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Powerquality Enhancement for DG- Smart Grid Interconnections Bycustom Power Devices

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***Abstract*— This paper presents a technical review of power quality problems associated with distributed generation systems and how custom power devices are used for reducing the need of construction in new transmission line, control of real and reactive power in grid interconnection .FACTS controllers are increasing the dynamic control and compensated of the transmission lines and also providing the transfer capability of grid interconnection in transmissions and distributions.**

***Keyword-* Distributed generation, power quality, grid interconnection, Flexible alternating currents in transmission (FACTS) Controllers.**

I. Introduction

The existing power generation may increasing as the use of more fossils fuels so their is need to reduce the emissions. The overall authorities are depends on privatization of electricity generation, transmission and distribution's it is responsible about the planning and operation of the power system according to certain criteria and policies. The basic objective of the operator in system are vertically integrated utilities so it would be maintain reliable and uninterrupted services to the load. The reliability of the system is composed of two aspects; adequacy and security. System adequacy is defined as ability to supply the energy requirements of the system taking into account planned and unplanned outages of the electrical components.[1]

In the new system so much new distributed generation being installed so it is critical that the power system impacts be assessed accurately that why these DG units can be applied in a manner that avoids causing degradation of power quality, reliability and control of the utility system. This paper is reviewing issues concerning to DG smart grid interconnection connected to the distribution side of the network.and role of custom devices While Interconnecting DGs to the utility, they may go to be set forth. Foremost among them are

(*i*) Safety of utility personal working on electrical system
(*ii*) Safety of utility customers and general public demand
(*iii*) Protect and minimize possible damage to electrical power system (EPS) and other customer's property.
(*iv*) Ensure proper operation to minimize adverse operation conditions on EPS.

II. Power Quality Issues Related With Interconnection Of DG

Even though DG is a real option to meet the power demand of the industry, there are varieties of technical, operational, commercial, and regulatory issues that have to be considered before the DG plants are interconnected with the main grid. Interconnection is basically meant for back wheeling the excess power produced by a DG plant to the grid. The interconnection issues have enough potential to prevent distributed generation projects from being developed.[2]

Interconnection issues are broadly classified as :

(*ii*) Operational issues
(*iii*) Economical issues

For example; the reliability of the power system may be degraded if the deregulated system is not properly coordinated with the electric power system protection. The integration of deregulated system could influence the power quality due to poor voltage regulation, voltage flickers and harmonics. These conditions can have a serious impact on the operation and integrity of the electric power system as well as cause damaging conditions to equipment.

Technical Issues

The main technical issues for Distributed Generation connection relate to reliability and power quality of supply, protection, islanding and stability of the system.[2]

A. Reliability and power quality issue

The large-scale development of distributed energy resources expected deterioration of power quality is expected and on the other hand, an adverse effect on the existing power quality of the distributed energy resources is also found.

Power quality is important because electronic devices and appliances have been designed to receive power at or near certain voltage and frequency parameters and deviations may cause appliance malfunction or damage.

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In addition to simple voltage and frequency ranges, discussions of power quality include on harmonics, power factor, DC injection, and voltage flicker.

The following effects may occurred during the operation are :-

(a) Over voltage and under voltage.

A typical definition is given as "A measured voltage having a value greater than or less than the nominal voltage for a period greater than 1min when used to describe a specific type of long duration variation.

(*b*) Voltage fluctuations**.**

The term "voltage fluctuations" is used to cover a wide range of changes in the voltage magnitude. The severity of voltage fluctuations is quantified through the "short-term flicker severity" and the "long-term flicker severity".

(*c*) Low-frequency and high-frequency harmonics.

The power-electronic interfaces of DG units contribute to waveform distortion. The current waveform contains frequency components at integer multiples of the power system frequency and at integer multiples of the switching frequency. The former is referred as "low-frequency harmonics" and the latter as "high-frequency harmonics

B. Protection issue

The presence of DG can cause various problems related to incorrect operation of system protections. The conflicts between DG and protection schemes are as :

(*i*) Lack of coordination in the protection system;
(*ii*)Ineffectiveness of line reclosing after a fault and difficult lines back-feeding;
(*iii*) Unforeseen increase in short circuit currents;
(*iv*) Undesired islanding and untimely tripping of generators interface protections.

