A DIRECT CURRENT CONTROL APPROACH FOR EFFICIENT GRID POWER TRANSFER WITH UNIFIED POWER FLOW CONVERTER

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Abstract—**To study the reactive power regulation of UPFC in micro grid, the relationship between reactive power flow and voltage in micro grid is analyzed theoretically in this paper .UPFC response faster than other devices at the time of maintaining power quality and system stability. UPFC improves the voltage stability, reactive power compensation, damping the oscillations and real power balance. Voltage stability control is major problem in distribution network. Lower the reactive power in network which cause the losing stability. The simulation result shows the voltage at PCC point will be unstable under two conditions. A direct current control method is used here. The UPFC which maintain the voltage balance at PCC point in the micro grid access to the grid and meet the flexible regulation and stable operation of micro grid.**

Keywords— **UPFC, Micro grid, Voltage Stability, Reactive Power Flow Control , Transmission line**

I. INTRODUCTION

The centralized traditional large power supply mode has some defects such as low reliability, environmental pollution, system instability and poor flexibility. In order to solve this problems, the distributed generation installed near the users becomes an alternative choice. Due to the shortcomings of DG, such as randomness and intermittency, DGs will have a great impact on the large power grid when transmitted to the grid directly. So the concept of microgrid is proposed. The microgrid can make full use of these new energy sources and interconnect the DGs with the loads, which work independently as a reliable and stable power supply and also used as a generation transmitting power to the large power grid. Distributed generation (DG) considered as "taking power to the load". Maintenance cost for DG such as fuel cells and photovoltaic's is quite low because of the absence of moving parts. One of the major problem in distribution network is voltage collapse which is the major reason behind the blackouts for some decades. Voltage instability is the reason for the voltage collapse which make the voltage of the system decay to lowest level from which cannot able to recover itself. The voltage collapse means when a power grid is loaded more its maximum load ability level. The consequence of voltage collapse lead to a partial or full power interruption in the system.

UPFC is the most powerful FACTS devices. It has the ability to control three parameters of power flow either simultaneously or separately namely voltage magnitude of the buses (V),impedance of the transmission line (Z),phase angle between buses (θ).FACTS controllers has the ability to controlling the network in a very fast manner. The features of FACTS can be exploited to improve the voltage stability, steady state and transient stability of complex power system. This will increase the existing network very closer to its thermal loading capacity, thereby avoiding the need to construct new transmission lines. The famous FACTS devices are namely SVC, STATCOM, TCSC, SSSC and UPFC.UPFC is a second generation FACTS device which has the independent control of active and reactive power besides improving reliability and quality of the supply.

The application of UPFC to distribution network with a wind power generation system. Which reduce the reactive power exchange between the distribution network and wind power generation system. Due to this low voltage ride through the wind power system is improved. UPFC can control reactive power exchange between wind farm and grid to improve the dynamic stability of voltage of wind farm. At present, the power control of micro grid mainly within the micro grid. In this paper micro grid system is regarded as whole and power flow control is implemented from the outside of the system.

In this paper, firstly analyzed the relationship between reactive power flow and voltage in the micro grid. Then the operating principle of UPFC is explained. Based on this direct current control method is proposed. Last, the micro grid model in the grid -connecting mode with UPFC is established in Mat lab/Simulink. The simulation result shows the UPFC can control the reactive power exchange between the microgrid and the distribution network at sudden load change operation. It also can stabilize voltage and power balance at PCC point.

*A. **Relation between Reactive Power Flow and Voltage in Microgrid***

There are mainly two factors that cause the voltage fluctuation in the microgrid. One of that is change of reactive power flow in the system. The other one is the change of loads connected to the system. Therefore, voltage is closely related to the reactive power flow. Under any operating conditions, it is efficient that the reactive power output by the power generation terminal is equal to the reactive power required by the power supply terminal that means, the reactive power balance need to be satisfied. Regarding the micro grid system as an inverter, the distribution network as an ideal source, the grid-connected micro grid equivalent circuit shown in Fig.1, transmission lines is represented by inductance and resistance.

