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Performance of DSTATCOM in Conjunction with DG Operation for Power - Quality Improvement

Authors
G.Vamsi Krishna[1], T.Srinivasa Rao[2], U. Anjaiah[3]
[1]PG Student Scholar, Avanthi Engineering College, Makavarapalem, Visakhapatnam
[2]Associate Professor, Avanthi Engineering College, Makavarapalem, Visakhapatnam
[3]Assistant Professor, Avanthi Engineering College, Makavarapalem, Visakhapatnam

Abstract
With the increase in the use of renewable sources, application of Distributed Generation in the distribution system has acquired more attention. Distributed Generation has become increasingly more accepted since the demand for reliable and secure power systems with high power quality increases. Distributed generation will continue to be an effective energy solution under certain conditions and for certain types of customers, particularly those with needs for emergency power, uninterruptible power. A Distribution static compensator (DSTATCOM) is a shunt compensation device that is generally used to solve power quality problems in the distribution systems. In all electric power systems, power quality issues arise due to high energy demand loads such as pulse loads. In this paper a new algorithm to generate reference voltage for a distribution static compensator (DSTATCOM) operating in voltage-control mode is preferred. The proposed scheme ensures that unity power factor (UPF) is achieved at the load terminal during nominal operation. In this paper, implementing Power quality circuit with voltage source converter in the BLDC Motor drive using Distributed Generation is developed. Simulation work is performed using MATLAB / SIMULINK environment.

Index Terms—*Distributed Generation, Distributed Static Compensator, Current Control Mode, Power Quality (PQ), Voltage-Control Mode, Voltage-Source Inverter, BLDC Motor.*

INTRODUCTION

Power Quality (PQ) is the key to successful delivery of quality product and operation of an industry. Due to increase in the application of electronic loads and electronic controllers which are sensitive to quality of power, serious economic consequences and of revenue losses arises. Poor PQ can cause malfunctioning of equipment performance, increase of harmonics, voltage imbalance, sag and flickering problems and resonance. These issues adversely affect production and its quality leading to huge loss in terms of product, energy and may cause damage to the equipment. Thus, it becomes imperative to be aware of quality of power grid and the deviation of the quality parameters from the norms /standard such as IEEE-519 standard [1] to avoid breakdown or damage to the equipment.

In the present day distribution systems (DS), major power consumption has been in reactive loads. The typical loads may be computer loads, small rated adjustable speed drives (ASD) in air conditioners, fans, refrigerators, pumps and other domestic and commercial appliances which are generally nonlinear. These loads draw lagging power-factor currents and therefore give rise to reactive power burden in the DS. Moreover, situation worsens in the presence of unbalanced and non-linear loads, which affect the quality of source currents to a large extent. It affects the voltage at point of common coupling (PCC) [2]. This has adverse effect on the sensitive equipments that are connected at PCC and may damage them. Excessive reactive power demand increases feeder losses and reduces active power flow capability of the DS, whereas unbalancing affects the operation of transformers and generators [3], [4].

From the past few decades, the energy consumption has been increasing as exponential rate. This increase in power demand was increasing the power outages. The conventional sources will become rare, endangered and may extinct after few decades. These also produce lots of carbon dioxide that adds to the greenhouse effect in the atmosphere while uranium leaves different dangerous byproducts. So researchers have developed an alternative for the production of electricity by renewable energy sources. Solar and wind are two of them. Firstly, they are used as stand-alone systems, to feed the local loads in remote areas, but later, they have become some of the main sources [5], [6].

PROPOSED CONTROL SCHEME

Consider a DSTATCOM-compensated distribution system as shown in Fig.1. It uses a three-phase, four-wire, two-level, neutral-point-clamped VSI, which allows independent control of each leg. Shunt capacitor eliminates high-switching frequency components. A proportional-integral (PI) controller is used to regulate the dc capacitor voltage at a reference value.

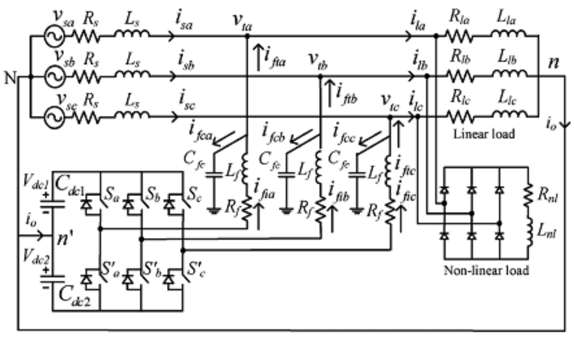

Fig.1. Circuit diagram of the DSTATCOM-compensated distribution system.

