IMPACT OF UPQC ON PROTECTION OF DISTRIBUTED GENERATION INTEGRATED DISTRIBUTION SYSTEM

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Abstract – *The process of providing protection to the distribution network fed from the three phase generation system along with the distributed generation is difficult and different from providing protection to the distribution system fed from three phase generation system only. If the network is fed from two generating systems and if any fault occurs in the distribution system, the current from the generation adds to the fault current existing in the grid. Due to this, there is a rapid increase in fault current in the grid, which inturn leads to the major damage to the equipments in the transmission and distribution system. It also leads to the voltage fluctuation and reactive power imbalance in the grid. In this work the behavior of the distributed generation along with the distribution system in the event of fault and without fault under various load conditions are studied. To provide protection to the distribution system against the above challenges, a device has been developed known as Unified power quality conditioner (UPQC). UPQC provides protection to the power system with two different compensation circuits. In this work, UPQC can be configured in two ways and the simulation results of both the configurations are compared and better configuration is obtained. In this project all the simulations are done using Matlab/Simulink.*

***Key Words*: Unified power quality conditioner, Distributed generation, Distribution system,**

1.INTRODUCTION

Electricity is very essential for mankind in today's world. The demand for electric power is increasing day by day, due the increase in consumption of electric power in industrial, domestic, agriculture and in various sectors. As the demand for electricity is increasing, the generation of electricity has also increased. The most used generation plants are coal, oil, hydro and renewable energy plants. During the last five years, power generation from coal and renewable energy sources contributed more for the increase of power generation, whereas the contribution from oil, natural gas has decreased in last five years. The generation of electric power from coal, oil and nuclear imposes greater effect on the environment. The emission from these generations pollutes the environment severely. Therefore, renewable energy sources are being used in the generation of electric power to prevent the pollution of environment and also these acts as backup sources for generation of power, in case of failure of generation from thermal or nuclear sources.

In some cases where the electricity demand is very high, a single source for generation of power is not sufficient in order to meet the greater demand. Therefore, the generation of electric power from different sources especially renewable energy sources (distributed energy sources) are integrated in a micro grid with a common DC bus operating at same frequency. By using this, the power is supplied to the consumers in a reliable manner without the interruption of the supply. Now a days, wind turbines, photovoltaic, fuel cell, hydro turbines, coal are commonly used. In this project fuel cell is used as distributed generation source. It acts as a backup source during the time of fault in the existing generation system.

Advantages of integrating distributed generation into the distribution network are as follows,

- Up gradation of transmission and distribution system in case of supplying greater power than the normal supply power can be avoided.
- In case of increased load demand, distributed generation meets the additional load demand in the distribution system.
- Distributed generation can be operated in an economic way.

Integration of distributed generation into the distribution network not only has advantages, it has disadvantages too. They are as follows,

- Co-ordination of protecting devices is greatly affected by the integration of distributed generation.
- Deviation of voltage profile occurs and harmonics are generated along with the imbalance in the reactive power of the system
- Providing protection is the difficult task, as the flow of power is bi-directional.
- Increase in the level of fault current during any fault condition in the system.

In order to avoid the above challenges various power electronic devices were designed. During the initial stages shunt active or shunt passive filtering devices were used in order to resolve power quality related issues. But due to some limitations of these devices flexible AC transmission system (FACTS) devices and power devices were designed. These devices worked better than the shunt filters.

Now, a highly efficient device for solving power quality related issues has been designed i.e, Unified Power

Quality Conditioner (UPQC). UPQC performs the operation of Dynamic Voltage Regulator (DVR), as well as the Static compensator (STATCOM). This designed UPQC compensates the reactive power imbalance in the system, prevents the increase of fault current in the system during various fault conditions, prevents the deviation in the voltage profile, it also has the ability of removing the harmonics of various orders. UPQC performs all the above actions by using various control techniques which are based on voltage controllers and current controllers.

This work deals with the lowering of the fault current to avoid damage to the various devices in the system and to compensate the reactive power in the distribution system during fault at different loading conditions. The performance of the UPQC is evaluated by placing UPQC between, Distributed generation source (fuel cell) and Point of common coupling (PCC) and between Load and Point of common coupling (PCC). The performance of UPQC is also evaluated for different active power, different inductive and capacitive reactive power of the Load.

1.1 Unified Power Quality Conditioner (UPQC):

The basic concept of UPQC is to protect the distribution system during fault by compensating reactive power in the system, avoiding voltage interruption and removing current harmonics. The reactive power in the system varies with respect to the load.