The power delivered by the micro grid system is;

$$P = \text{UI}\cos\varphi = \frac{EU}{X}\sin\delta \qquad (1)$$

$$Q = \text{UI}\sin\varphi = \frac{EU}{X}\cos\delta - \frac{U^2}{X} \qquad (2)$$

When the load is fixed in micro grid system, the active power output is certain. Equating (1) and (2) are;

$$Q = \sqrt{\left(\frac{(EU)^2}{X^2}\right) - P^2 - \frac{U^2}{X}} \qquad (3)$$

The relationship between reactive power and voltage required by the load is;

$$Q = \frac{U^2}{X} \quad (4)$$

If the reactive power output from the system power supply does not increase with increase of reactive load, the balance between the reactive power at the power supply terminal and the load terminal at the rated voltage cannot be guaranteed. To achieve reactive power balance at lower voltage levels, the system voltage need to be reduced. Otherwise, if the reactive power is greater than the reactive load demand, the system will operate at a higher voltage level.

*B. **Analysis of Reactive Power Flow Control in Micro grid by Using UPFC***

*1. **The Basic Working Principle of UPFC***

The UPFC is most versatile and complex power electronic equipment. It is emerged for the control and optimization of power flow in electrical power transmission systems. It offers potential advantages for the static and dynamic operation of transmission lines. The UPFC devised for the real-time control and dynamic compensation of ac transmission systems and providing the multifunctional flexibility required solving more problems facing in the power. UPFC is to control and simultaneously or selectively, all the parameters of affecting power flow in the transmission line. UPFC independently control both real power flow and reactive power flow in the line, unlike all other controllers like SVC, STATCOM, and SSSC etc. UPFC consist of two back to back converters VSC1 and VSC2, are operated from a DC link provided by a dc storage capacitor. These arrangements operate the UPFC as an ideal ac to ac converter which the real power can freely flow either in direction between the ac terminals of the two converts and each converter independently generate or absorb reactive power as its own ac output terminal.

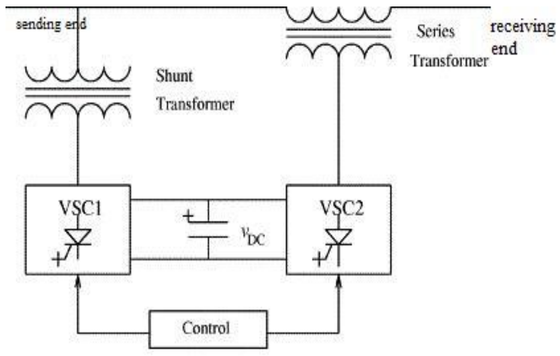

Fig.2.UPFC basic scheme

One VSC is connected in shunt to the transmission line via a shunt transformer and other one is connected in series through a series transformer. The DC terminal of two VSCs is coupled and it creates a path for active power exchange between the converters. VSC provide main function of UPFC by injecting a voltage with controllable magnitude and phase angle in series with the line via an injection transformer. The injected voltage act as a synchronous ac voltage source. The transmission line current flows through the voltage source resulting the reactive and active power exchange between it and the ac system. The reactive power exchanged at the dc terminal. The real power exchange at the ac terminal is converted into dc power which appears at the dc link as a real power demand. VSC1 supply or absorb the real power demanded by converter2 at the common dc link to support real power exchange resulting from the series voltage injection. The dc link power demand of VSC2 is converted back to ac by VSC1 and coupled to the transmission line bus via shunt connected transformer. In addition, VSC1 also generate or absorb controllable reactive power if it is required and thereby provide independent shunt reactive compensation for the line. So VSC1 can be operated at a unity power factor or to be controlled to have a reactive power exchange with the line independent of the reactive power exchanged by VSC1. Similarly, there can be no reactive power flow through the UPFC dc link.