The shunt capacitor eliminates high switching frequency components.

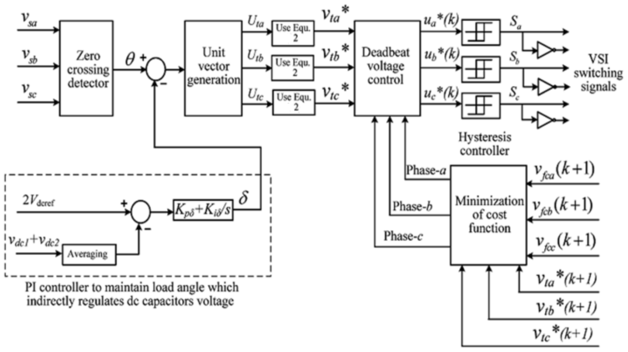

Fig.2 Overall block diagram of the controller to control DSTATCOM in a distribution system.

Here, $v_t^*(k+1)$ is the future reference voltage which is unknown. One-step-ahead prediction of this voltage is done using a second-order Lagrange extrapolation formula as follows:

$$v_t^*(k+1) = 3v_t^*(k) - 3v_t^*(k-1) + v_t^*(k-2)$$
(1)

$$V_t^* = \sqrt{V^2 - (I_{la1}^+ X_s)^2} - I_{la1}^+ R_s$$
(2)

The term $v_t^*(k+1)$ is valid for a wide frequency range. Variable *u* is a switching function which is either +1 or -1 depending on the switching state. $u_t^*(k)$, is converted into the ON/OFF switching command to the corresponding VSI switches using a deadbeat hysteresis controller.

DISTRIBUTED GENERATION

Distributed energy is the energy generated or stored by a variety of small, grid connected devices, generally known as Distributed Energy Resources.

Conventional power stations, such as coal, nuclear and hydro power plants, require transmitting power over long distance. While, DER systems are decentralized and more flexible that are located close to load centre. Distributed energy resources will be a valuable part to ensure reliable management of electric grid. DER systems are renewable energy sources including small hydro, biomass, biogas, solar power, geo thermal power.

Many DER applications require interconnection with the grid [7]. Proper interconnection equipment allows the facility operating the DER the ability to:

a) Operate the DER equipment to supplement peak power demands with grid.
b) Obtain backup power from the area electric power system in the event of a DER system outage, eliminating the need for complete system redundancy.
c) Take advantage of the opportunity to export power to remote areas.
d) Improve overall customer system reliability by providing an alternative power supply option.

Economies of Scale

Central power plants are integral part of grid which is generally located either close to resources or at load centre. These supply power to load centers and from there to customers.

Central plants could deliver comparatively cheap and reliable power to remote customers through grid. Thus grid has become the main driver of remote customer's power costs and power quality problems which became more sensitive, as digital equipments require extremely reliable power. Hence efficiency and reliability of power has become more important, but from smaller units located near to site of demand.

DG sources development has aroused due to following factors:

a) Concern over cost of generation of central power plant due to environmental issues.
b) Increasing age, deterioration and capacity constraints due to transmission and distribution.
c) Increase in relative economy of mass production of smaller units over of larger units.
d) Higher relative prices of energy, overall complexity and total cost of metering and billing.

i. Integration With grid

Owing to reliability concerns, DG resources would be connected to same transmission grid as of central stations. Various problems like power quality issues, voltage stability, harmonics, reliability, protection and control. Behavior of protection devices on the grid must be examined for all combinations of distributed and central power stations.

Power plants like Solar and wind are intermittent and unpredictable. So they create stability issues for voltage and frequency. Voltage issues effect grid equipments like tap changers which should respond too often and wear out quickly. Without any form of energy storage, high solar generation increases much power during day compared to night [8].

The DG systems have shorter construction times and have reduced financial risk of over or under building. It has significant reduction in fuel disruption risk and fuel forward price risk as these resources are naturally available. They improve system stability due to multiplicity of inputs and reduce regional consequences of system failure. They improve transmission and distribution reliability due to reduced peak loading.

The main problem with DG technique was that the grid becomes more complex due to increase in number of inputs which becomes difficult to analyze. Hence, there may be a fatal mistake in designing time current curve of protective devices like fuses, circuit breakers and protective relays that may momentarily cause tripping of other power sources if only steady state analysis was preferred.

