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D-STATCOM for Reactive Power Compensation

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Abstract: **this paper proposes, a simple control strategy for DSTATCOM with communication in loop is proposed. The proposed reactive compensation technique is based on the voltage sag and the power flow in the line. The power flow and the voltage at different locations of the feeders are communicated to the DSTATCOM to modulate the reactive compensation. The single-phase DSTATCOM compensates for the reactive power deficiency in the phase while the DGs supply "maximum available active power." During reactive power limit of the DG, the "maximum available active power" is fixed to a value lower than maximum active power to increase reactive power injection capability of the DGs. A primary control loop based on local measurement in the DSTATCOM always ensures a part of reactive compensation in case of communication failure. It is shown that the proposed method can always ensure to achieve acceptable voltage regulation. The data traffic analysis of the communication scheme and closed-loop simulation of power network and communication network are presented to validate the proposed method.**

Keywords: **Distributed Genarators, DSTATCOM, Microgrid, Power, Reactive compensation Single Phase, Microgrid.**

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. However, 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. Recently, 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 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 power grid and effective support. DG can also lead to improved reactive power support and voltage profile, removal of transmission bottlenecks, usage of environmental friendly resources and postponement of investments in new transmission systems and large-scale generators. Normally, the distribution grids are conceived as a 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., voltagesource inverters, because they do not generate a 50 Hz voltage. The CERTS (Consortium for Electric Reliability Technology Solutions) 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. Microgrids can also enhance local reliability, reduce feeder losses, support local.

II. RELATED WORKS

Goodwin.et.al Technological advances and environmental pressures are driving the interconnection of renewable energy sources to the distribution network. The interconnection of large amounts of non-traditional generation however causes problems in a network designed for 'conventional' operation. The use of power electronics interfaces and the 'bundling' of micro-generation and loads into so called Microgrids, offers a potential solution. Each Microgrid is designed to operate as a ‘good citizen’ or near ideal conventional load. This paper discusses the various elements of the new Microgrid concept and presents suggestions for some typical control strategies for the various system elements.

Sheetal Shinkhede .et. al, That reviews the importance of a flexible ac distribution system device for microgrid applications. The device aims to improve the power quality and reliability of the overall power distribution system that the microgrid is connected to. Extended Kalman filters are also studied for frequency tracking and to extract the harmonic spectra of the grid voltage and the load currents in the microgrid. Also this paper high lights on DG grouping in order to harmonize the investment of assets, the quality of power supply and the cooperation with the existing power grid.

Basha et.al proposes to improve the power quality in a utility connected grid by using converter based single phase micro sources. The voltage unbalance can be severe if single-phase rooftop mounted PVs are distributed randomly between the households. Moreover, there can also be single-phase nonlinear loads present in the system. The cumulative effect of all these will cause power quality problem at the utility side. To counteract this problem, we have proposed two different schemes. In this first scheme a distribution static compensator (DSTATCOM) is connected at the utility bus to improve the power quality. The DSTATCOM only supplies reactive power and no real power. In the second scheme, a larger three-phase converter controlled DG is placed that not only supplies the reactive power but also provides active power. The efficiency of the controllers have been validated through simulation for various operating conditions using MATLAB/SIMULINK.

Firuz Zare et.al, shows how the power quality can be improved in a microgrid that is supplying a nonlinear and unbalanced load. The microgrid contains a hybrid combination of inertial and converter interfaced distributed generation units where a decentralized power sharing algorithm is used to control its power management. One of the distributed generators in the microgrid is used as a power quality compensator for the unbalanced and harmonic load. The currentreference generation for power quality improvement takes into account the active and reactive power to be supplied by the micro source which is connected to the compensator. Depending on the power requirement of the nonlinear load, the proposed control scheme can change modes of operation without any external communication interfaces. The compensator can operate in two modes depending on the entire power demand of the unbalanced nonlinear load. The proposed control scheme can even compensate system unbalance caused by the single-phase micro sources and load changes. The efficiency of the proposed power quality improvement control and method in such a microgrid is validated through extensive simulation studies using PSCAD/EMTDC software with detailed dynamic models of the micro sources and power electronic converters.

