ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 2, Issue 11 , November 2015

Modeling and Simulation of a DSTATCOM for Improvement of Voltage Stability in Microgrid using SPWM Technique

T.VIGNESH, K.DHIVYA, R.CHINNAIYAN
ASSISTANT PROFESSOR/EEE, JAY SHRIRAM GROUP OF INSTITUTIONS, TIRUPUR
ASSISTANT PROFESSOR/EEE, JAY SHRIRAM GROUP OF INSTITUTIONS, TIRUPUR
PG SCHOLAR/ME-PED, JAY SHRIRAM GROUP OF INSTITUTIONS, TIRUPUR

ABSTRACT: In this paper, a concept of voltage in-stability in a microgrid which is a power quality issue and the voltage stability improvement using static synchronous compensator (STATCOM) are discussed. The microgrid system in this chapter has a Alternating Current (AC) bus and Direct Current (DC) bus, interconnected together with a tie line DC–AC converter. AC bus of the microgrid is designed to operate in synchronism with the utility grid. During the islanded mode of operation, i.e. when the power is absent in the utility grid, the AC bus voltage would fluctuates due to variation of reactive power of load on the Microgrid. Hence it is necessary to regulate the AC bus voltage. A static synchronous compensator (STATCOM) would be a better solution for compensation of reactive power and minimize voltage fluctuations on AC bus of the microgrid. STATCOM is a power electronic device that is used for regulating the voltages and the reactive power in the system. The performance of STATCOM in microgrid system is simulated using MATLAB/SIMULINK and observed for different type of power generating system under balanced and unbalanced loads.

KEYWORDS: Microgrid, Voltage Stability, Power Quality, STATCOM, Active Filters, Stability, SPWM Technique, Voltage fluctuations.

I. INTRODUCTION

With the growing demands for electricity, the advantages which the large power grid reflected in the past few years enable it developed rapidly and become the main power supply channels in the world. There are some major drawbacks with the power supply of the centralized power grid high cost and difficult to run, increasingly difficult to meet with users high safety and reliability requirements.

In recent days because of environmental considerations, technological developments and governmental incentives for renewables, the grid architecture is changing from centralized to decentralized energy supply with distributed generation (DG) units connected to the utility grid. Compared with the centralized power generation, distributed generation has its own advantages with less pollution, higher energy efficiency, more flexible installation sites, transmission and distribution of resources, lower operating costs, and reduction of power transmission line loss.

Distributed generation can reduce the total capacity of power grid and improve grid peak performance, improve power supply reliability is a strong complement to large powergrid and effective support of DG can also lead to improved reactive power support and voltage profile, usage of environmental friendly resources and postponement of investments in new transmission systems and large-scale generators.

Distribution grids are conceived as passive top-down architecture, with a unidirectional power flow, but the increasing presence of DG units leads to bidirectional power flow in an active distribution network. Another major change is that most DG units are connected to the ac-grid via power electronic interfaces, e.g., voltage source inverters, because they do not generate a 50 Hz voltage.

The CERTS defines the microgrid as a small-scale, low-voltage system consisting of a combination of generators, loads and energy storage elements, mainly with power-electronic interface. A key advantage is that the microgrid appears to the power network as a single controllable unit.

Micrograds can also enhance local reliability, reduce feeder losses, support local voltage, increase efficiency through CHP and provide uninterruptible power supply (UPS) functions. Furthermore, microgrids can facilitate the penetration of renewables and other forms of DG into the utility grid and assist in better power quality. The microgrid can operate in grid-connected or stand-alone mode Schematic diagram of a microgrid is shown in Figure1.

