Reliable, Effective and Efficient Operation of DG Source for Power Flow Control in Coordination with Main Utility Network at Common Load Bus Using Static Device

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Abstract: - This research work examines reliable, effective and efficient operation of DG source in coordination with main utility network using static device, so that consumer is optimally benefited.
The investigation made in our research work reveals that utility can achieve the required loading level and at the same time, it can improve the system power factor, or regulate the Point of common coupling (PCC) /common load bus voltage while mitigating harmonics and correcting unbalance. The response time and stabilization time of DG source, both are reduced with the help of static device/UPFC. Therefore Flexible Dispersed Generation (FDG) with the help of UPFC enhances the performance of distribution networks. In turn, the FDG is competitive in the new restructured market.

Key-Words: - Dispersed Generation (DG), Distributed Resource (DR), Energy Management System (EMS), Power flow, PCC or Common Load bus, Utility Supply, MATLAB/Simulink Simpower tool box, Static Device.

1 Introduction

DGs are small (usually under 10 MW), modular electric generation and storage technologies that provide electric capacity and/or energy when and where needed. They are owned by a customer, utility or another entity, and connected to the grid at a distribution voltage level [1].

The Distributed Generation option is enjoying a global popularity to offset the future load growth [1], [2]. The Discos/end-users can install DG units within their service area. Due to the availability of such a flexible option at the distribution voltage level, the distribution network is now being transformed from passive network to an active one.

The mechanical switched/control equipment simply can not match with the trend of fast on-line decision making as required in EMS. In this regard Flexible AC Transmission system (FACTS) is reckoned conceptually a target for long term development of power systems in the coming decades. It suggests that control of power can be affected by changing three parameters namely impedance, voltage, magnitude and voltage angle difference between the ends of the line.

Among the various FACTS devices, Unified Power Flow Controller (UPFC) is regarded as the most effective version since it serves to control the three parameters at the same time. Case study on a 3-bus test system is given to indicate that the improved UPFC power flow control approach is reliable and efficient in the sense that DG source shares load with utility supply instantly.

2 Reviewing Conventional Power Flow Control Strategies/Approaches

There are two existing/conventional methods of sharing DG power for various types of DGs in coordination with main/utility supply at load bus.

- *Method 1:* DR/DG can be used as a stand-alone service to meet customers demand.
- *Method 2:* DR/DG can be also used in conjunction with traditional utility

service i.e. DG source and utility supply are connected to common load bus to share load.

In stand-alone service method, load bus is bifurcated into two buses such as some load (considering DG rating and type) is shifted to the bifurcated load bus which is connected with DG and remaining load is supplied by utility which is connected with main load bus.

The process of shifting some part of load from main bus (during peak hour or during any application of DG with utility supply on DG) to bifurcated bus is done through manual switching.

When DG supply is available to feed some load than isolator switch, disconnects main supply connection to the load connected to bifurcated bus. In this way DG supplies to bifurcated bus load independently i.e. main supply is not connected in parallel with DG to supply total load. Instead when DG supply is disconnected than main supply is connected with bifurcated bus load through manual switching.

In the second method of interconnection of DG with utility supply, DG is first synchronized with utility supply and than DG source input is increased to raise the speed and hence the frequency of DG output, so that DG is able to share load with utility supply. Utility owned-DGs are usually used as a base load to provide part of the main required power and support the grid by enhancing the system voltage profile, reducing the power losses and improving the system power quality.

When input to DG source is increased than it tries to raise its frequency but it can't do it as it is synchronized with main supply instead it takes/shares load with main supply, so that frequency on both sides is maintained at which synchronism is made. Usually it is observed that stabilization time taken by DG source to control smooth power flow or share load smoothly at load bus with utility is roundabout 20 seconds [2] which is high enough and needs to be reduced so that load do not sense any kind of disturbance due to load sharing by the DG source. This stabilization time also depends upon response time of DG source and response time of DG sources varies from 0.6 seconds to 2.7 seconds [2]. This issue is main focus point in this research paper.