T.Sandhya et.al, Renewable electricity generation has never seen the level of investment and incentives that have been put in place by governments around the world during the last decade. However, despite the envisaged environmental and security of supply benefits that the harvesting of indigenous, renewable sources might bring about, their integration into the power system creates significant challenges to both the network operators and developers. The power quality challenges become even greater when large volumes of renewable generation capacity are connected to distribution networks, traditionally designed to be passive circuits with unidirectional power flows. This paper presents two schemes to meet the different power quality challenges in the utility grid due to Distribution Generation. In this first scheme is DSTATCOM and second is three phase Distributed Generation. This work is aimed at demonstrating, from the planning perspective, the benefits that the adoption of the different compensators might bring the system to a ‘fit and forget’ approach.

III. PROPOSED WORK

The main contribution of the paper lies in improving reactive compensation with coordinated control of DGs and DSTATCOM with communication in loop for a microgrid. The proposed control ensures stable fast acting reactive power compensation within voltage regulation limit based on power flow. Converter control with integrated communication network demonstrates stable operation, while data traffic analysis shows the communication network requirements and limitations for this purpose.

IV. MICRO GRID

Microgrids are modern, small-scale versions 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 microgrids generate, distribute, and regulate the flow of electricity to consumers, but do so locally. Smart microgrids are an ideal way to integrate renewable 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 interconnectedness means that when part of the grid needs to be repaired, everyone is affected.This is where a microgrid can help. A microgrid generally operates while connected to the grid, but importantly, 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.A microgrid can be powered by distributed generators, batteries, and/or renewable resources like solar panels. Depending on how it’s fueled and how its requirements are managed, a microgrid might run indefinitely.

Series compensation:

In series compensation, the FACTS is connected in series with the power system. It works as a controllable voltage source. Series inductance exists in all AC transmission lines. On long lines, when a large current flows, this causes a large voltage drop. To compensate, series capacitors are connected, decreasing the effect of the inductance.

Shunt compensation:

In shunt compensation, power system is connected in shunt (parallel) with the FACTS. It works as a controllable current source. Shunt compensation is of two types:

Shunt capacitive compensation:

This method is used to improve the power factor. Whenever an inductive load is connected to the transmission line, power factor lags because of lagging load current. To compensate, a shunt capacitor is connected which draws current leading the source voltage. The net result is improvement in power factor.

Shunt inductive compensation:

This method is used either when charging the transmission line, or, when there is very low load at the receiving end. Due to very low, or no load – very low current flows through the transmission line Shunt capacitance in the transmission line causes voltage amplification (Ferranti effect). The receiving end voltage may become double the sending end voltage (generally in case of very long transmission lines). To compensate, shunt inductors are connected across the transmission line. The power transfer capability is thereby increased depending upon the power equation

$$P = \left(\frac{EV}{X}\right)\sin(\delta)$$

In the case of a no-loss line, voltage magnitude at the receiving end is the same as voltage magnitude at the sending end: $V_s = V_r = V$. Transmission results in a phase lag δ that depends on line reactance X.

$$\underline{V_s} = V\cos\left(\frac{\delta}{2}\right) + jV\sin\left(\frac{\delta}{2}\right)$$

$$\underline{V_r} = V\cos\left(\frac{\delta}{2}\right) - jV\sin\left(\frac{\delta}{2}\right)$$

$$\underline{I} = \frac{\underline{V_s} - \underline{V_r}}{jX} = \frac{2V\sin\left(\frac{\delta}{2}\right)}{X}$$

As it is a no-loss line, active power P is the same at any point of the line:

$$P_s = P_r = P = V\cos\left(\frac{\delta}{2}\right)\cdot\frac{2V\sin\left(\frac{\delta}{2}\right)}{X} = \frac{V^2}{X}\sin(\delta)$$

Reactive power at sending end is the opposite of reactive power at receiving end:

$$Q_s = -Q_r = Q = V\sin\left(\frac{\delta}{2}\right)\cdot\frac{2V\sin\left(\frac{\delta}{2}\right)}{X} = \frac{V^2}{X}(1-\cos\delta)$$

As δ is very small, active power mainly depends on δ whereas reactive power mainly depends on voltage magnitude.