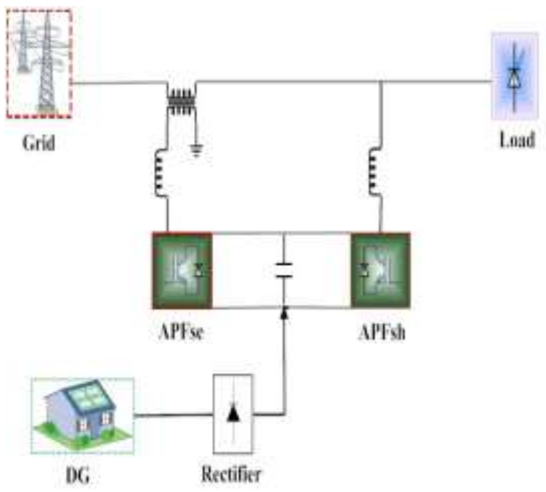

Fig -1: Basic structure of UPQC with distributed generation

Basic circuit diagram of UPQC is as shown in the above fig.1

There are two Voltage source inverters present in the circuit. These voltage source inverters are connected by common DC link. A capacitor is connected in between the inverters. Capacitor should be maintained with 150% of the maximum line to line source voltage for the UPQC to operate effectively for protecting distribution system. Both the inverters are connected to AC line in a different way using injection transformers. i.e., one inverter is connected in series with the AC line called as series inverter and another is connected in parallel with the AC line called parallel inverter.

Series compensator consists of series inverter and its control circuit. It is used to maintain voltage at the terminal at rated frequency and magnitude. Whereas, Shunt compensator consists of shunt inverter and its control circuit. Shunt compensator avoids the rapid variation of current during faults by maintaining the sinusoidal variation of current at source in phase with the voltage at the source at rated frequency and magnitude.

1.2 Control circuits for shunt and series compensation:

This shunt compensation circuit basically consists of three control loops. They are, two current control loops and one voltage control loop. The main purpose of using shunt compensation is to obtain purely sinusoidal waveform of current in phase with the source voltage. It is not possible for the voltage control loop to do so. It is the current control loop that makes the source current to have desired amplitude and shape as that directed by voltage control loop. The energy stored in the capacitor remains constant only when the incoming energy is equal to the demand. During steady state conditions, the energy stored in the capacitor is given to the load at constant average rate. If the capacitor voltage decreases, then the voltage control loop senses the decrease in voltage and draws more current from the source till the capacitor voltage reaches the reference value. If the voltage across capacitor tends to increase, the voltage control loop senses the increase in voltage and decreases the current drawn from the source. By this way voltage control loop controls the amplitude of the current at the source and also controls the output voltage.

Pulse Width Modulation (PWM) technique is used for controlling series compensation circuit. PWM technique is carried out by comparing two different signals, such as sinusoidal signal considered as reference signal and sawtooth considered as modulating signal. Pulses are generated when the value of reference signal is greater than the modulating signal. These pulses are used to control series compensation circuit in UPQC.

1.3 Configuration of UPQC:

i. **Between Point of common coupling (PCC) and Fuel cell:**

In this case, UPQC provides protection against fault that occurs between PCC and fuel cell only. This configuration fails to provide protection against faults at any point in the considered system. If the fault occurs between PCC and fuel cell, then the distribution system is protected by adjusting the reactive power between the distributed generation source and three phase supply through series APF, to control the transfer of active power in a proper way.

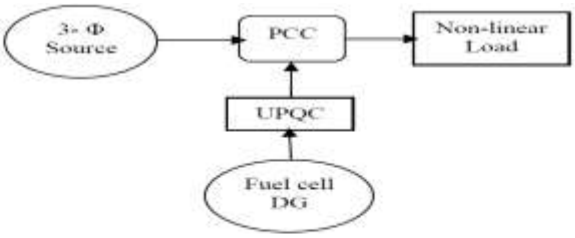

Fig -2: Integration of UPQC between Fuel cell and PCC

ii. Between Point of common coupling (PCC) and load:

In this case, UPQC is connected between load and PCC. This configuration provides effective protection to the distribution network compared to the above configuration by compensating the reactive power. Series APF of UPQC is connected near the distributed generation to regulate the voltage by inserting the voltage in phase with voltage at PCC.