3 FACTs Applications to Power Flow Control

Operating principle of UPFC

The schematic diagram of a UPFC is shown in Fig. 1 [3], [4]. It shows unified power flow controller consists of two-voltage source converters (VSC). The two Voltage Source Converters (VSC) of UPFC are connected through a common DC link capacitor. Each converter has a coupling transformer with the utility (AC system) interface. The VSCI/shunt converter, known as static synchronous Compensator (STATCOM), injects an almost sinusoidal current, of variable magnitude, at the point of connection [6]. The VSC2/series converter, known as Static Synchronous Series Compensator (SSSC), injects an almost sinusoidal voltage, of variable magnitude, in series with the line. By regulating the series injected voltage *Vse*, the complex power flow $(P_r + jQ_r)$ through the line can be controlled.

The complex power injected by the series converter $(P_{se} + j\ Q_{se})$ depends on its output voltage and line current. The injected active power P_{se} of the series converter is taken from the dc link, which is in turn drawn from the AC system through the shunt converter. On the other hand, both the series and shunt converters are capable of absorbing or supplying reactive power independently. The reactive power of the shunt converter can be used to regulate the voltage magnitude of the bus at which the shunt transformer is connected. By selecting suitable control modes of UPFC, it is possible to control bus voltage, real power and reactive power through the line [4].

It is know clear from above discussion that, when the STATCOM/VSC1 and the SSSC/VSC2 operate as stand-alone controllers, they exchange almost exclusively reactive power at their terminals. When both VSCS are operating together as a UPFC, the injected voltage in series with the line can be at any angle with respect to the line current; therefore, the exchanged power at the terminals of each converter can be reactive as well as real, The result is that the real and reactive power flow in the line can be regulated selectively [7].

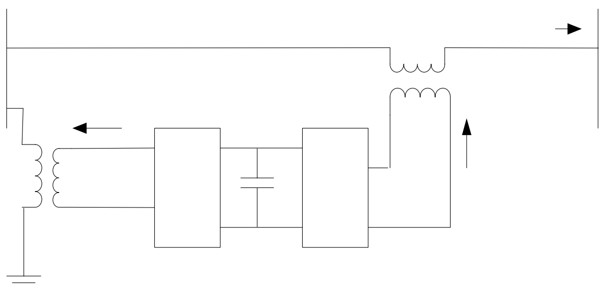


Fig.1. Schematic diagram of a UPFC system.

The active and reactive powers transmitted from the sending end to the receiving end over a line are:

$$P = \frac{V_S V_R \sin\theta}{X}$$

$$Q = \frac{V_R (V_R - V_s \cos\theta)}{X}$$

In the equations above, V_s is the amplitude of the sending end voltage, V_R is the amplitude of the receiving end voltage, X is the line impedance, and θ is the angle difference of the both end voltages.

Terminal voltage (V_t) generated by an electrical machine is given by following equation.

$$V_t = E_g - (IR)_{drop}$$

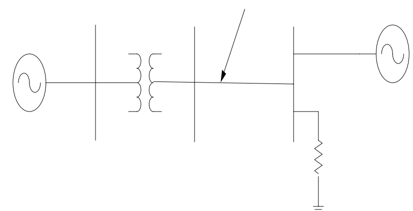
where
E_g is EMF generated by machine.
and
$(IR)_{drop}$ is internal voltage drop of machine.

From above discussion, it is obvious that, within the framework of traditional power flow concepts, the UPFC is able to control, voltage, power flow, and stability of a power system simultaneously or selectively by controlling all the parameters (voltage, impedance and phase angle) that affect the power flow in a line. This concept is used for controlling DG output for instant load sharing with utility supply at common load bus.

4 Proposed Strategy for Smooth Power Flow Control

4.1. Test System

Fig. 2 shows one line diagram of a test system with main source and DG supplying common load bus load for proposed smooth power flow control strategy.



Test system consists of the upper transmission system of 132 KV and the distribution system of 11KV. B3 is load bus at 11 KV, which consumes the active power of 17.8 MW. DG source is installed at bus B3 and is having capacity of 6.5 MVA at 11KV. We assume that DG is a synchronous Generator used at common load bus. Overhead line is 11 KV, 1cct, 5 Km in length having, R= 0.01293 (Ω/Km), L=0.9337 (mH/Km), C=0.0121 (μF/Km).