Series compensation:

FACTS for series compensation modify line impedance: X is decreased so as to increase the transmittable active power. However, more reactive power must be provided.

$$P = \frac{V^2}{X - Xc}\sin(\delta)$$
$$Q = \frac{V^2}{X - Xc}(1 - \cos\delta)$$

Shunt compensation:

Reactive current is injected into the line to maintain voltage magnitude. Transmittable active power is increased but more reactive power is to be provided.

$$P = \frac{2V^2}{X}\sin\left(\frac{\delta}{2}\right)$$
$$Q = \frac{4V^2}{X}\left[1 - \cos\left(\frac{\delta/2}{2}\right)\right]$$

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 aim of operating Microgrid sub-systems is to move away from considering DG as badly behaved system components, of which a limited

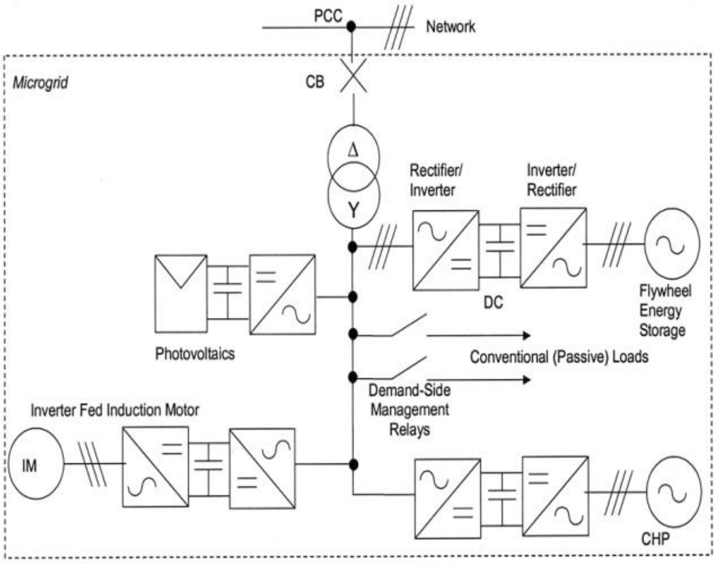


Figure.1 Simple example Microgrid

Amount can be tolerated in an area, to 'good citizens' (Lasseter 2001), i.e. an aggregate of generation and load which behave as nearly ideal conventional loads. Although the concept of using Microgrids to provide ancillary services to the local network has also been discussed, present commercial incentives are probably insufficient to encourage this.

A critical feature of the Microgrid is the power electronics. 'The majority of the microsources must be power electronic based to provide the required flexibility to ensure controlled operation as a single aggregated system' (Lasseter et al. 2002a). Such as system must be capable of operating despite changes in the output of individual generators and loads It should have 'plug-and-play' functionality: 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. Key, immediate issues for the microgrid are power flow balancing, voltage control and behaviour 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 microsources and loads (e.g. figure 2). It could be prohibitively expensive to compensate for load growth or poor power quality, by uprating 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.The requirement for energy storage

An assumption used in this paper is that a central controller, or 'system optimizer' (Lasseter 2002b) will be required to coordinate the power electronic