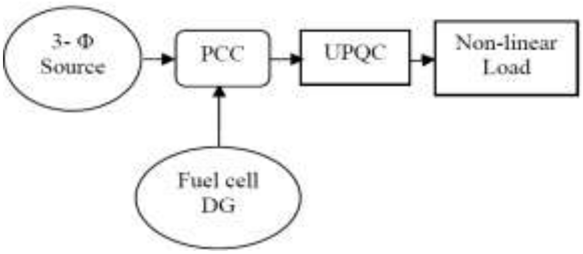

Fig -3: Integration of UPQC between PCC and Load

1.4 Methodology:

Steps for the compensation of reactive power:

- Measure the distribution system parameters such as Current (I), Voltage (V), Reactive power (Q) and Active power (P) without distributed generation.
- Measure the above parameters with distributed generation.
- Compute the reactive power of the distribution network during faults.
- If the current waveform in the distribution network is non-sinusoidal due to the fault, The reactive power in the network is compensated by the current control loop. i.e., Shunt compensation.
- If the voltage waveform in the distribution network is non-sinusoidal due to the fault,
  The reactive power in the network is compensated by voltage control loop. i.e., Series compensation.

In both cases UPQC compensates the reactive power and proportionate filters. They are Shunt filter and Series filter.

Flow chart for the analysis of compensation of reactive power:

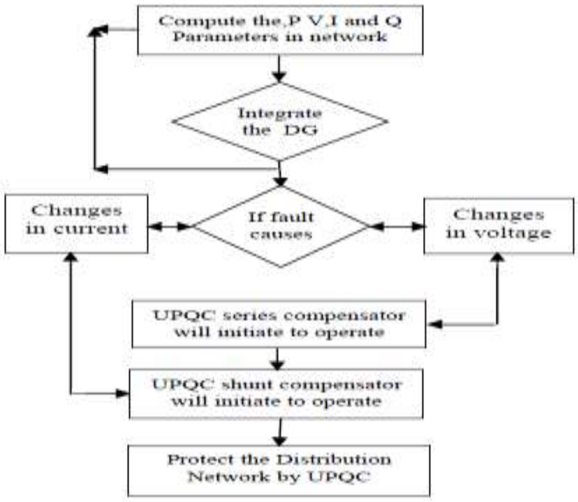

Fig -4: Flow chart for the analysis of compensation of reactive power

1.5 Simulation results:

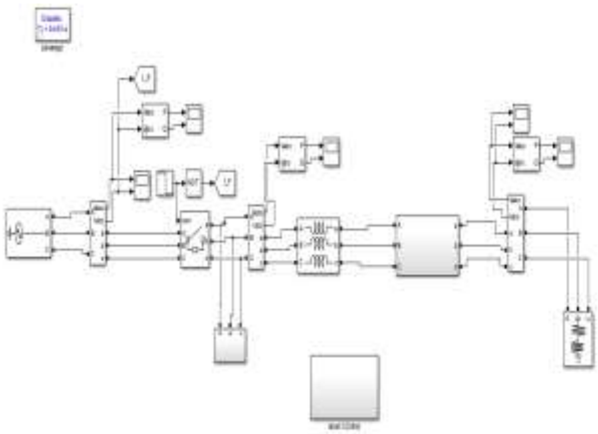

Fig -5: Three phase transmission and distribution circuit with fault and UPQC between PCC and load

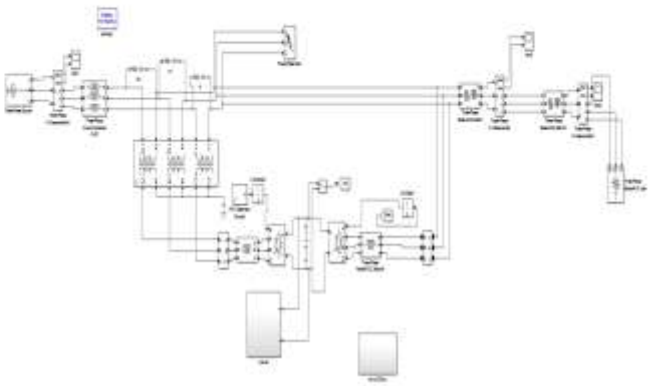

Fig -6: Three phase transmission and distribution circuit with fault and with UPQC between fuel cell and PCC