Traditional distribution systems were not designed to have active power generating units in them. Power is supplied by the transmission system and power flow is mainly unidirectional. But with the DG in the system, power flow can be bi-directional.

C. Stability

A small-size DG units, compared to the large centralized power stations, will not influence the operation of the power network and hence their impact can be neglected. When networks begin to contain large numbers of DG units with higher capacities, the dynamics of the distribution system effect distribution system's stability.The following stability are categorized are:

(a) Transient stability.

Transient stability of system are the first swing stability among the most important practical concerns in power system operation and planning studies. It has been observed that the utilization of DG units reduces the magnitude of the maximum power angle deviation. This indicates that the existence of the DG units improves significantly the transient stability of the system. This also means that the increase of the penetration level of DG units within power systems provides the opportunity to handle larger disturbances. In some critical cases with more severe faults, the use of DG units can maintain synchronism due to the reduction of the maximum power-angle deviation between generators[2].

(b) Oscillatory stability.

The oscillatory instability occurs only due to the insufficient damping of the electromechanical oscillations. Increasing penetration of DG causes lower damping and higher frequency with small numbers of DG units near some of the load nodes, the DG controllers have only local action and the global damping of the controller mode is worsened. The use of a large number of DG units which are uniformly dispersed in the low voltage area extends the controller action to cover most of the load nodes. Hence the performance of this mode is slightly

III. Impact Of Distributed Generation On Power Quality

The presence of DG in the power system has changed the structure of the network and has a great impact on real time operation and planning of the grid. When a DG is connected into a weak distribution system, it will increase the fault level, degrade system stability and may lead to power reversal the impact of the DG on system stability . Although the introduction of the DG at distribution level may influence system stability limits. The influence depends on many factors such point of connection, level of penetration of the DG, technology of the DG, modeling and control of the DG and others. Of course, the characteristics of the distribution and transmission system influence the outcome.

The introduction of DG into the power system may provide protection against electricity interruptions and to a low quality service. The different technology adopted cause uninterruptible power supply and small diesel engines can provide voltage support and improve the quality of supply**.** On the other hand, the introduction of the DG can have detrimental effects on system operation leading to power quality problems.

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Problems related to voltage instabilities, complicated reactive power requirements and fluctuations of available power , especially in case of wind and solar DG.[2]

(i) Alternative Expansion or Use of local Network

DG may be a viable substitute or alternative for capital investments in transmission & distribution networks. In many instances, the introduction of the DG can relieve transmission and distribution congestion. Several studies have shown that the introduction of DG has resulted in cost savings. In addition, the proximity of DG to load centers lead to reduction in system losses.

(ii) Grid Support

The operation of the power system in the restructured environment i.e deregulated, requires the availability of sources of reactive power and spinning reserves upon the request of system operators. These are called ancillary services and DG are one of many sources for such services.

DG has much potential to improve distribution system performance and it should be encouraged. However distribution system designs and operating practices are normally based on radial power flows and this creates a special challenge to the successful introduction of distributed generation. In this paper issues of grid is that must be considered to insure that DG will not degrade distribution system power quality, safety or reliability.

Today's electrical power systems typically connect a few fairly large generators to a large number of small and widely distributed loads. For several reasons, future generation in India and elsewhere will probably include many more units of rather smaller size. Drivers for this trend include a shift towards the use of renewable resources, a desire for increased energy efficiency, an aversion to the risk and long construction periods characteristic of large stations The benefit of assembling machines in factories rather than in the field, and a general deregulation of the utility industry which favours diversity.

The modelling studies have reviewed the impact of distributed generation on utility distribution systems, including power quality, feeder protections, service reliability and public safety . Many issues have been identified for study, to assess the merit sand drawbacks of Distributed Generation (DG) as compared to traditional power distribution systems. Some studies have attempted to quantify the levels of DG penetration relative to feeder capacity or existing load, where one or more of these pose a limiting constraint. At this time, the penetration of DG on power systems is relatively low, measured either in terms of aggregate system load or available generating capacity.