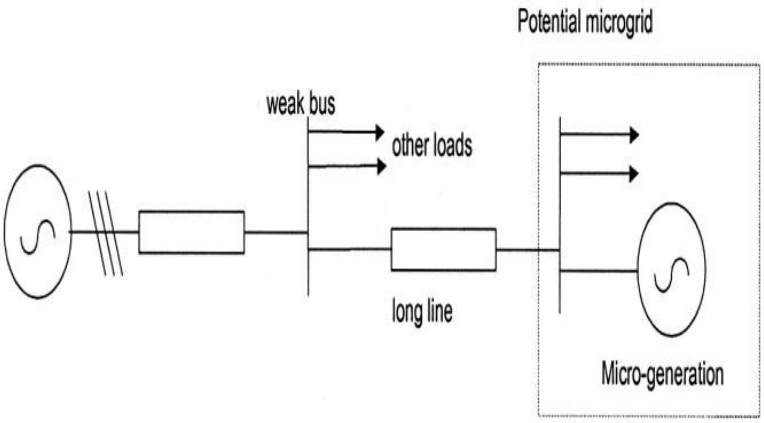


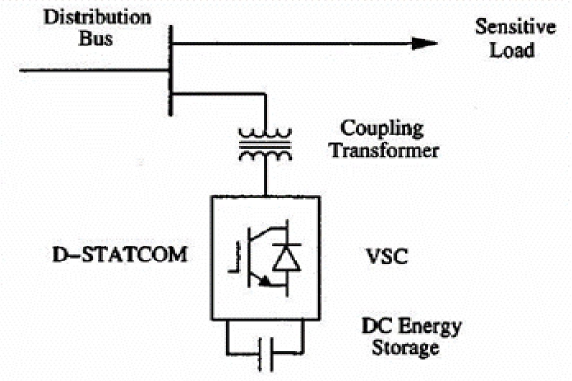
Figure.2 Potential Microgrid: remote combination of microsource(s) and loads.

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.

V. DSTATCOM

A voltage-sourced converter (VSC) with PWM provides a faster control that is required for flicker mitigation purpose. A PWM operated VSC utilizing IGBTs and connected in shunt is normally referred to as "STATCOM" or "DSTATCOM". A shunt-connected synchronous machine has some similarities with the STATCOM, but does not contain power electronics. The capability of the synchronous machine to supply large reactive currents enables this system to lift the voltage by 60% for at least 6 s. D-STATCOM has the same structure as that of an STATCOM. It can potentially be used in the context of (EMI). The valves are cooled with circulating water and water to air heat exchangers. PWM switching frequencies for the VSC typically range between 1-2 kHz depending on the converter topology, system frequency and specific application.

The Block diagram of the D-SATCOM shows that phase locked loop (PLL) technique is used for voltage sag detection and mitigation. However, this technique provides good results only if voltage sag is not coupled with phase angle jump. The reactive power control strategy for the D-STATCOM has been employed for load compensation. PI controller is used to control the flow of reactive power to and from the DC capacitor. Phase-locked loop (PLL) has been used to generate the switching signals for the VSC.



The DSTATCOM has been developed using DSP controller to achieve excellent overall performance. Simulation results show that the designed D-STATCOM is capable of mitigating voltage sag caused by three phase balanced fault. However, as PLL is used for detection and mitigation of sag in the control strategy, it provides good results only if sag is not accompanied by phase jumps.