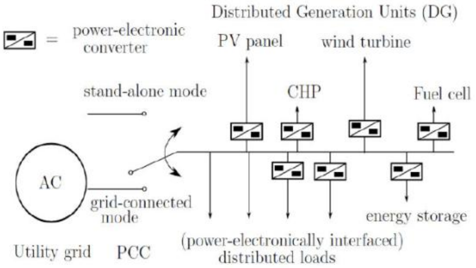


Fig. 1 Microgrid with (power-electronically interfaced) loads, storage and DG units in stand-alone or grid-connected mode

II. MICRO GRID

Microgrid is a modern, small-scale version of the centralized electricity system. They achieve specific local goals, such as reliability, carbon emission reduction, diversification of energy sources, and cost reduction, established by the community being served. Like the bulk power grid, smart microgrid can generate, distribute, and regulate the flow of electricity to consumers. Smart microgrid is an ideal way to integrate renewable energy resources on the community level and allow for customer participation in the electricity enterprise.

The grid connects homes, businesses and other buildings to central power sources, which allow us to use appliances, heating/cooling systems and electronics. But this inter connected grid needs to be repaired which will affect all the systems in the grid.

A microgrid generally operates while connected to the grid it can break off and operate on its own using local energy generation in times of crisis like storms or power outages, or for other reasons. It can be powered by distributed generators, batteries and renewable resources like solar panels. Depending on how it fueled and how its requirements are managed, a microgrid might run indefinitely.

This combination of units is connected to the distribution network through a single point of common coupling (PCC) and appears to the power network as a single unit. The concept of using microgrid is to provide ancillary services to the local network has also been discussed, present commercial incentives are probably insufficient to encourage this.

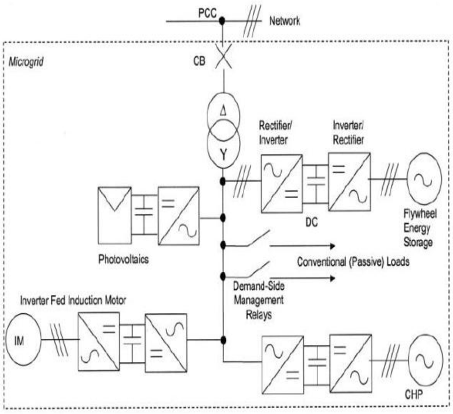


Fig. 2 Simple Example Microgrid.

A critical feature of the microgrid is the power electronics devices. The majority of the micro sources must be power electronic based to provide the required flexibility to ensure controlled operation as a single aggregated system. The system must be capable of operating despite changes in the output of individual generators and loads. It should have plug-and-play functionality and it should be possible to connect extra loads without reprogramming a central controller (up to a predefined limit). It should be possible that some of these are loads conventional. Likewise it must be possible to add generation capacity with minimal additional complexity. The immediate issues for the microgrid are power flow balancing, voltage control and behavior during disconnection from the point of common coupling (islanding). Protection and stability also need to be considered, but are outside the scope of this article.

The most immediate sites for application of the microgrid concept would be existing remote systems which consist of a bundle of micro sources and loads (figure: 2). It could be prohibitively expensive to compensate for load growth or poor power quality, by upgrading the long supply line and the feeder to the weak source bus. Upgrading the local sub-system to a microgrid could be a cheaper option. A necessary feature of such a microgrid is that it can act as a semi-autonomous system, i.e. when the main network is not available, the microgrid can still operate independently. This also has the potential to significantly improve the power quality of microgrid systems by allowing them to ride through some faults. This is an advantage for sub-systems in larger installations requiring heterogeneous power quality.

The implementation of power flow control (P and Q). Response to the onset of autonomous operation (islanding) and resynchronization can be functioned. The requirement for energy storage

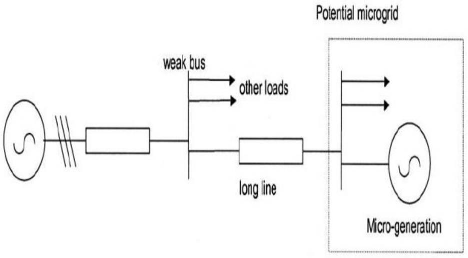


Fig. 3 Potential Microgrid: remote combination of micro source and loads.