CONTROLLER FOR DC BUS CAPACITOR VOLTAGE

Average real power balance at the PCC will be

$$P_{pcc} = P_{lavg} + P_{loss} \quad (3)$$

Where P_{pcc}, P_{1avg}, and P_{loss} are the average PCC power, load power, and losses in the VSI, respectively. The power available at the PCC, which is taken from the source, depends upon the angle between source and PCC voltages, that is, load angle δ. Hence δ must be maintained P_{pcc} constant to keep constant. The voltage of the dc bus of DSTATCOM can be maintained at its reference value by taking inverter losses P_{loss} from the source. If the capacitor voltage is regulated to a constant reference value P_{loss}, is a constant value. Consequently, δ is also a constant value. Thus, it is evident that dc-link voltage can be regulated by generating a suitable value δ of .This δ includes the effect of losses in the VSI and, therefore, it takes care of P_{loss} the term in its action. To calculate load angle δ, the averaged dc-link voltage $(V_{dc1} + V_{dc2})$ is compared with a reference voltage, and error is passed through a PI controller. The output of the PI controller, which is load angle δ, is given as follows:

$$\delta = K_{p\delta} e_{vdc} + K_{i\delta} \int e_{vdc}\, dt \quad (4)$$

Where $e_{vdc} = 2V_{dcref} - (V_{dc1} + V_{dc2})$ is the voltage error. Terms $K_{p\delta}$ and $K_{i\delta}$ are proportional and integral gains, respectively. δ must lie between 0 to 90^0 for the power flow from the source to PCC. Hence, controller gains must be chosen carefully [9].

V.MATLAB/SIMULINK RESULTS

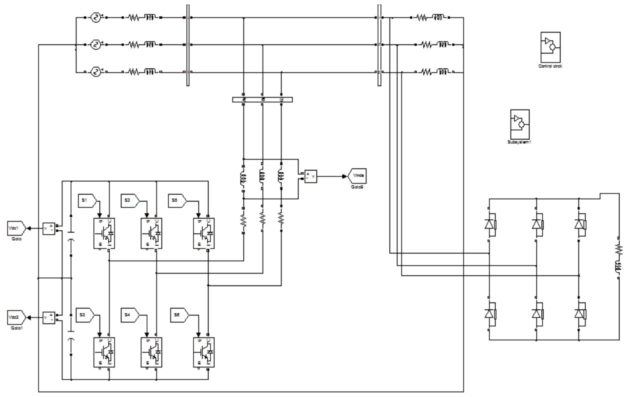

Fig.3. Simulation results for Conventional/Proposed system.

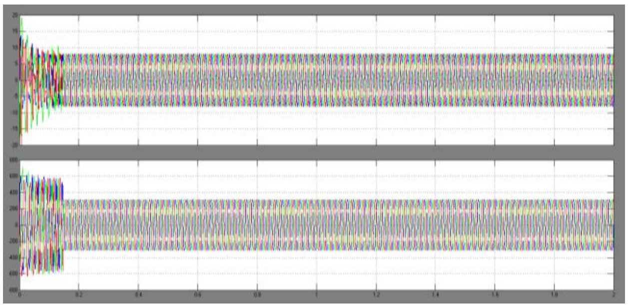

Fig.4. Source voltage and current.

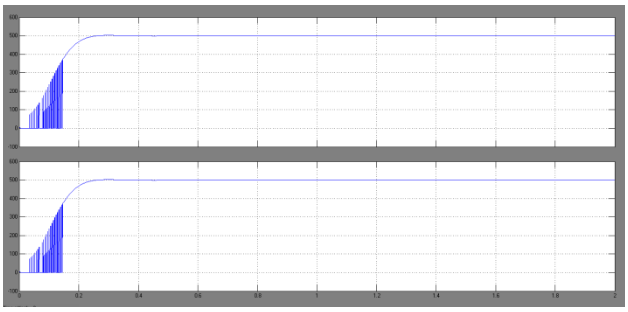

Fig.5. dc link voltage.

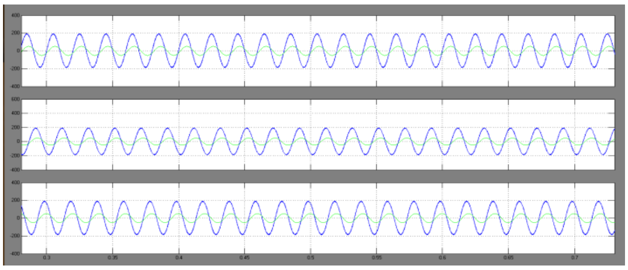

Fig.6. Terminal voltages and source currents using the traditional method. (a) Phase-A. (b) Phase-B. (c) Phase-C.