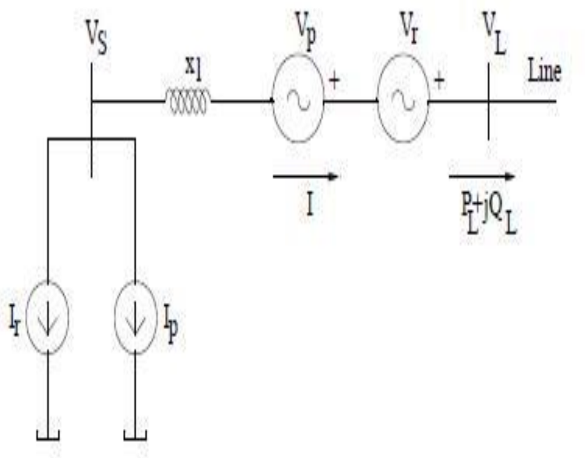

Fig.3.equivalent circuit of UPFC

The equivalent circuit of UPFC is shown in Fig.3 the shunt converter draws both active (Ip) and reactive current (Ir).The active current is not independent. The active power is related to Vp by the relation in steady state.

$$\text{V Ip} = I\,Vp$$

The equivalent circuit of UPFC is viewed as two port network. The shunt converter is connected in shunt at one port and the series converter is connected series with the line at other port. If the series injected voltages such as Vp and Vr are controlled to regulate the power and reactive power in the line. All these quantities are measured at the line side port of the UPFC.

2. Control of UPFC

The UPFC consist of two converters that are coupled in the DC side.

A. Control of Shunt Converter

Shunt converter block diagram is shown in Fig. 8.The shunt converter draws a controlled current from the system. One component of this current Ip which is automatically determined to balance the real power supplied to the series converter through the DC link. This real power balance is enforced by regulating the DC capacitor voltage by feedback control.

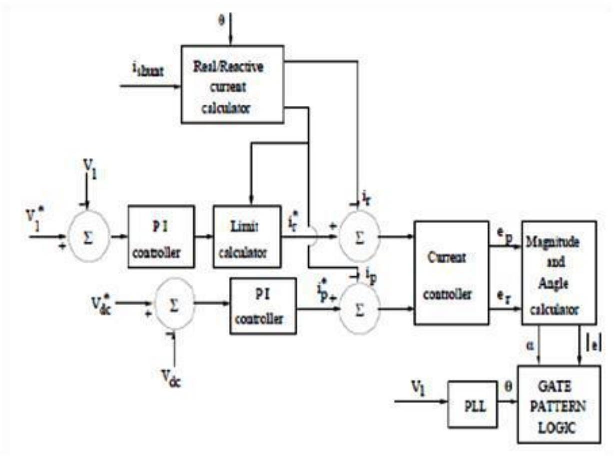

Fig.4.Block diagram of shunt controller

The other components of the shunt converter, current is reactive current (Ir) which can be controlled by STATCOM. There are two operating or control modes for a STATCOM or the shunt converter. In VAR control mode, the reactive current reference is founded by the inductive or capacitive VAR command. The feedback signals obtained from current transformers (CT) which is located on the bushings of coupling step down transformer.

B.Control of the series converter

Block diagram of series controller that shown in Fig.5.In this control mode of series converter, the series injected voltage is determined by a vector control system, it ensure the flow of desired current (phasor) that is maintained during some system disturbances .Otherwise the system control dictates the modulation of the power and reactive power.

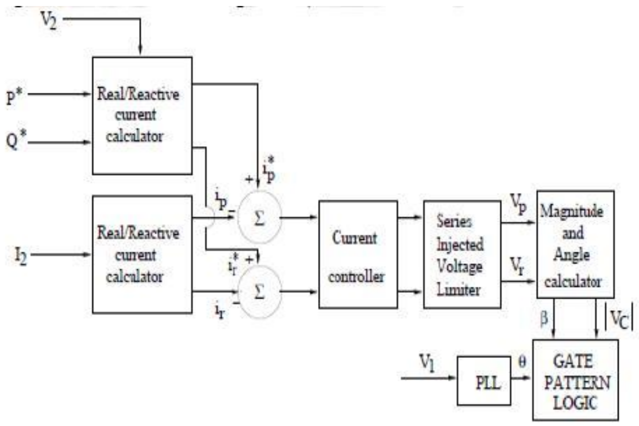

Fig.5.Block diagram of series controller

Normal conditions gives the regulation of complex power flow in the line. The conditions require for system stability by damping power oscillations. The different control modes of series voltage are given;

1. Direct voltage injection mode the converter generates a voltage pharos response to the reference input. The special case, when desired voltage is reactive voltage, then the voltage is quadrature with line current.