4.2. Proposed Strategy

In our proposed strategy as shown in Fig. 3, we have designed a control circuit such that it has two inputs one sensing and measuring DG output and other will sense and measure load to be served than it calculates/generates, difference/required Power needed to be supplied by main supply. This difference/required Power to meet the load demand act as one input to

FACTs controller while its other input is connected with main supply.

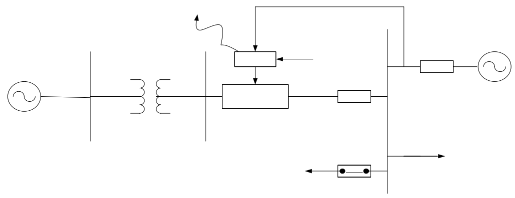


Fig 3 Proposed Power Flow Control Strategy

Actually here the purpose of this type of controller design is to use FACT device to provide/control/order power flow as directed by control circuit in coordination with DG power available, instantly so that response time of DG and hence stabilization time is reduced.

Example

If DG Capacity/Supply = 5.8 MW

Load = 17.8 MW and

Power T/F rating in the path of main to serve load

= 12 MW

Than Control circuit output = LOAD – DG
= 17.8 – 5.8

= 12 MW

Hence 12 MW power flow is supplied/directed by controller using FACT device and sharing of DG source power is very instant and with reduced transients in initial time interval.

5 Developing Test System Using MATLAB/Simulink Simpower System Tool box

The Simulink model/diagram for test system is developed in the environment of Simpower toolbox of MATLAB as shown in the Fig. 4. The active power shared by the utility supply and DG source to serve the load is shown in Fig. 6 and Fig. 7. Also active power contributed by the utility supply and DG source is shown in Fig. 8.

These waveforms are obtained by simulating the Simulink diagram for test system in the environment of Simpower toolbox of MATLAB [8]. DG source terminal voltage output waveform is also shown in Fig. 5. Simulation stop time is set from 0 to 6 to completely analyze the stabilization time for the active power outputs of both DG source and utility supply along with load active power drawn from both DGs source and utility supply.