Initially, the traditional method is considered. Fig.10. shows the regulated terminal voltages and corresponding source currents in phases a, b, and c, respectively. These waveforms are balanced and sinusoidal. However, source currents lead respective terminal voltages which show that the compensator supplies reactive current to the source to overcome feeder drop, in addition to supplying load reactive and harmonic currents.

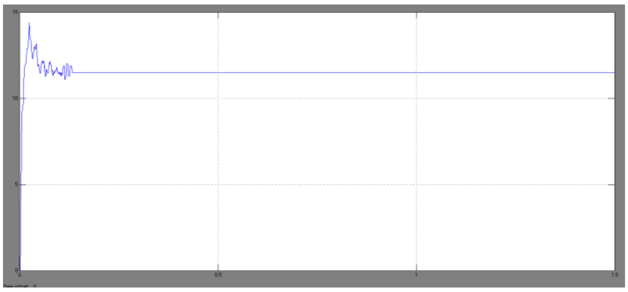

Fig.7. Phase- source RMS currents.

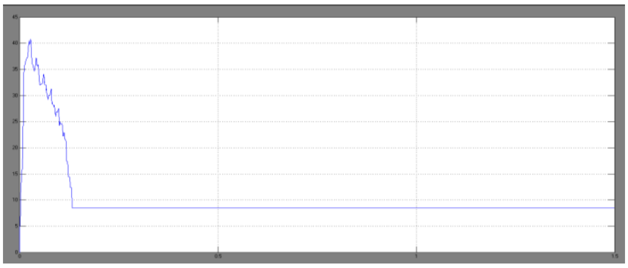

Fig.8. Phase- compensator RMS currents.

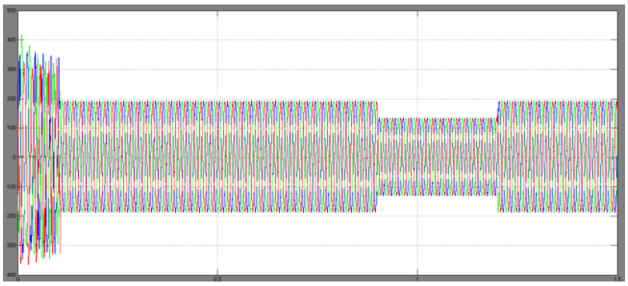

Fig.9. Simulation results for Source Voltage During Sag.

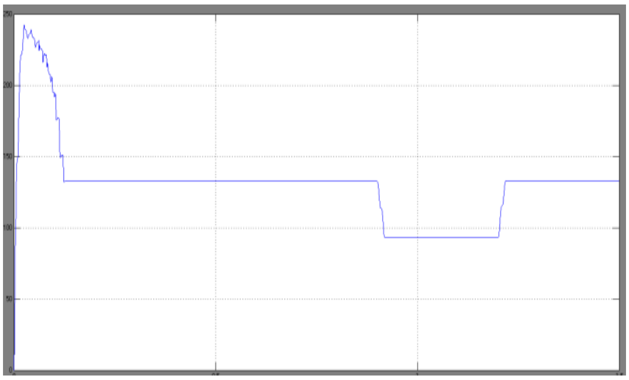

Fig.10. Simulation result for RMS value of source voltage during sag

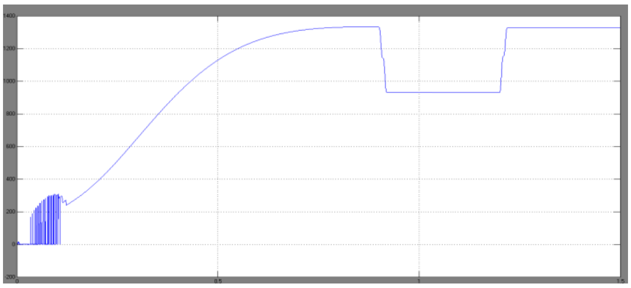

Fig.11.Simulation results for dc link voltage.