2. Phase angle shifter emulation mode, injected voltage phase shifted to the voltage by an angle specified by the reference input.

3. Line impedance emulation mode, series injected voltage is controlled which is proportion to line current.

4. Automatic power flow control mode, reference inputs determines the real and the reactive power that is (P and Q) specified location in the line.

3. Simulation Analysis

To verify the effect of STATCOM on reactive power flow control and voltage stabilization in the micro grid, a grid-connected micro grid system is established by MATLAB, which is shown in Fig.6.

I.

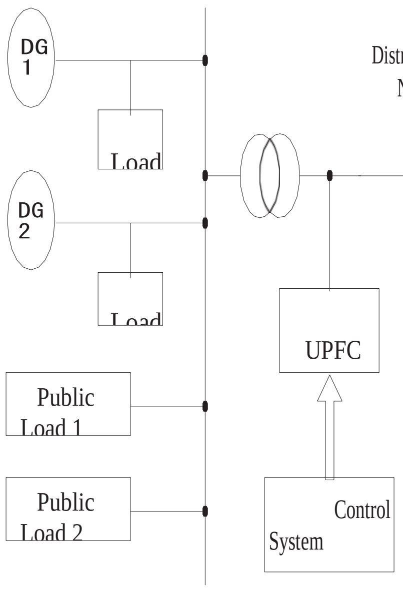

Fig.6.The simulation system diagram

The micro grid system consists of two distributed power supplies and four loads, which are converged to a common bus PCC point and connected to the distribution network via a transformer; UPFC is connected to public connection bus. UPFC regulating reactive power to stabilize voltage at PCC point under voltage fluctuation at the distribution network side and the load fluctuation at micro grid side is verified by the simulation, and the condition of reactive power and voltage fluctuation at the PCC point is compared without adding the UPFC device. The basic simulation parameters are shown in TABLE I.

Table I. Simulation Parameters Of The System

	Physical Quantity	Value
Microgrid	Rated voltage/V Rated frequency/Hz Load1/kw Load2/kw Public load1/kw Public load2/kw	380 50 50 40 60 30
Distribution Network	Rated voltage/kw	25

A. The Operating Condition 1: Load is Suddenly Increased or Decreased in Power Distribution Network

When load is suddenly increased or decreased at the distribution network side, voltage will fluctuate, which causes voltage fluctuation at PCC point and influences power quality of micro grid, by the time UPFC can regulate reactive power of micro grid according to period of fluctuation for the system before simulation, and voltage and reactive power maintain stable. At 0.2s, for the load is suddenly decreased at grid side, a 6% step occurs to voltage, which causes voltage fluctuation at PCC point, reactive power becomes larger; at 0.3s, for the load is suddenly increased at grid side, a 6% decline occurs to voltage, which causes voltage decline at PCC point, reactive power becomes smaller; the voltage at grid side is restored to normal after 0.4s. When UPFC is accessed to system, at 0.2s, UPFC detects a rise of reactive power and assimilates part of the reactive power reference voltage and maintain the voltage balance at the PCC point.