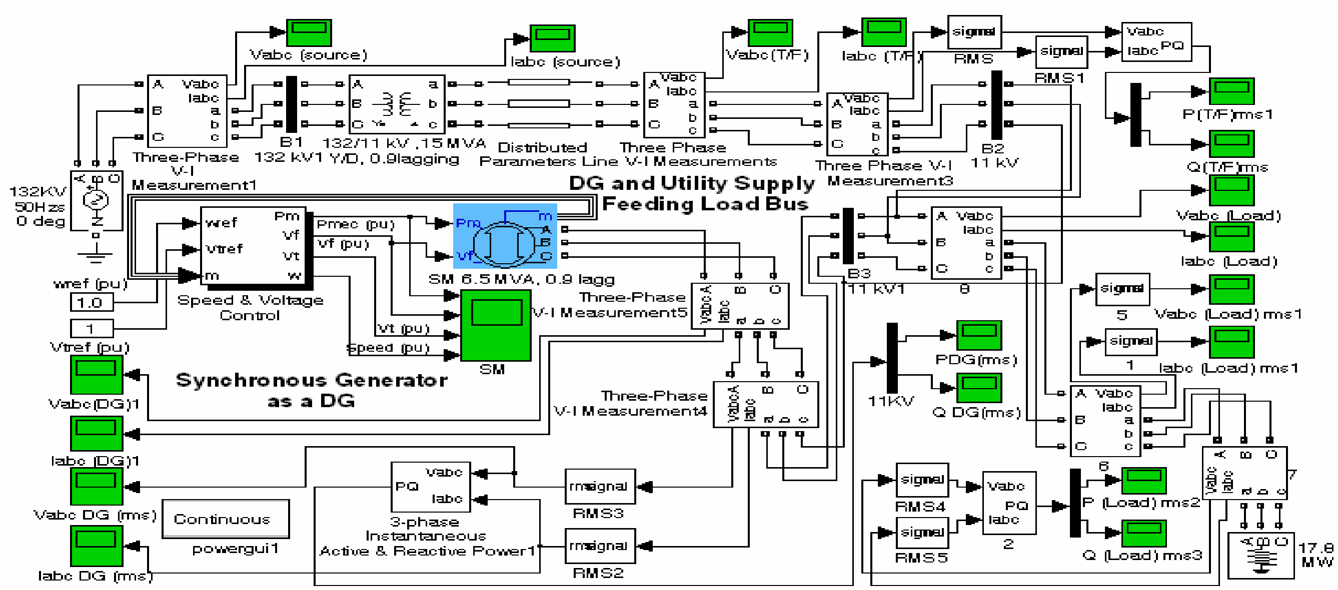
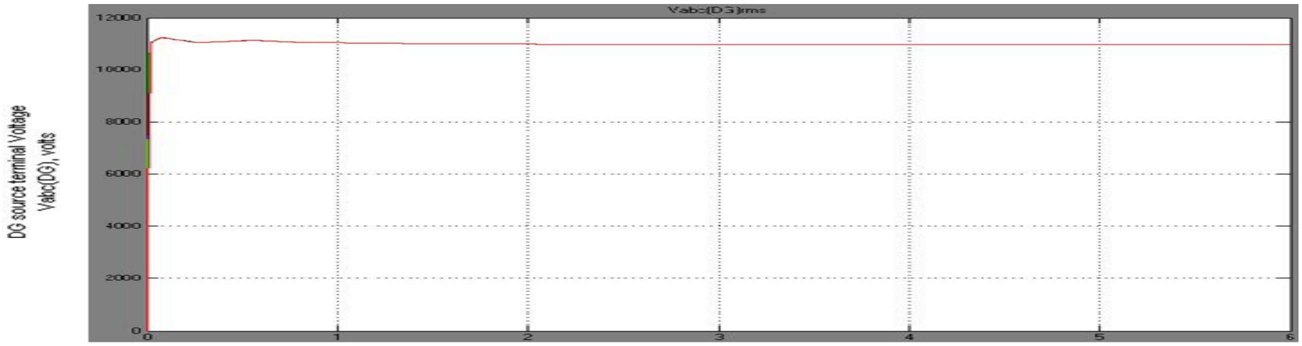
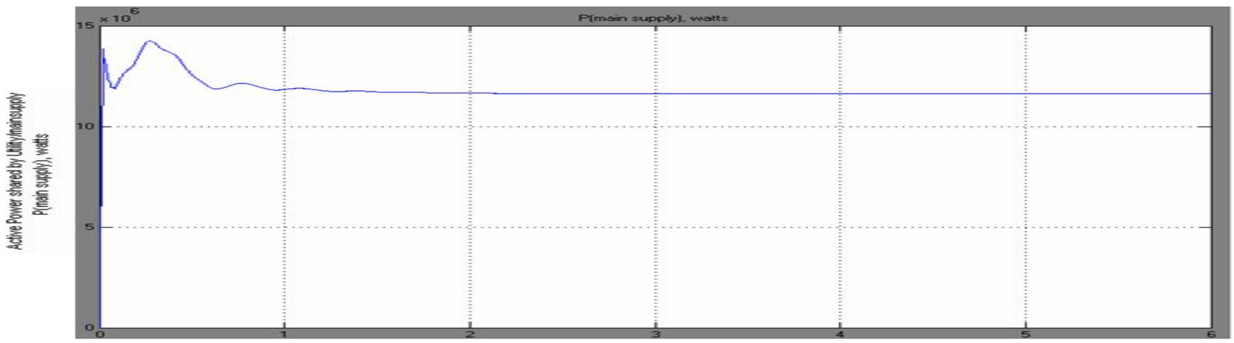