Existing Standards and regulations governing DG operation that are simpler and least disruptive to utility operations. They tend to require that the DG not take part in voltage and frequency control. If a disturbance takes place that causes either voltage or frequency to deviate beyond specified limits, the DG is required to isolate from the grid, and then reconnect when normal operation is restored. Thus frequency and voltage continue to be maintained just as they would without the presence of any DG.

Therefore attention is shifting towards considering the cumulative effect on the bulk power system due to significant levels of DG capacity. It can be expected that such large-scale presence will have global or system-wide impacts that are not yet fully understood. The paper is s concerned primarily with the impact on system stability. Other relevant issues may include impact on resource scheduling to meet real demand, for the provision of ancillary services such as reactive power support, for spinning reserve to accommodate contingencies, and for black start capability following major outages. These however are not within the present scope.

Stability covers the ability of the power system to supply rated voltage to loads. It includes the need for generators to maintain synchronism (angular stability) when the transmission lines are heavily loaded and stressed by transients such as system faults. Stability may be affected by large-scale presence of DG units because of their differing characteristics, as follows:

Table 1 –
Categories of power Quality Problems

Power Freq Disturbance	Electro Magnetic Interferences	Power System Transient	Power System Harmonics	Electrostatic Discharge	Power Factor
Low Freq phenomena Produce Voltage sag/swell	High freq phenomena interaction between electric and magnetic field	Fast, short-duration event Produce distortion like notch, impulse	Low frequeny phenoena Produce wavefom distortion	Current flow with different potential Caused by direct current or induced electrostatic field	Low power factor causes equipment damage

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They tend to carry small power ratings, ranging from just a few 10's of kW to perhaps 5 MW, compared to 100's or 1000's of MW for centralized plants. Their proportional mechanical inertia is reduced, so stability is lost more rapidly after a system disturbance.

They are connected on distribution systems, within several kilometers of loads while centralized plants may transmit power 100's of kilometers to major load centres. This helps promote angular stability, but increases the number of disturbances likely to trip the unit[2].

They are generally classified as being non- dispatchable, delivering power or at will. In this respect, their production must be viewed statistically and cannot be relied upon to meet the system demand for aggregate real or local reactive power.

Their protections and controls differ significantly from larger plants because they are typically unstaffed. They are not allowed to regulate terminal voltage or system frequency. In due course, a greater proportion of DGs are likely to utilize advanced technologies such as fuel-cells, solar, wind or biomass, with a power converter interface for delivering power to the grid. The dynamic operating characteristics of such units may differ dramatically from rotating machines.

In a future, leading to their characterization essentially as those relaying on a power converter based interface i.e custom devices or those utilizing a more conventional rotating synchronous machine then carried out taking into account steady-state conditions.

Voltage and angular stability consideration including various DG control modes and system contingencies. This provides a basis for generalizing findings related to the impact of large-scale DG penetration on the stability of grid networks.

IV. IMPLEMENT OF CUSTOM POWER DEVICES IN GRID INTERCONNECTION

The Custom Power (CP) concept was first introduced by N.G. Hingorani in 1995 . Custom Power embraces a family of power electronic devices, or a toolbox, which is applicable to distribution systems to provide power quality solutions. The following CUSTOM FACTS Technology are:

The term FACTS describes a wide range of controllers, many of which incorporate large power electronic converters, that can increase the flexibility of power systems making them more controllable.

Some of these are already well established while some are still in the research or development stage.

In general, FACTS devices possess the following technological attributes:

1. Provide dynamic reactive power support and voltage control.
2. Reduce the need for construction of new transmission lines, capacitors, reactors, etc which
    a) Mitigate environmental and regulatory concerns.
    b) Improve aesthetics by reducing the need for construction of new facilities such as

Transmission lines.
Improve system stability.
Control real and reactive power flow.
Mitigate potential Sub-Synchronous Resonance problems.

To determine which FACTS device would be the most beneficial is to be examined the following devices:

- Thyristor Controlled Series Capacitor (TCSC)
- Thyristor Controlled Phase Angle regulator (TCPAR)
- Static Condenser (STATCON)
- Unified Power Flow Controller (UPFC)[1]

This technology has been made possible due to the widespread availability of cost effective high power semiconductor devices such as GTOs and IGBTs, low cost microprocessors or microcontrollers and techniques developed in the area of STATCOM is a shunt-connected custom power device specially designed for power factor correction, current harmonics filtering, and load balancing. It can also be used for voltage regulation at a distribution bus It is often referred to as a shunt or parallel active power filter. It consists of a voltage or a current source PWM converter. It operates as a current controlled voltage source and compensates current harmonics by injecting the harmonic components generated by the load but phase shifted by 180 degrees. With an appropriate control scheme, the STATCOM can also compensate for poor load power factor.

