

Integrated Technique of UPQC with Microgrid

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ABSTRACT: Microgrid is a system which combines loads and micro sources performing as a single system to produce power. The architecture of the microgrid comprises of interface controls disturbances like unbalances, harmonics and other power quality noises. To control these noises, it is advisable to place power quality conditioner between each micro grid and the utility grid. The main concern for the interconnection between the microgrid and distribution system is to reduce the impact of power quality problems on the main power systems. These power quality problems can be named as harmonic contents in load current and voltage and frequency deviations in grid voltage. This paper is to propose a solution to overcome this power quality issues through flexible distribution system for microgrid. This concept is made up of two main components such as series and shunt converters shared by Direct Current (DC) link capacitor². The PCC and DC link of the flexible transmission system device is derived from distributed energy source. Another proposal is made in this paper for integration, placement and control of unified power quality conditioner (UPQC) in distributed generation (DG) - based grid connected/autonomous microgrid micro generation (μ G) system. The shunt of UPQC Active Power Filter (APFsh) and the DG converters (with storage) are placed in the Point of Common Coupling (PCC). In the islanded mode or in the interconnected mode, the DG converter with storage will handle the supply of active power and the shunt part of UPQC will handle the reactive and harmonic power of the load. In this concept the DG converter will be connected even during voltage disturbances including phase jump. In the islanding mode the DG converter with storage will supply active power and the shunt part of UPQC will handle the reactive and harmonic power of the load. Hence the system can work in island and interconnect mode. The DG converter needs to supply only active power under all circumstances and will never be disconnected from the system even during voltage disturbances.

KEYWORDS: Power Quality, Unified Power Quality Conditioner(UPQC), Microgrid.

I. INTRODUCTION

Unified power quality control is a vast subject that has been studied and investigated by many researchers as a vital way to enhance power quality. The attribute of UPQC- unified power quality conditioner is to handle the disturbances and deliver high performance of the critical load. The UPQC consists of two inverters which shares a single dc link capacitor. This can compensate the voltage sag and swell, voltage and harmonic current and control the voltage stability and power flow. Since there is no energy storage in the dc link the UPQC cannot handle the voltage interruption.

The urge in DG-distributed generation is rapidly increasing as it is predicted to play an important role in the future power systems. DG can provide solution for many problems that the conventional power system possess. Let's consider an example; there is an energy security problem in a large scale power system. The cause for the problem is that a few transmission facilities are responsible for providing electric power for huge customers. The above problem which is caused by some for the transmission-line trip can be optimised through large number of DGs installed in the power system. DG can also provide great economic advantages, like reducing the loss of transmission line and reduce the cost of high voltage equipment. However if a DG is

performing in standalone mode then there are some significant problems of voltage and frequency variation. Hence when a small DG is considered it has to be connected to the power system in order to maintain the frequency and voltage. Many studies have proved that the interconnection system for DG through inverters which provides the power system as the inverter delivers versatile functions by which it enhances the ability of DG.

Power quality problems are another interesting subject that is drafting the attention of many as this can cause significant impact on the economy through industrial customers. One method to tackle this problem is the use of custom power compensation technique. A model to showcase this is the UPQC. This UPQC is mainly to justify the impacts of the power quality disturbances which is the voltage sags. Ideally the UPQC works by inserting a voltage component along with the load voltage so that the load side voltage can be maintained to its minimum level at the time of voltage disturbances. In case of load demand it can be met by adjusting the power flow from the energy storage within the series compensator (SC) over the disturbance interval.

Electrical grids are to be more intelligent, more distributed and flexible. The electric grids will be dominated by the new power electronic equipment in the next coming years. The concept of grid is to become more distributed and so the energy consumption and generation areas are not differentiated. In today's world the challenge for electrical and energy engineering is to distribute power generators and dispersed energy-storage devices are to be integrated into a grid. The concept of electrical grid, also named as smart grid (SG), delivers power from suppliers to consumers with the help of digital technology and to control appliances at consumers' place in order to save energy and hence reducing the cost. This also increases the reliability and transparency.

The minimization of harmonic currents which is generated due to harmonic voltages and the non-linear loads in the end user side are the dominating and most important components for power quality improvement. The magnetic flux has widely replaced the harmonic current in a transformer core. This was introduced by the shunt active power filter (APFsh). Due to the development in the modern power electronic devices and state of art electronics has provided a lot of improvement in APF. This includes the series or shunt at the utility point of common coupling (PCC) to reduce the voltage or current distortions or deviations. The main concern of all these envelopments is to improve the quality of power supply in the network and reduces the effect of voltage and current disturbances. Else poor power quality and harmonic power losses will lead to increase in cost for the consumers.