An assumption used in this paper is that a central controllers or system optimizer will be required to coordinate the power electronic interfaces in the microgrids. This will be a slow acting outer control loop, the principle function of which is to determine the balance of steady-state real and reactive power flow between the microgrid components and the network. The central controller communicates to the individual units by a comparatively low bandwidth (and hence inexpensive) link.

III. VOLTAGE FLUCTUATION PROBLEM ON AC BUS

In non-islanded mode of operation, in absence of STATCOM, local excessive reactive power demand is supplied by the utility grid. Sudden transients in the reactive power demand are taken care of by utility grid and the AC bus voltage is maintained. However, in islanded mode of operation, in absence of STATCOM, reactive power demand is completely supplied by the converters of the power sources such as wind power plants, solar plants and the conventional synchronous generators of the pico-hydro plants. With limited capability to supply the reactive power demand, islanded AC-bus of microgrid shows drastic fluctuations in the voltage. This provokes need of AC-bus voltage regulating control system to be embedded in STATCOM.

IV. BASIC CONFIGURATION OF STATCOM

V.

The STATCOM is a shunt device. It should therefore be able to regulate the voltage of a bus to which it is connected. The operating principle of a STATCOM in this mode has been termed as the STATCOM in voltage control mode. In its most basic form, the STATCOM configuration consists of a VSC, a dc energy storage device; a coupling transformer connected in shunt with the ac system, and associated control circuits. Fig.4 shows the basic configuration of STATCOM. The VSC converts the dc voltage across the storage device into a set of three phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the STATCOM output voltage allows effective control of active and reactive power exchanges have been made to recover the situation with solutions based between the STATCOM and the ac system. The VSC connected in shunt with the ac system provides a multi functional topology which can be used for up to three quite distinct purposes:

- Voltage regulation and compensation of reactive power.
- Correction of power factor.
- Elimination of current harmonics.

As seen in Fig. 4, STATCOM is comprised of a coupling transformer, voltage based inverter and DC energy storage element. If it is a rather small capacitor, energy storage element can only be involved in reactive power exchange with the STATCOM line. If an accumulator or another DC voltage resource is used in the place of the DC capacitor, energy storage element can be involved in active and reactive power exchange with the transmission system. The voltage amplitude of the output and phase angle of STATCOM can be changed. The amplitude of AC output voltage basic component of an inverter can be controlled using STATCOM.

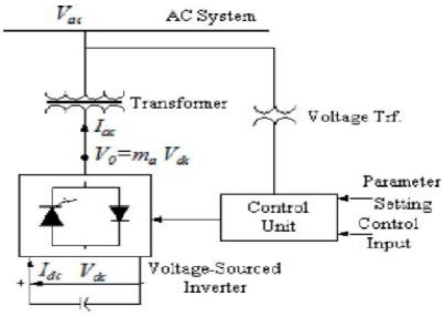


Fig. 4 STATCOM circuit diagram

Representation STATCOM using V-I graphic of under non-stop functioning condition was given in the Fig. 5. The graphic shows that the power system is provided with both inductive and capacitive flows in regular intervals.

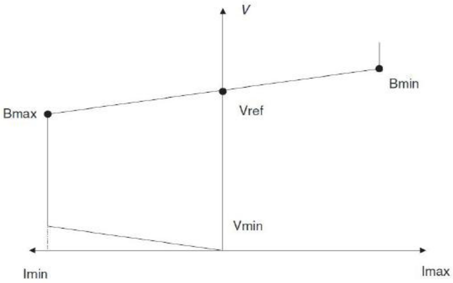


Fig. 5 V-I characteristic of STATCOM under non-stop work conditions.