Fig.4. Simulink Model showing DG and main sharing load at common bus



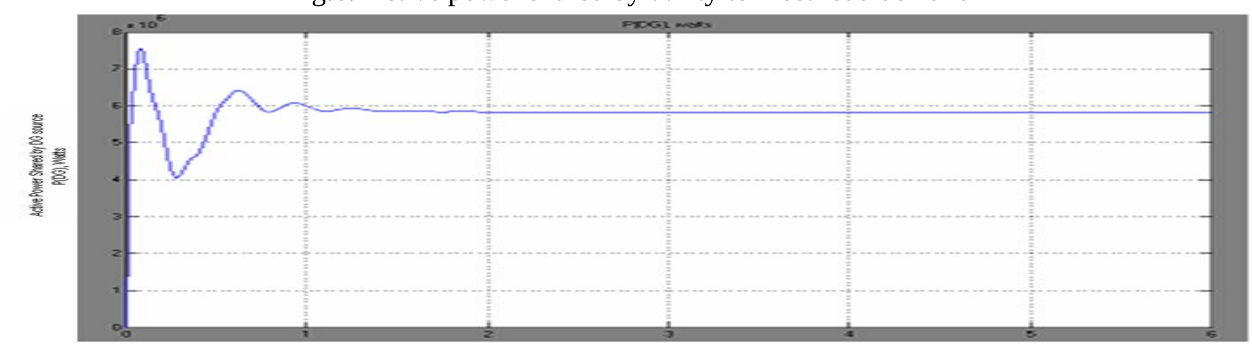
Simulation time

Fig.5. DG source terminal voltage



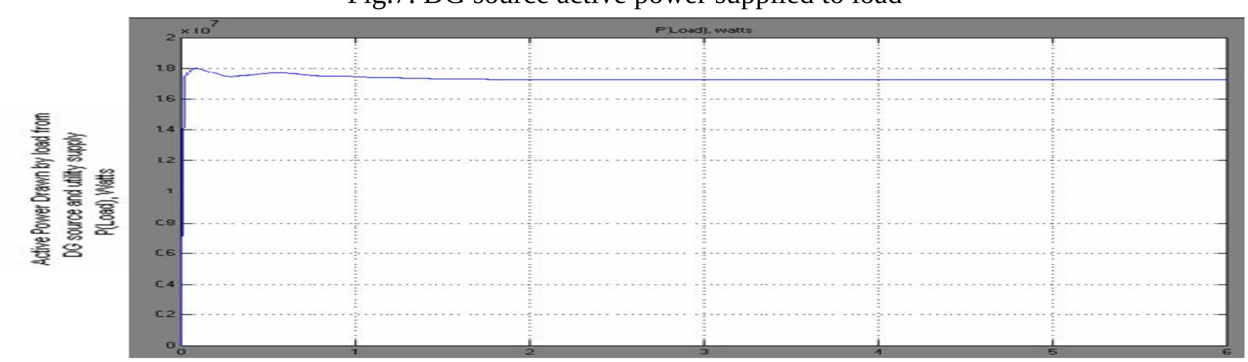
Simulation time

Fig.6. Active power shared by utility to meet load demand



Simulation time

Fig.7. DG source active power supplied to load



Simulation time

Fig.8. Total Active Power drawn by load (watts) from DG source and Main supply both

Ode 23tb [stiff/TR-BDF2] Simulink solver is used as developed Simulink model involves nonlinear elements.

6 Discussing Simulation Results

- DGs directly inject power to certain loads which help in reducing loading unbalance.
- DGs can defer/reduce network upgrading.
- DG reduces the overloading of the existing equipment thus increases their life.
- DG provides some or all required power without the need of increasing the capacity of main generators.
- DG time taken to smoothly share load with utility supply with the help of static device (UPFC) is reduced hence stabilization time is also reduced. Due to which transients that appear in initial seconds of DG output are also reduced.

Proposed Power flow control strategy at common load bus in the presence of DG using UPFC has number of advantages.

- Firstly, the fast soft switching techniques are applied so that problem of transients and harmonics is avoided.
- Secondly, Power flow is economical.
- Thirdly, DG application/usage is economical.
- Finally, Reliable, Effective and Efficient operation of DG in coordination with main utility network is achieved. Hence, the consumer is optimally benefited.

7 Concluding Remarks

A technique of power flow control is proposed along with simulation studies, so that power flowing from utility supply side to the common load bus can be controlled economically, effectively and efficiently in the presence of DG. The control of power flow from Main/utility supply and DG source to common load bus is such that, load does not sense any king of disturbance.

The studies are performed based on well known software package MATLAB/Simpower tool box.

The work proposes use of static/FACT device, Unified power flow controller (UPFC) to control power flow at load bus by utility in coordination with DG source so that response time taken by DG source to share load with utility and transients that appears in initial seconds are reduced.

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