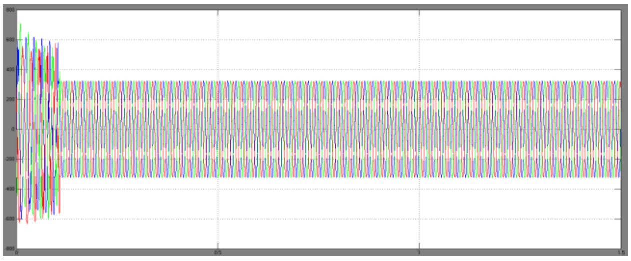

Fig.12. Simulation results for load voltage after compensation

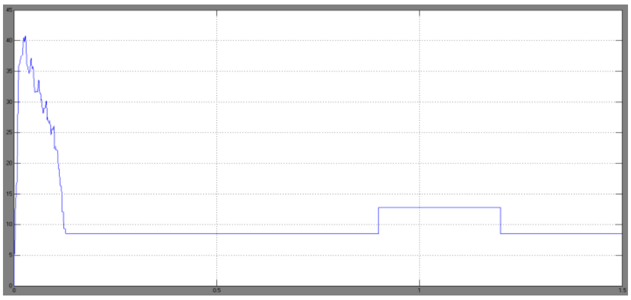

Fig.13. Simulation results for compensation current of D-STATCOM.

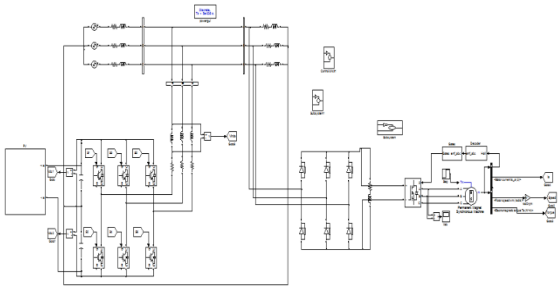

Fig.14. Simulink Circuit for Conventional D-STATCOM with BLDC drive.

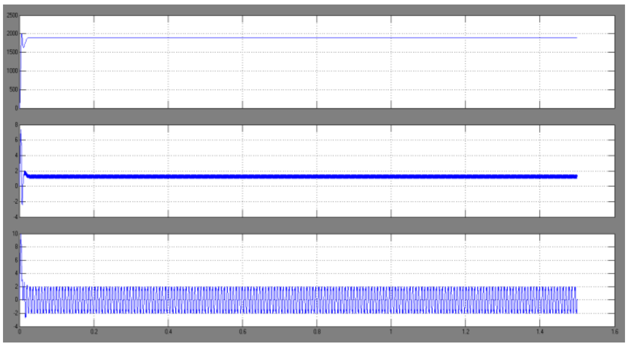

Fig.15. Speed, Torque and Armature Current of BLDC Drive.

CONCLUSION

In this paper, a control algorithm has been preferred for the generation of reference load voltage for a voltage-controlled DSTATCOM with Distributed generation. Distributed generation will continue to be an effective energy solution under certain conditions and for certain types of customers, particularly those with needs for emergency power and uninterruptible power supply. Installation and use of DG systems by customers and/or utilities can produce reductions in peak load electricity requirements, depending on how the DG is operated. Because most investment decisions for new plant and equipment in the electric power industry are driven by peak load requirements and reductions in peak load. In addition, reductions in peak load, particularly during critical peak periods which typically occur during excessively hot weather, can reduce the costs of electricity. Peak load reductions can eliminate or reduce the need for power from these most expensive power plants. Finally, reductions in peak load can reduce "wear and tear" on electric delivery equipment, thus reducing maintenance costs, extending equipment life, and reducing overall capital investment requirements.

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AUTHORS PROFILE

G.VAMSI KRISHNA is an M-Tech scholar at AVANTHI college of Engineering & Technology under JNTU, Kakinada. He received his B-Tech degree from Dadi Institute of Engineering & Technology under JNTU Kakinada. His current research interests mainly include Distributed Generation and Renewable Energy Resources.

T.SRINIVASA RAO is an Associate Professor and Head of the Department in AVANTHI College of Engineering & Technology, Visakhapatnam. He is currently working towards Ph.D. He got his M-Tech degree from GITAM University. His current research interests are Power Systems and Power System Analysis.

U.ANJAIAH is an Assistant professor in AVANTHI College of Engineering & Technology, Visakhapatnam. He got his M-Tech degree from JNTU Kakinada and his B-Tech degree from AKULA GOPPAYA College of Engineering and Technology, Tadepalligudem. His current research interests are High Voltage Engineering and Power Systems.