The amplitude value of the flow from the inverter to the line can be calculated with the equation (1) below:

$$I_{ac} = \frac{V_0 - V_{ac}}{X} \tag{1}$$

Where X represent the leakage reactance of the coupling transformer. Mutual exchange of reactive power can be stated in the equation (2) below:

$$Q = \frac{V_0^2 - \mathrm{V_0}\,\mathrm{V_{ac}} \cos\alpha}{X} \tag{2}$$

If the inverter output voltage in the system is beyond compared to AC system voltage, the inverter will provide active power from DC capacitor to the AC system. If the inverter output voltage in the system is behind compared to AC system voltage, the inverter will extract active power from the AC system. The amount of active power exchanged constantly is rather small. The active exchange between voltage based inverter and AC system can be calculated with the equation (3) below:

$$P = \frac{\mathrm{V_0}\,\mathrm{V_{ac}} \sin\alpha}{X} \tag{3}$$

VI. PRINCIPLE OF STATCOM

STATCOM is to suppress voltage variation and control reactive power in phase with system voltage. It can compensate for inductive and capacitive currents linearly and continuously. Fig.3 shows the vector diagram at the fundamental frequency for capacitive and inductive modes and for the transition states from capacitive to inductive and vice versa.

The terminal voltage (V_{bus}) is equal to the sum of the inverter voltage (V_{VSC}) and the voltage across the coupling transformer reactive VL both capacitive and inductive modes. It means that if output voltage of STATCOM (VVSC) is in phase with bus terminal voltage (V_{bus}) and VVSC is greater than V_{bus}, STATCOM provides reactive power to system. If V_{VSC} is smaller than V_{bus}, STATCOM absorbs reactive power from power system. V_{bus} and VVSC have the same phase, but actually they have a little phase difference to component the loss of transformer winding and inverter switching, so absorbs some real power from system.

Fig.6 is STATCOM vector diagrams, which show inverter output voltage VI, system voltage VT, reactive voltage VL and line current I in correlation with magnitude and phase δ. Fig.3 a and b explain how VI and VT produce capacitive or inductive power by controlling the magnitude for inverter output voltage VI in phase with each other. Fig.6 c and d show STATCOM produces or absorbs real power with VI and VT having phase ±δ. The transition from inductive to capacitive mode occurs by charging angle δ from zero to a negative value. The active power is transferred from the AC terminal to the DC capacitor and causes the DC link voltage to rise. The active and reactive power may be expressed by the following equations:

$$P = \frac{V_{bus}\ V_{VSC}}{X_L} \sin\delta \tag{4}$$

$$Q = \frac{V_{bus}^2 - V_{bus}\ V_{VSC} \cos\alpha}{X_L} \tag{5}$$

Vvsc -output voltage of STATCOM
V_{bus} -bus terminal voltage
X_L -inductive reactance of coupling transformer

A STATCOM is a voltage source inverter which converts DC input voltage into AC output voltage by which it regulates active and reactive power in the system. The AC voltage is controllable both in magnitude and phase. It can exchange active power if energy source is added on DC side.

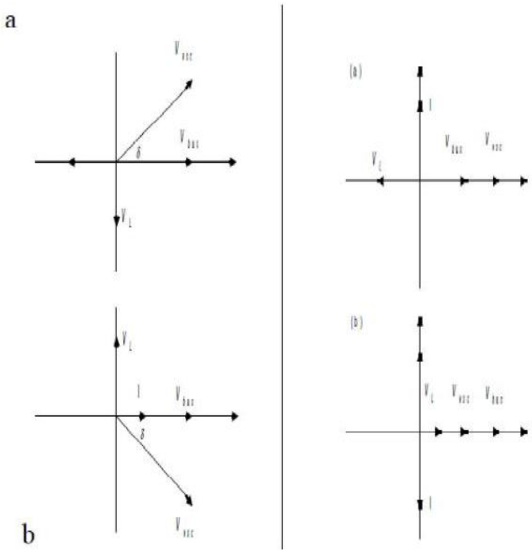


Fig. 6 Vector diagram of STATCOM;(a)capacitive mode, (b)inductive mode, (c)active power release and (d) active power absorption.