1.1 Inter Connected Mode:

The DG output in the UPC mode can be controlled to a constant level. In order to achieve this voltage in the interconnected point and the current released by the DG are measured as s . The voltage and current are measured to calculate the active power released by the DG. This is turn is fed back to the generator controller (GC). The DG now can handle the load variation and provide constant power output when the micro grid is connected to the main grid. If the microgrid demands for more power, then it can be supplied by the main source.

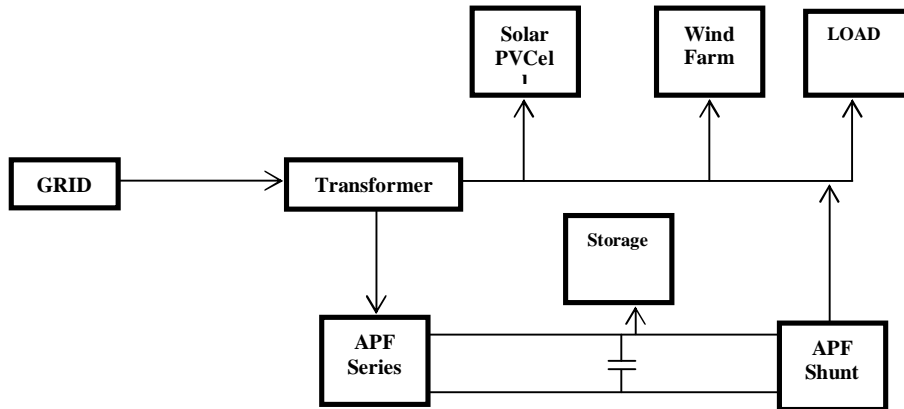


Fig 1.1 Inter Connected Mode

1.2 Island Mode:

The Microgrid is not connected to the utility grid in the Island mode. Two inverters are used in this mode. The voltage and frequency references are provided by voltage source inverter (master) and the other inverter acts like current sources (slaves) which follow the references from the VSI. This mode can be achieved by allowing small errors as the control of the expandable distributed system has no communication. Hence these control techniques are called as droop control methods. The microgrid in the island operation consists of photovoltaic panels (PV), battery bank for voltage regulation, wind turbine and a small generator. The converters are used to double the PV and the battery storage for the low voltage grid allows the microgrid operation in grid interconnected mode or islanded mode and the power that is flowing in the feeder. The extra loads are handled by the wind and solar, which leads to constant load in the utility grid. This makes the microgrid a dispatch able load from the utility side, which allows for demand-side management arrangements. When the system is in the islanded mode the local feeder flow-versus-frequency droop function makes sure that the power is in balances mode. The DG converter continues its connection to retain the voltage at PCC and the APF series is disconnected during the grid failure. The APF shunt will handle the non active power for the non linear load to maintain undistorted current at PCC for the linear loads. Hence the DG converter with storage will provide only active power and hence need not be disconnected from the system.

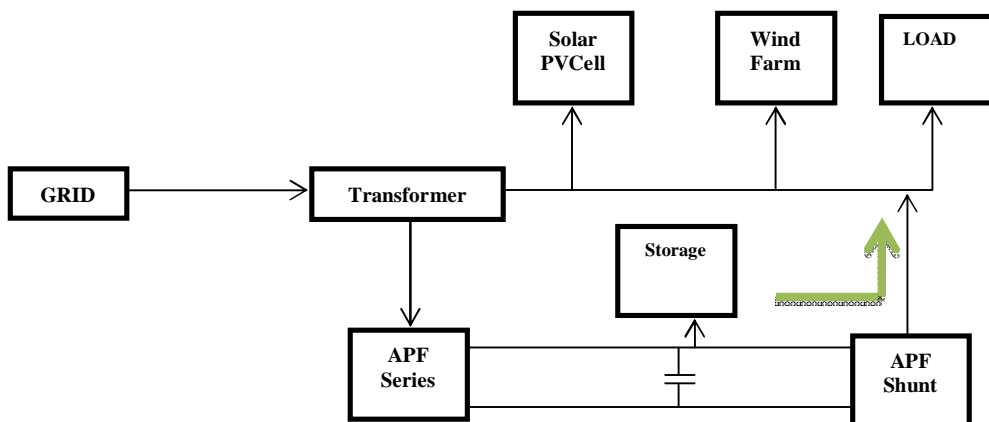


Fig 1.2 Island Mode

II. DESIGN PARAMETERS

The proposed designs strategy is to create reference signals for both the series and shunt APFs of UPQC-L. This approach is to get reference voltage signals for the series APF. The shunt APF uses the two closed loop PI controllers.