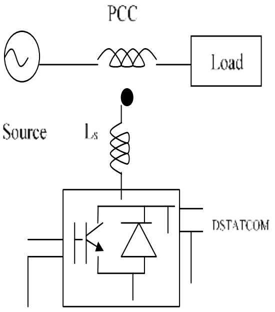


Figure.3 Block diagram of DSTATCOM circuit

VI. RESULTS

We used MATLAB for implementation

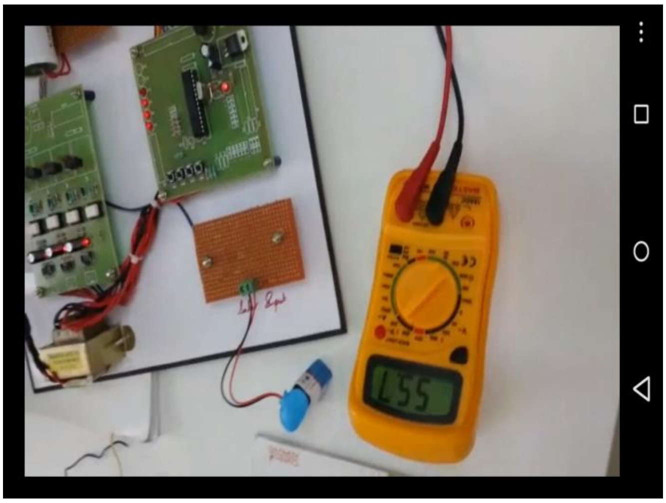


Figure.4 Kit for With Compensation

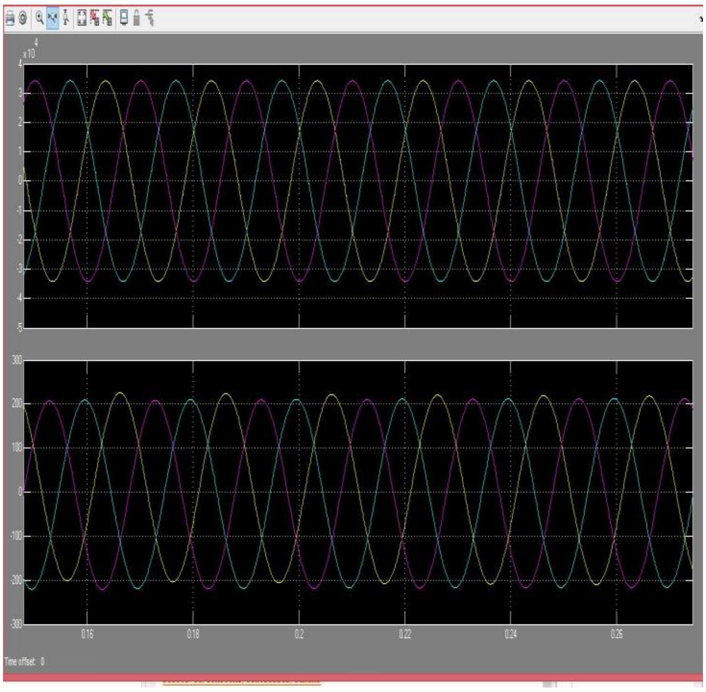


Figure.5 Current vs. Voltage

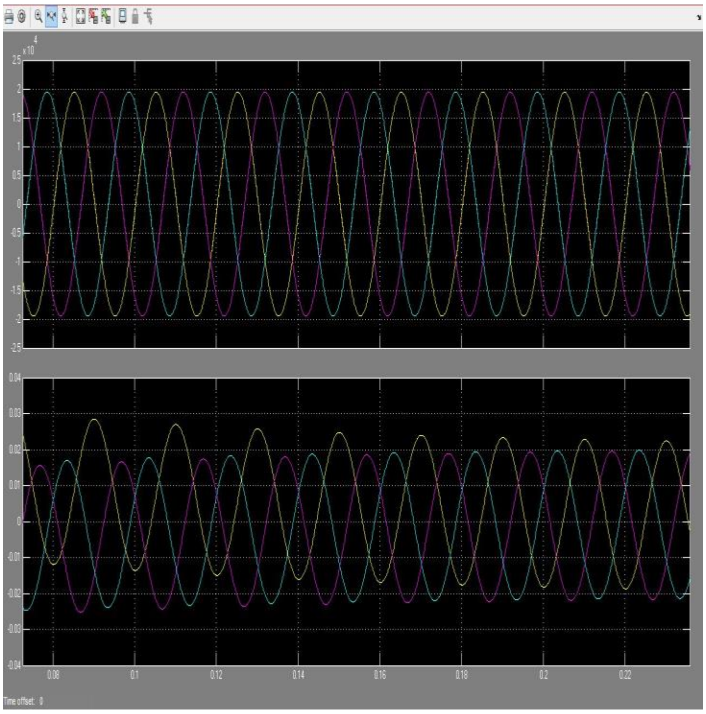


Figure.6 Output Wave form

VII. CONCLUSION

In this paper, a new control technique for single-phase DSTATCOM with communication is proposed. The application is aimed for microgrid feeding single-phase loads with feeder's spanned geographically far apart covering small communities. The proposed reactive compensation is based on local measurement as well as the power flow in the lines. It is shown that the proposed method reduces the voltage drop more effectively while maintaining the voltage regulation with a high penetration of the DGs. Data traffic analysis for the communication setup verifies the data transfer requirement. The closed loop simulations of the power network and the communication network validate the DSTATCOM superior performances under different operating conditions.

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