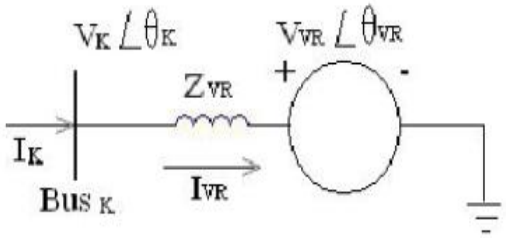


Fig. 7 Equivalent circuit of STATCOM

STATCOM is represented as a voltage source for the full range of operation, enabling a better voltage support.

VII. D-STATCOM MODELING USING MATLAB-SIMULINK

Fig. 8 shows the test system used to carry out the various DSTATCOM simulations presented in this section. The test system composes a 230 kV, 50 Hz generation system, represented by a Thevenin equivalent, feeding into the primary side of a 3-winding transformer. A varying load is connected to the 11 kV, secondary side of the transformer. A two-level D-STATCOM is connected to the 11 kV tertiary winding to provide instantaneous voltage support at the load point

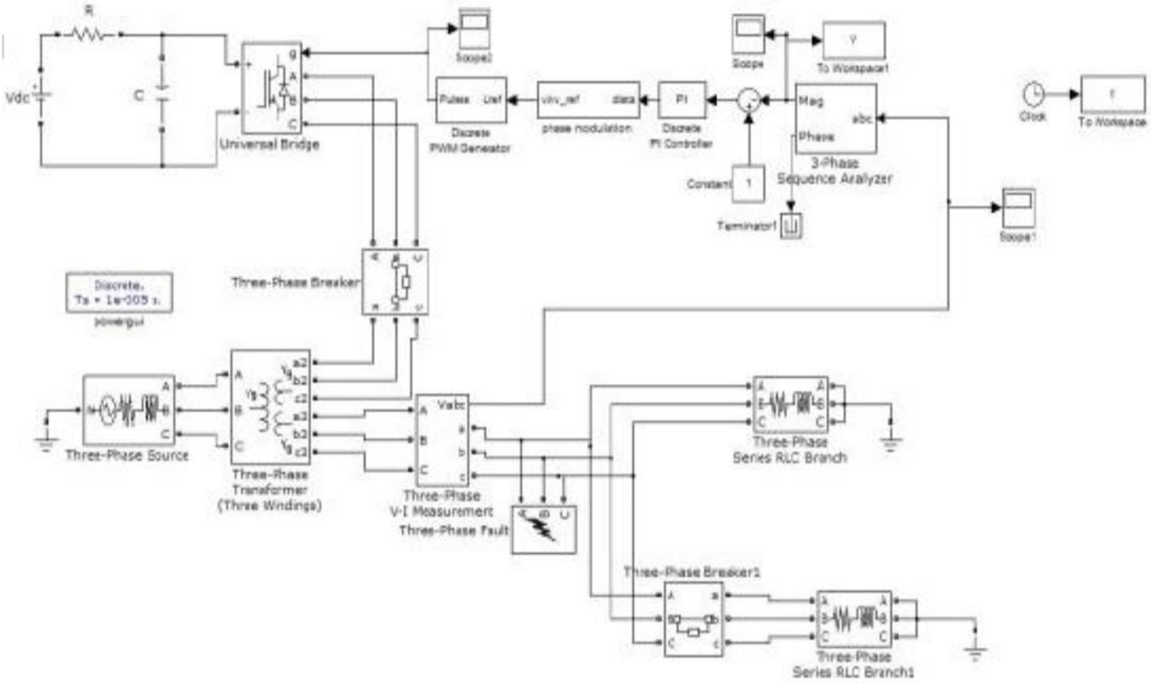
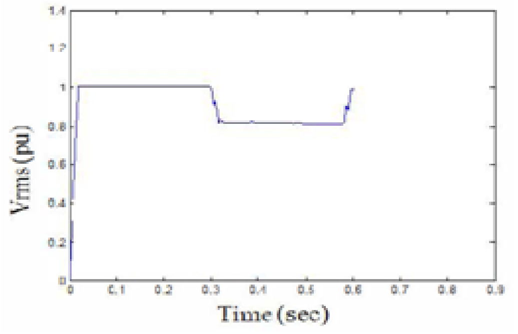