2.1 Shunt Part:

There are two closed loop PI controllers in the control strategy for shunt APF. The first controller is used to find the amplitude of the in-phase components of reference supply currents (I_{spdr}). The second controller is to calculate the amplitude of the quadrature components of reference supply currents (I_{spqr}). The first controller is analysed with the DC bus voltage of back-back VSI capacitor of UPQC. The second controller is analyzed with the peak value of load voltage (v_t^*). Three-hase reference supply currents consist of two components to normalize the load voltage. The first of them is the supply currents in phase with the source voltage. This is required to provide active power for the load and losses of UPQC. The second component lies in the quadrature with the source voltage. This is required to provide reactive power for load and to regulate voltage. These supply currents should handle the supply voltages for maintain the voltage while the supply currents must be in phase with the supply voltages for the purpose of unity power-factor operation. These two conditions namely, power factor control to unity and voltage regulation at PCC is not possible to achieve simultaneously. Having this into consideration, the shunt APF of UPQC of the control algorithm is made flexible so that either the voltage regulation or unity power factor operation is achieved.

The non fundamental current of the load is handled by APFsh by providing I_{shin} quadrature to V_{pcc} . When the voltage sag is visible in the supply side, APFse handles the sag by adding the needed voltage to bring the voltage to constant and zero phases at PCC. APFsh also takes additional current from the source to provide power to APFse. Now the increased source current $I_{_s}$ remains in phase to V_{pcc} . but this leads to changes in the magnitude and phase angle of the compensating current, $I_{_sh}$ has the additional active component of current (x) is added to the shunt compensator current.

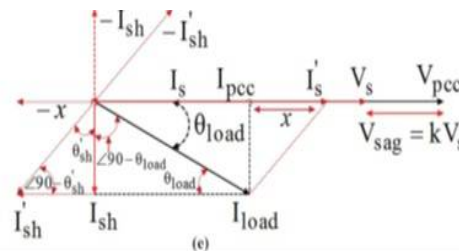


Fig 2.1 Shunt Control UPQC

2.2 Series Part:

The three phase voltage reference signal is extracted for series APF based on Unit Vector Template Generation. This is achieved with the help of Unit Vector Templates generator. The three phase in-phase unit (U_{va} , U_{vb} , U_{vc}) are generated from the three phase supply voltage (V_{sa} , V_{sb} , V_{sc}). The desirable peak amplitude (V_t^*) of load voltage is multiplied with the Unit Vector Templates to get the reference load voltages denoted as V_{lar} , V_{lbr} and V_{lcr} as:

$$V_{lar} = V_t^* \times U_{va}$$

$$V_{lbr} = V_t^* \times U_{vb}$$

$$V_{lcr} = V_t^* \times U_{vc}$$

The APFse appear in series with the grid. When there is no energy available from the DG unit and shunt, then the APF will handle the reactive and harmonic part of the load current, the active fundamental part of the load current (I_{loadfp}) flows through APFse. Hence the APFse should also have the same current rating as

the active load fundamental requirement. The main characteristic of the APFse is the voltage rating as it determines other aspects like compensating range, the requirement to include energy storage devices and the size of the series transformer. If the voltage of the APFse increases then the losses also tend to increase. Hence the voltage input should be kept as minimum as possible to reduce equipment cost and standby losses.

2.3 Active Power Filter:

As discussed earlier, this paper prioritises unified power quality conditioners UPQC. UPQC aims at integration of series active and shunt-active filters. The main target of UPQC is to handle and compensate reactive power, negative-sequence current, supply voltage flicker/imbalance and harmonics. To simplify the concept of UPQC, it helps in the enhancement of power quality at the point of installation on power distribution systems or industrial power systems. The UPQC is hence expected to be the most efficient powerful solution for large capacity loads sensitive to supply voltage flicker/imbalance. Another specific UPQC in this paper we have two types of UPQC's. The first model is the UPQC for industrial power systems and power distribution systems. The second is the specific UPQC for supply voltage-flicker/imbalance-sensitive load. This is being installed by electric power consumers on their premises. In this paper we provide much attention to the specific UPQC which consists of series active and shunt-active filter. The series active filter helps in the elimination of supply voltage flicker/imbalance from the load terminal voltage, and pushes an existing shunt-passive filter to absorb and destroy the current harmonics produced by nonlinear load. This removal of supply voltage flicker can lead to low frequency fluctuation of active power flowing in or out of the series-active filter. The shunt-active filter plays the dc-link voltage regulation, which leads to significant reduction of capacity of the dc capacitor.

2.4 DC Link Capacitor:

Let us consider the below.