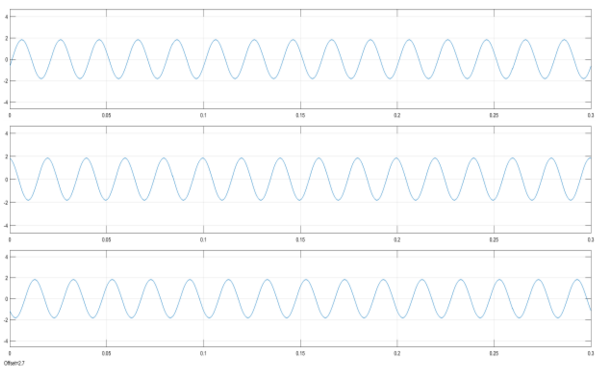

Fig.7.Id-Iq current waveform

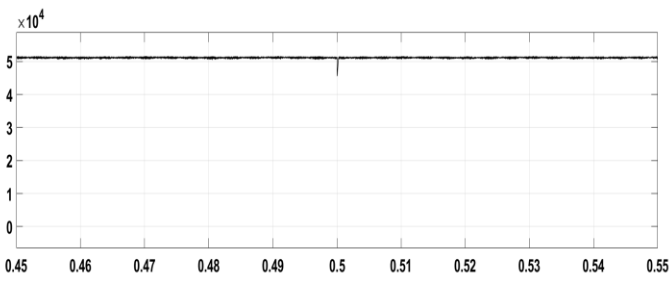

Fig.8.Power distribution network

B. The Operating Condition 2: Load is Suddenly Increased in Micro grid

When load is suddenly added into micro grid enough for power of micro grid to satisfy power required for the load, the voltage at PCC point suddenly drops, reliability of system decreases UPFC can compensate reactive power at PCC point and stabilize voltage. Voltage and reactive power are stable before simulation, at 0.2s, for load is suddenly added into load side of micro grid, voltage at PCC point drops approximately 10%.In order to keep stable reactive power of micro grid system, reactive power is delivered to micro grid from grid side, reactive power at PCC point rises, but it can't completely compensate reactive power, the voltage keeps at 0.9pu. When UPFC is accessed, for the reactive power compensation effect of UPFC, delivered reactive power from grid side to micro grid increases, the voltage at PCC point rises, comparing with the condition without accessing UPFC, there is almost no change for voltage, voltage almost keeps stable. As is known form operating condition and operating condition B. UPFC can control reactive power exchange between power distribution network and micro grid, stabilize voltage of PCC point, stability and reliability are improved.

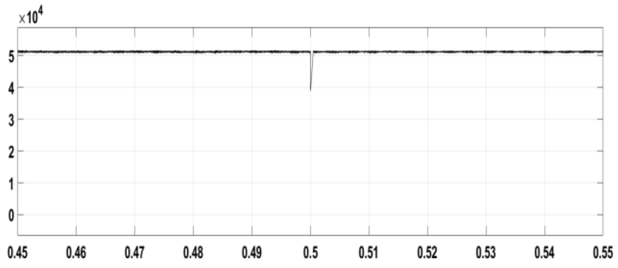

Fig.9.Power distribution in a micro grid

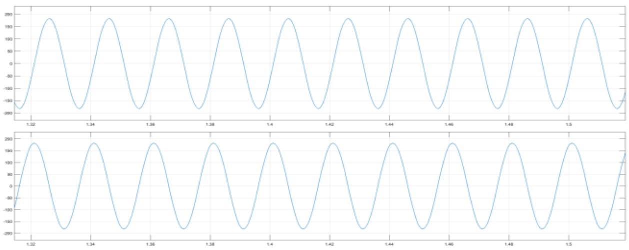

Fig.10.Vd-Vq voltage waveform

The relationship between reactive flow and voltage in micro grid is analyzed, the basic principle for UPFC controlling reactive flow in micro grid is researched, according to steady mathematical model, a control strategy based on direct current control is presented in this paper. The simulation is carried out by Mat lab/Simulink, the simulation under two operating condition is finished. The results show that, when grid-side voltage fluctuates, UPFC can control reactive power of micro grid and power distribution network and stabilize voltage at PCC; when voltage at load side fluctuates in micro grid, UPFC can effectively compensate reactive power, restrain voltage reduction, and improve stability and reliability of system. UPFC improves system voltage regulation and losses are minimized.

II. CONCLUSION

The relationship between reactive flow and voltage in micro grid is analyzed, the basic principle for UPFC controlling reactive flow in micro grid is researched, according to steady mathematical model, a control strategy based on direct current control is presented in this paper. If the power factor is very low or the load at Bus is very large, the PI controller gives oscillations at the output and took more time to settle down. Then PI controller has to be tuned to new values in order to get better results. The simulation is carried out by Matlab/Simulink, the simulation under two operating condition is finished. The results show that, when grid-side voltage fluctuates, UPFC can control reactive power of micro grid and power distribution network and stabilize voltage at PCC; when voltage at load side fluctuates in micro grid, UPFC can effectively compensate reactive power, restrain voltage reduction, and improve stability and reliability of system. UPFC improve the transient stability and faster steady state is achieved, thereby congestion is less due to improving transient stability.

III. REFERENCES

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