Fig. 8 Modeling of D-STATCOM for voltage sag and voltage swell

VIII. EXPERIMENTAL RESULTS

A. Voltage Sag - Without D-STATCOM

In the first case simulation is did without DSTATCOM and a three phase-to-ground fault is applied at point A, via a fault resistance 0.20 Ω, Ground Resistance 0.001. The fault is created for the duration of 0.3seconds to 0.5seconds.it if found that there is voltage sag. The output wave for the load without DSTATCOM shown below in the figure 9.



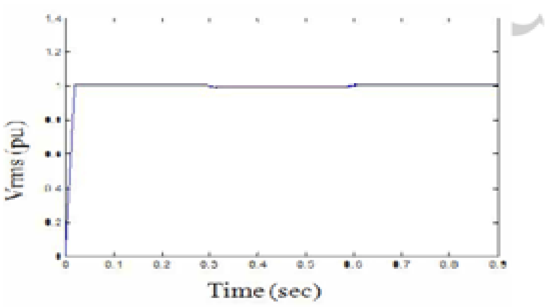


Fig. 9 Voltage waveform without DSTATCOM

Fig. 10 voltage waveform with DSTATCOM

B. Voltage Sag - With DSTATCOM

The second simulation is carried out using the same scenario with DSTATCOM, then the voltage sag is mitigated almost completely .The output wave for the load with D-STATCOM shown in above figure 10.

C. Voltage Swell - Without D-STATCOM

The first simulation contains no D-STATCOM and a three-phase fault is applied at point A, during the period 300-600ms. The voltage swell at the load point is 20% with respect to the reference voltage, as shown in below figure 11.

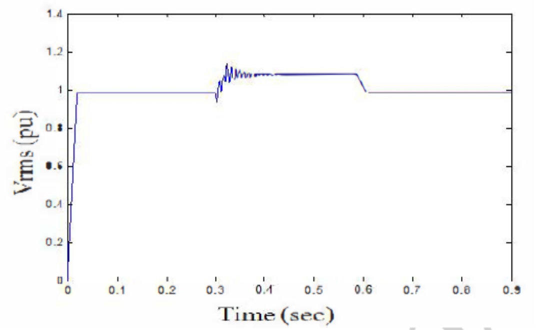


Fig. 11 Voltage swell without DSTATCOM

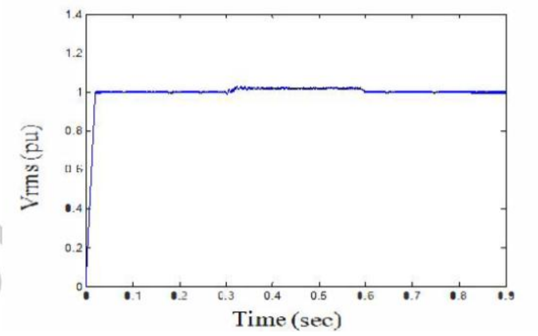


Fig. 12 Voltage swell with DSTATCOM

D. Voltage Swell - With DSTATCOM

The second simulation is carried out using the same scenario as above, but now D-STATCOM is connected to the system, then the voltage swell is mitigated almost completely, and the rms voltage at the sensitive load point is maintained at 98% as shown in above figure 12.

E. Response of DC voltage regulating Control System

With sudden change in the reactive power demand on AC bus, capacitor voltage on the DC link of the STATCOM tends to decrease drastically. Losses in the power circuit are increased due to increased reactive power output of STATCOM. To cope up with the increased losses the delta of STATCOM is made more lagging by the regulating PID control system. Fig 13 shows the response of the control system. Capacitor voltage experiences a droop in the start but is observed to return back to the reference value. From the control effort, it can be seen that the delta has settled to a greater lagging value.