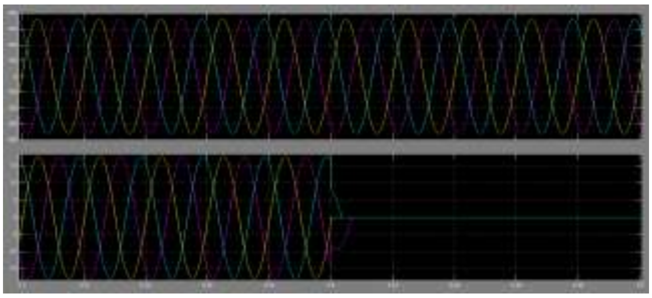

Fig -7: Waveforms of voltage and current at three phase generating source

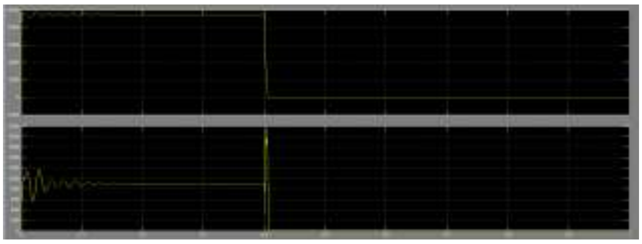

Fig -8: Reactive power at three phase source

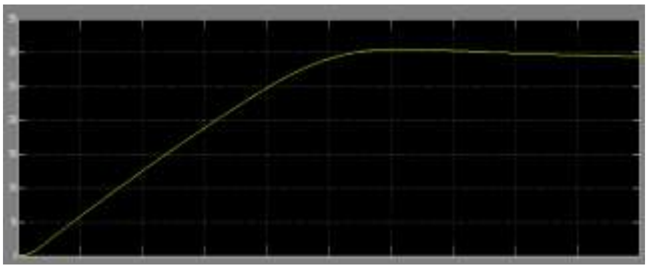

Fig -9: Output voltage of fuel cell

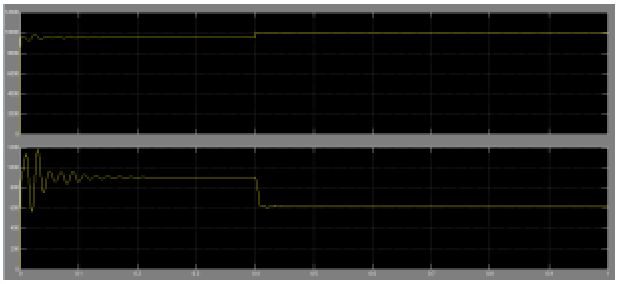

Fig -10: Active and reactive power output of fuel cell

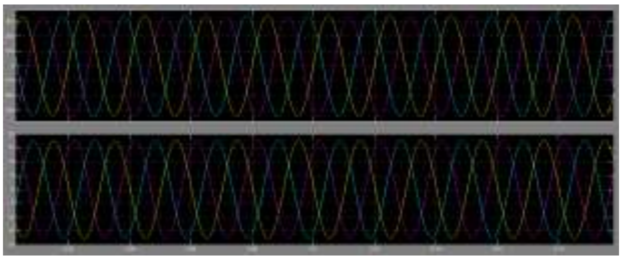

Fig -11: Output voltage and current waveforms at the load

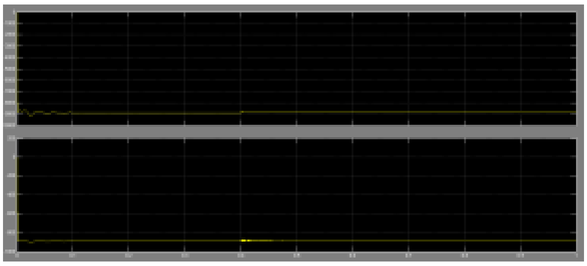

Fig -12: Active and reactive power consumed by the load

1.6 Conclusion:

As the demand for electricity varies continuously, it is very difficult to maintain the reliability in meeting the varying load demand. Therefore, in this project to meet the increase in demand of electricity, distributed generation is integrated into the existing power network. The distributed generation used in this project is capable of serving the additional load demand and it is capable of fulfilling the load demand in case of fault in the existing generation system. In case of fault in the network, fault current increases rapidly due to the integration of distributed generation into the distribution network. In this project, in order to reduce the fault current and also to compensate the reactive power imbalance in the network a device called UPQC has been installed. In this work, UPQC is installed in the network in two different configurations. From the results we can conclude that, UPQC installed between PCC and load works better to reduce fault current, to maintain the lower phase angle between the voltage and current, to compensate reactive power imbalance when compared with the other configuration of UPQC.

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