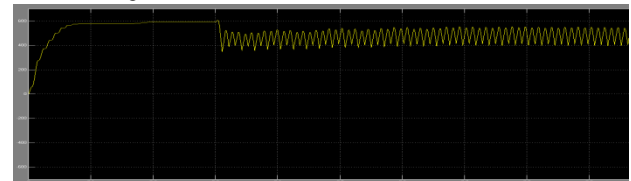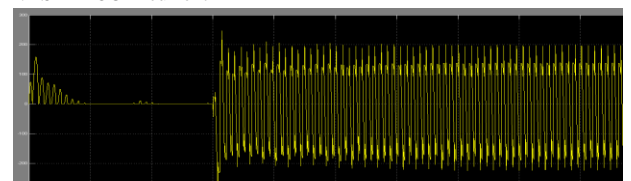
2.load currents

4.DSTATCOM current

Fig.5 Different waveforms observed during switch on of DSTATCOM

B. Voltage Regulation

Other PI controller realized over supply voltage is used for voltage regulation. When load is increased suddenly it is observed that the dc bus voltage and supply voltage is fall down but control algorithm used here regulates both the dc voltage and ac voltage at PCC.

C. Load Balancing

Initially a balanced three-phase linear load is supplied by alternator. Three-phase to two-phase load is obtained by switch off phase 'A' of the three-phase linear load. Now the load is unbalanced and transient responses are observed with unbalanced load. It is observed that distorted voltages at PCC are improved by DSTATCOM.

VI. CONCLUSION

Power quality improvement as major concern for small isolated distribution system has been discussed throughout the paper. A small alternator coupled with diesel engine supplying power to linear/nonlinear balanced and unbalanced loads is presented here. A Distribution Static Compensator model is proposed in this paper for power quality improvement of this small distribution system. Some power quality aspects like power factor correction, voltage regulation and load balancing have been discussed with proposed DSTATCOM model. It is observed that performance of DSTATCOM model presented here in this paper improves these factors of power quality. This total system modeled in Matlab using Simulink and Simpowersystems toolboxes. Necessary waveforms are obtained and observed to verify the results.

VII. APPENDIX

System parameters used in simulation

Alternator system parameterts: 42.5 kVA, 400V (L-Lrms), 2 pole, 50Hz, H=0.1157s

Stator: R_s=0.04808, L_l=0.08, L_{md}=2.11, L_{mq}=0.93

Field: R_f=0.02662, L_{lfd}=0.1582

Dampers: R_{kd}=0.0754, L_{lkd}=0.1098, R_{kq1}=0.07311, L_{lkq1}=0.06414 (all in p.u.)

DSTATCOM parameters: R_c=0.1Ω, L_c=2.5mH, C_{dc}=4700μF, h_b=0.3A

Controller Parameters: K_{pd}= 0.2, K_{id}= 0.5, K_{pa}= 0.15, K_{ia}= 0.5

Linear load:

Load Parameters: R_1= 30Ω, L_1= 71.6mH and R_2= 20Ω, L_2= 47.73mH

REFERENCES

[1] N.G.Hingorani and L.Gyugyi, *Understanding FACTS*, Standard Publishers, Delhi. 2001.

[2] [Online].Available:http://www.yamahageneratorstore.com/ef2800i.htm

[3] E. Acha, V.G. Agelegis, O. Anaya-Lara and T.J.E. Miller, *Power Electronic Control in Electrical Systems*, Newness Power Engineering Series, Oxford, Britain, 2002.

[4] A.Ghosh and G.Ledwitch, *Power Quality Enhancement using Custom Power Devices*, Kluwer Academic Publishers, London, 2002.

[5] W. E.Reid, "*Power Quality issues – Standards and guidelines*", IEEE Transaction on Power Delivery, Vol. 32, No.3, May/ June 1996.

[6] R. Arnold, "*Solutions to the power quality problem*", Power Engineering Journal, Vol. 15, No. 2, April 2001,pp. 65-73.

[7] *IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations*, IEEE Std 387-1995, 1996.

[8] Bhim Singh, Alka Adya, A.P. Mittal, J.R.P. Gupta, "*Power Quality Enhancement with DSTATCOM for Small Isolated Alternator feeding Distribution System",* IEEE conference on PEDS,2005.

[9] H. Akagi, Y. Kanazawa and A. Nabae, "*Instantaneous Reactive Power Compensators Comprising Switching Devices without energy storage Components,*" IEEE Transactions on Industry Applications, vol.20,no.3, May/June 1984, pp. 625-630.

[10] B. N. Singh, A. Chandra and K. Al-Haddad, "*DSP based indirect-current controlled STATCOM-I Evaluation of current controlled techniques,*" IEE Proc. on Electric Power Applications, Vol.147.2, March 2000, pp.107-112.