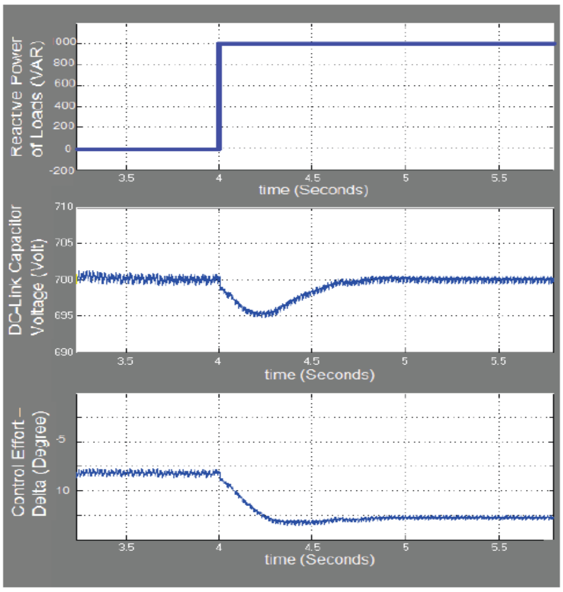


Fig. 13 Response of dc voltage regulating control system based on change in reactive power demand

F. Response of AC bus voltage regulating/ Reactive power control system

With sudden islanding or sudden increase in the reactive power demand in islanded operation, leads to sudden droop in the AC bus voltages. (fig 14) Reactive power control system responds to the situation and maintains the AC bus voltage to the reference value by supplying the excessive reactive power demand. (fig. 15)

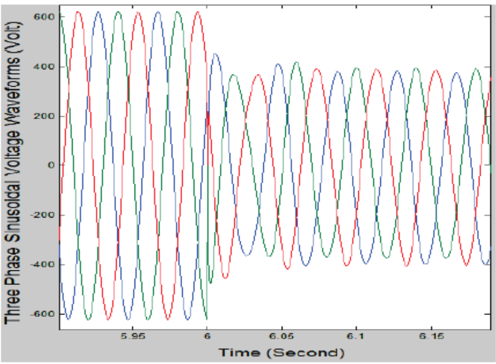


Fig. 14 Response of AC bus voltage without STATCOM

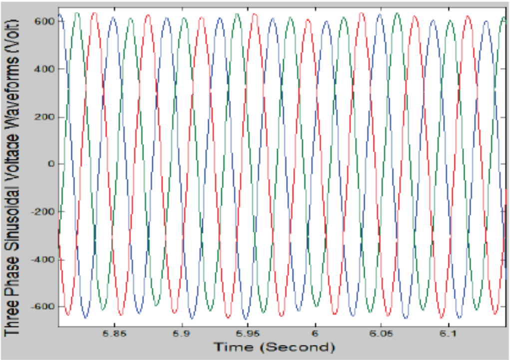


Fig. 15 Response of AC bus voltage with STATCOM

IX. CONCLUSIONS

This paper discusses application of STATCOM in a microgrid with islanding scheme. STATCOM is designed for the reactive power compensation of microgrid and AC bus voltage regulation. STATCOM is simulated along with the microgrid in MATLAB to observe and improve transient response of AC bus voltage with STATCOM response of the controls to dynamic loading and islanding scenarios. In this work, the investigation on the role of Distribution Static Synchronous Compensator (D-STATCOM) can compensate the voltage sag and swells under faulty condition. In order to achieve improved power quality levels simulated with or without DSTATCOM connected to the distribution system.

Compensation techniques of custom power electronic device D-STATCOM with SPWM was presented. The control scheme was tested under a wide range of operating conditions, and it was observed to be very robust in every case. For modeling and simulation of a D-STATCOM by using the highly developed graphic facilities available in MATLAB/SIMULINK were used. The simulations carried out here showed that the D-STATCOM provides relatively better voltage regulation capabilities. It can be concluded that DSTATCOM improves the power quality and remove the voltage Sag/Swell condition in distribution network.