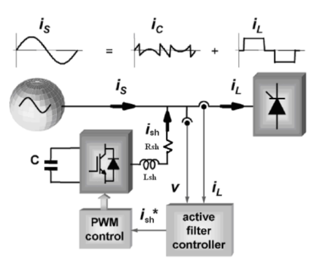

Fig (1) System configuration of STATCOM

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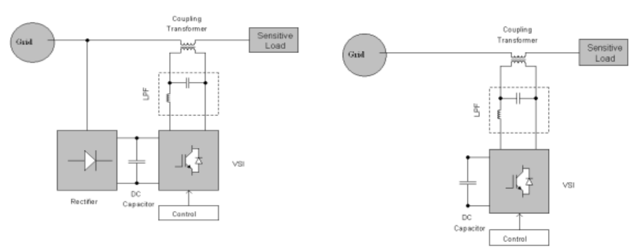
The DVR is a series-connected custom power device to protect sensitive loads from supply side disturbances (except outages). It can also act as a series active filter, isolating the source from harmonics generated by loads. It consists of a voltage-source PWM converter equipped with a dc capacitor and connected in series with the utility supply voltage through a low pass filter (LPF) and a coupling transformer as shown in Fig.(2)



Fig(2) (a) Rectifier supported (b) DC capacitor supported DVR

This device injects a set of controllable ac voltages in series and in synchronism with the distribution feeder voltages such that the load-side voltage is restored to the desired. Amplitude and waveform even when the source voltage is unbalanced or distorted.

UPFC is the integration of series and shunt active filters, connected back-to-back on the dc side and share a common DC capacitor as shown in Fig 3.

The series component of the UPFC is responsible for mitigation of the supply side disturbances: voltage sags/swells, flicker, voltage unbalance and harmonics. It inserts voltages so as to maintain the load voltages at a desired level; balanced and distortion free. The shunt component is responsible for mitigating the current quality problems caused by the consumer: poor power factor, load harmonic currents, load unbalance etc. It injects currents in the ac system such that the source currents become balanced sinusoids and in phase with the source voltages.

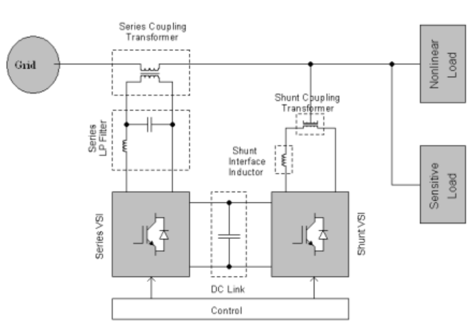


Fig (3) System configuration of UPFC

The application of the STATCOM is already reported for wind power applications in stability enhancement, transient, flicker mitigation etc. As the traditional STATCOM works only in leading and lagging.

The term FACTS describes a wide range of controllers, many of which incorporate large power electronic converters, that can increase the flexibility of power systems making them more controllable. Some of these are already well established while some are still in the research or development stage. Power transfer in most integrated transmission systems is constrained by transient stability, voltage stability, and power stability. These constrains limit the full utilization of available transmission corridors. FACTS is a technology that provides the requisite corrections of transmission functionality in order to fully utilize existing transmission systems and, therefore, minimize the gap between the stability and thermal limits. FACTS technology is based on the use of reliable high-speed power electronics, advanced control technology, high-power microcomputers and powerful analytical tools. The key feature is the availability of power electronic switching devices that can switch electricity at megawatt levels (kV and kA levels). The impact of FACTS controllers on transmission systems is thus like lv to have a significant impact on power system networks world wide. Amongst the different types of FACTS controllers, UPFC is considered to be one of the most effective in the control of power flow. It comprises two back-to-back gate-turn-off thyristor (GTO) based voltage source converters (VSCs) connected by a dc -link capacitor.