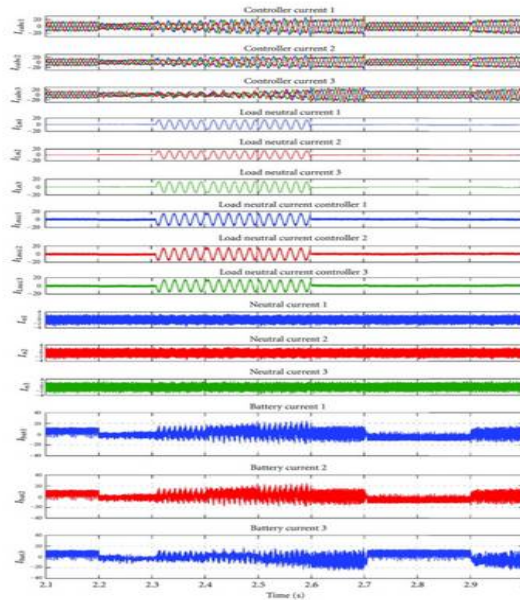
- Voltage at the source side before UPQC- v_s
- Load voltage at the load- v_L
- Voltage injected by the series APF - v_{inj}
- DC link voltage between two inverters- V_{dc} .
- Current on the source side- i_s
- Current drawn by the loads- i_L
- Neutral current on the source side- i_{sn}
- Load neutral current- i_{ln}
- Current injected by the shunt APF- i_{sh} .

According to the principles discussed, the APF must be able to work on high-sag/swell condition and even during interruption (depending on the interruption time) before it goes to the islanded mode.

In this stage the DC link capacitor must be able to

1. Minimize the ripple in the steady state and maintain the DC voltage.
2. Should act as an energy storage and supply for the non active power of the load.
3. Should be able to supply the power difference between the load and source in case of sag/swell or any kind interruption.

It is advisable to consider a higher value for C_{dc} so that the above conditions can apply. It greatly helps in lower the steady-state ripples and provides a better transient response.



III. CONTROLLER DESIGN

The block diagram of the UPQC μ G -IR controller is same as the UPQC controller except that the additional islanding detection and reconnection capabilities. For smooth operation between the UPQC μ G -IR and μ G is provided through a communication channel (signal transfer). The generation of these signals depend on the swell/sag/interrupt/supply failure conditions. According to the hierarchical control this task is performed in Level 2 (secondary control). The Level 1 handles with primary control of the UPQC in order to perform the basic functionalities in the interconnected and the islanded mode. The overall concept and technique along with the control strategy is to provide power quality at the time of interconnected and islanded modes. This deals with the detection of the reconnection and islanding mode and that to ensure the DG converter is connected and supply active power to the load. This helps to reduce the power failure possibility and complexity of the converter in the islanded mode.

The five main elements that contribute for UPQC μ G -IR controller are

1. Series part (APFse) control
2. Synchronization and reconnection (SynRec)
3. Positive sequence detection
4. Shunt part (APFsh) and
5. Intelligent islanding detection.

Since SynRec and IsD are new features in UPQC, they will be discussed in detail.

IV. SIMULATION STUDY

An active distribution network (230 VL-N) along with 3-phase and 3-wire is used along with the UPQC μ G -IR and μ G. This is being tested in the MATLAB tools to study their performance.

The switching of mode during the reconnection and islanding process are done in off-line mode. Observations of the performance are stated below. The offline simulations are done for 2 s in the MATLAB to correctly analyze the complete performance of the system. The timeline used for the various performance of UPQC μ G -IR is also being evaluated. With the above scenarios two possible mode of operation are observed.

1. Forward flow
2. Reverse Flow

In forward flow mode, The DG power is less than the actual required load demand. The utility compensates the rest of the power to the load. In other case, when the DG power is higher than the expected load demand, then the extra energy is given to the grid and storage and this is termed as reverse-flow mode. In this stage the grid current becomes out of phase with the voltage at PCC.

In the aspect of IsD method, the APFse can replace the sag for up to 0.6 s which is like 30 cycles and then it goes back to the islanded mode. At 1.11s, i.e. after 30 cycle count completes, a utility disconnection is applied. After which the zero-crossing of V_{sag} -ref is detected and S2 and S3 are opened. After the disconnection the μ G operates in islanded mode. In this stage, the storage supplies the extra power if the DG power is lesser than the required power. If the DG power is higher than the requirement then the additional power is transmitted to the storage. The APFsh will still handle the compensation of non active power. Hence the DG converter need not be disconnected or change the control strategy (needs to provide only the basic active power) to supply power to the load. The performance of the UPQC μ G -IR during 1.0 -1.2 s is analyzed, where the islanding is exactly detected after the 1.1 s at zero-crossing detection.

V. CONCLUSION

This proposed method explains the integration and new placement technique of the UPQC μ G in the grid connected μ G condition. These simulations are performed in the MATLAB. The results from the research demonstrate that the new system can compensate the voltage disturbance at the PCC. It can also compensate the harmonic and reactive current of the load and can inject at the PCC at the interconnected mode. The performance of the UPQC μ G is being analysed with the bidirectional power flow condition as well. In the islanded mode, the DG converter supplies active power to the load and the shunt APF can compensate the reactive and harmonic power. Hence, the grid-tie DG converter can be still connected and need not change its control strategy in order to keep the μ G in operation in the island detection and even during the island mode operating.

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