REFERENCES

[1] Balaguer I.J. ; Dept. of Electrical Eng. , Michigan State Univ. , EastLansing, MI, USA ; “Control for Grid-Connected and Intentional IslandingOperations of Distributed Power Generation” *IEEE Transactions onIndustrial Electronics*, vol. 58, No. 1 , Dec. 2010.
[2] Majumder R. ; ABB Corp. Res., Vasteras, Sweden, “Reactive Power Compensationin Single-Phase Operation of Microgrid” *IEEE Transactions onIndustrial Electronics*, vol. 60, No. 4 ,Nov. 2012.
[3] MehrdadAhmadiKamarposhti, MostafaAlinezhad, *“ Comparison ofSVC and STATCOM in static voltage stability margin enhancement ”*,World Academy of Science, Engineering and Technology Vol:3 2009-02-20
[4] Hingorani, N. ; Gyugyi, L. ; Understanding FACTS:Concepts and Technologyof Flexible AC Transmission Systems , Chapter 5 :Static ShuntCompensators: SVC and STATCOM , Page(s): 135 - 207 , CopyrightYear: 2000
[5] Jamal Alnasseir “Theoretical and Experimental Investigations on SnubberCircuits for High Voltage Valves of FACTS Equipment for Over VoltageProtection” Master Thesis Project Erlangen 2007.
[6] PraneshRao and M. L. Crow, “STATCOM Control for Power SystemVoltage Control Applications” *IEEE Transactions on Power Delivery*, vol.15, NO. 4, October 2000.
[7] Madhusudan,Sir C.R. Reddy College,RamamohanRao, “Modeling andsimulation of a distribution STATCOM (D-STATCOM) for power qualityproblems-voltage sag and swell based on Sinusoidal Pulse Width Modulation(SPWM)” *IEEE Transactions*, March 2012.
[8] Y. W. Li, D. M. Vilathgamuwa and P. C. Loh, “A grid-interfacing power quality compensator for three-phase three-wire microgrid applications,”IEEE Trans on Power Electronics, Vol. 21, Issue 4, pp. 1021-1031, July 2006.
[9] A. Ghosh, A. K. Jindal and A. Joshi, “Inverter control using output feedback for power compensating devices,” Proc. IEEE AsiaPacificRegion-10 Conference TENCON, Bangalore, pp. 49-52, October 2003.
[10] A. Ghosh and G. Ledwich, "Load compensating DSTATCOM is weak ac systems," IEEE Trans. Power Delivery, Vol. 18, No. 4, pp. 1302-1309, 2003.
[11] Manojnair “Power quality” text book balaji learning published Edition: 11 is bn no. 978-81-910618-6-4.
[12] S. Ravi Kumar, S.Sivanagaraju, "Simualgion of D-Statcom and DVR in power system," ARPN jornal of engineering and applied science, vol. 2, no. 3, pp. 7-13, June 2007
[13] [3] H. Hingorani, "Introducing custom power", IEEE Spectrum, vol.32, no.6, pp. 41 48, June 1995.
[14] N.G. Hingorani and L. Gyugyi, “Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems”, 1st edition, The Institute of Electrical and Electronics Engineers, 2000.
[15] Dr. S.M. Ali B.K.PrustyM.K.Dash S.P. Mishra. “Role of facts devices in improving power quality in a grid connected renewable energy system.” Journal of Engineering Research and Studies E-ISSN0976-7916.
[16] HendriMasdi, Norman Mariun Senior MIEEE, S.M.Bashi MIEEE, A. Mohamed Senior MIEEE,Sallehhudin Yusuf MIEEE “design of a prototype d-statcom for voltage sag mitigation.”
[17] G. Venkataramana,andBJohnson, "A pulse width modulated power line conditioner for sensitive load centers," IEEE Trans. Power Delivary, vol. 12, pp. 844-849, Apr. 1997.