An exciting transformer connecting one VSC is arranged in shunt and a boosting transformer linking the second VSC is inserted into the transmission line. By virtue of its ability to control freely and independently three major parameters in power transmission *viz.* the line impedance and the magnitude and phase of the voltage, it provides both voltage regulation and improvement in stability. Because of the presence of FACTS controllers in a fault loop, the voltage and current signals at the relay point will be affected in both the steady state and the transient state. This in turn will affect the performance of existing protection schemes, such as the distance relay which is one of the very widely used methods in transmission line protection The main principle of this technique is to calculate the impedance between the relay and fault points; the apparent impedance is then compared with the relay trip characteristic to ascertain whether it is an internal or external fault. A common method of calculating this impedance is using power frequency components of voltage and current signals measured at the relay point.

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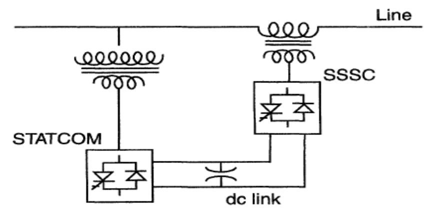
FACTS controllers has been employed to study the impact of studies clearly show that when FACTS controllers are in a fault loop, their voltage and current injections will affect both the steady state and transient components in voltage and current signals and hence the apparent impedance seen

While TCSC provides dynamic control of the series compensated lines, which could increase transfer capability, it could not be used to increase import capability because the path does not have any series capacitors. A TCPAR, is equivalent to a mechanically phase shifting transformer but unlike a UPFC it does not provide controlled reactive power generation. The TCPAR could not be used since the lines do not have a phase shifting transformer. Since a STATCOM mainly provides Rectifier supported dynamic reactive power to the system but as it does not directly control the flow of real power on a transmission line it was not considered[6].

A UPFCis a combination of real and reactive power control, appeared to be the most useful FACTS device for the system. It could potentially control power flow on the line, reduce the number of lines that can be overloaded, and potentially provide dynamic reactive power control during contingencies. The UPFC is a device which can control simultaneously all three parameters of line power flow(line impedance, voltage and phase angle). Such "new" FACTS device combines together the features of two "old" FACTS devices: The Static Synchronous Compensator (STATCOM) and the Static Synchronous Series Compensator (SSSC). In practice, these two devices are two Voltage Source Inverters (VSI's) connected respectively in shunt with the transmission line inverter is used for voltage regulation at the point of connection injecting an opportune reactive power flow into the line and to balance the real power flow exchanged between the series inverter and the transmission line. The series inverter can be used to control the real and reactive line power flow inserting an opportune voltage with controllable magnitude and phase in series with the transmission line. Thereby, the UPFC can fulfill functions of reactive shunt compensation, active and reactive series compensation and phase shifting. Besides, the UPFC allows a secondary but important function such as stability control to suppress power system oscillations improving the transient stability of power system. As the need for flexible and fast power flow controllers such as the UPFC, is expected to grow in the future due to the changes in the electricity markets.



Fig(4) shows combination of Static Synchronous Compensator(STATCOM) and a Static Synchronous Series Compensator(SSSC) which are coupled via a common dc link, to allow bidirectional flow of real power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM and are controlled to provide concurrent real and reactive series line compensation without an external electric energy source. The UPFC by means of angularly unconstrained series voltage injection, is able to control, concurrently or selectively, the transmission line voltage, impedance, and angle or, alternatively, the real and reactive power flow in the line. The UPFC may also provide independently controllable shunt reactive compensation [6]

Installation of a UPFC on any one of the lines may allow redistribution of the power flow on the lines, increasing the total South-of-SONGS path flow.. The STATCOM, which is the shunt element of the UPFC, can provide this reactive power in a dynamic form

High-Voltage DC Transmission and Static Var Compensators are examples of power electronic systems (i.e. FACTS devices) that are already well established. There are other ways to configure power electronic components to aid AC power transmission. The initial development techniques for many power electronic devices have been proven in numbers of variable speed motor drive installations. Presently these techniques are being applied to equipment having higher power ratings; i.e., capable of being installed within utility transmission and distribution systems.

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