Implementing UPQC based Intelligent Islanding for the Microgrid System

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Abstract: Increased penetration of small scale renewable energy sources in the electrical distribution network, improvement of power quality has become more critical than where the current harmonics or disturbances and level of voltage can vary widely. For this reason, Custom Power Devices (CPDs) such as the Unified Power Quality Conditioner (UPQC) can be the most appropriate solution used for improving the dynamic performance of the distribution network, where accurate prior knowledge may not be available. Therefore, the main objectives are (i) placement (ii) integration (iii) capacity enhancement and (iv) real time control of the Unified Power Quality Conditioner (UPQC) to improve the power quality of a distributed generation (DG) network connected to the grid or microgrid. A new integration method of the UPQC has been developed: helps to the DGs to deliver quality of power in the case of islanding and help to reintegrate with the grid seamlessly post fault. It perform both control operation such as Detection of Islanding and reconnection techniques, hence, it
is termed UPQC□G. The DG Inverter with storage supplies the active fundamental power only and the shunt part of the UPQC compensates the reactive and harmonic power of the load during both interconnected and islanding mode.

Keywords: *Distribution Network, Unified Power Quality Conditioner (UPQC) ,Custom Power Devices (CPDs),Microgrid (□G).*

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1. INTRODUCTION

1.1 Introduction

Power generation systems are facing the shortage of fossil fuel and the need to reduce emissions. Therefore, emphasis has increased on distributed generation (DG) networks with integration of renewable energy systems into the grid or on isolated micro grids (μGrid).This leads to energy efficiency and reduction in emissions and also reduces the long transmission line electrical power losses. With the increase of renewable energy penetration in the grid, power quality (PQ) challenges of the medium to low voltage power distribution system is becoming a major area of interest [2]. Most of the integration of renewable energy systems to the grid takes place with the aid of power electronics converters. Purpose of the power electronic converters is-to integrate the DG to the grid. However, high frequency switching of inverters can inject additional harmonics to the systems, creating major PQ problems if not implemented properly. On the other hand, Custom Power Devices such as STATCOM (Static compensator), DVR (Dynamic Voltage Restorer) and UPQC (Unified Power Quality Conditioner) are the latest development of interfacing devices between the distribution supply (grid) and consumer appliances. This equipment's are designed to overcome voltage or current disturbances and improve the power quality by compensating the reactive and harmonic power generated or absorbed by the load.

1.1.1 .Distributed Generation (DG) and Microgrid (μGrid)

Distributed generation (DG) is used to describe small-scale electricity generation, but there is no consensus on how DG should be defined. In some cases, DG is defined on the basis of the voltage level, whereas elsewhere the definition is based on the principle that DG is connected to circuits from which consumer loads are supplied directly [12]. Usually DG is classified according to its different types and operating technologies.

1.2 Necessity

1.2.1 Power Quality (PQ) issues in DG or Microgrid (μGrid) system.

Approximately 70 to 80% of all PQ related problems can be attributed to faulty connections and/or wiring [2]. Power frequency disturbances, transients, electromagnetic interference, harmonics and low power factor are the other categories of PQ problems that are related to the source of supply and types of load [3]. Among these events, harmonics are the most dominant. According to the IEEE, harmonics in the power system should be limited in two ways; -limit the harmonic current that a user can inject into the utility system at the point of common coupling (PCC) or limit the harmonic voltage that the utility can supply to any customer at the PCC. The DG interconnection standards are to be followed when considering PQ, protection and stability issues [8]. Among the DG sources, PQ issue related to solar and wind energy systems are the major concerns here.

1.2.2 Anti-islanding

Anti-islanding is one of the important issues for grid-connected DG systems. A major challenge for the islanding operation and control schemes is the protection coordination of distribution systems with bidirectional flows of fault current. Therefore overview of the existing protection techniques with islanding operation and control, for preventing disconnection of DGs during loss of grid, is important. In terms of DG connected grid or μGrid systems, however, DG integration includes some level of power electronics to improve controllability and operating range. Whatever

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connection configuration is used, each DG system itself has an effect on the PQ of the distribution or transmission system. These PQ problems related to the most commonly used DG systems (solar, wind, hydro and diesel) are given in Table 1.1 [19].

PQ Problems	Wind Energy	Solar Energy	Micro/ Small Hydro	Diesel
Voltage Sag/Swell	•		•	•
Over/Under Voltage	•			•
Voltage Unbalance		•		
Voltage Transient	•			
Voltage Harmonics	•	•	•	
Flicker	•	•		•
Current Harmonics	•	•	•	
Interruption	•	•		

Table 1.1 PQ problems related to DG systems

1.3 Objectives

The main objectives are:

(i) placement
(ii) integration
(iii) capacity enhancement and
(iv) real time control of the Unified Power Quality Conditioner for improving the power quality of a distributed generation (DG) network connected to the grid or microgrid.

The placement of a UPQC and its sensors in the network, Impact of their placement on the UPQC control to perform the specified task, performance of UPQC with bi-directional power flow in the network and the advantages of DG inverter in the presence of UPQC.

The issues of a successful integration of unified power quality conditioner (UPQC) in a distributed generation (DG)-based grid connected micro generation (μG) system are mainly: 1) To control complexity for active power transfer; 2) Ability to compensate non active power during the islanded mode; and 3) Difficulty in the capacity enhancement in a modular way [1]. For a seamless transferring power between the grid-connected operation and islanded mode, various operational changes are involved, such as switching between the current and voltage control mode, robustness against the islanding detection and reconnection delays, and so on [2], [3].Clearly, these further increase the control complexity of the μG systems. To improve the power quality and to extend the operational flexibility and in grid connected μG systems, a new placement and integration technique of UPQC have been proposed in [4], which is termed as UPQCμG. In the UPQCμG integrated distributed system, μG system with storage, the shunt part of the UPQC are placed at the Point of Common Coupling (PCC). And other series part of the UPQC is placed before the PCC and in series with the grid. Additionally the dc link is also connected to the storage, if present. For maintain the operation in islanded mode and reconnection through the UPQC, communication process between the UPQC μG and μG system is mentioned in [4]. In this system, the control technique of the presented UPQCμG is enhanced by implementing an intelligent islanding and reconnection technique with reduced number of switches that will ensure seamless operation of the μG without interruption. Hence, it is termed as UPQC μG−IR.

1.4 The benefits offered by the proposed UPQCμG−IR over the conventional UPQC are as follows.

1) It can compensate voltage interruption/sag/swell and non active current in the inter connected mode. Therefore, the DG converter can still be connected to the system during these distorted conditions. Thus, it enhances the operational flexibility of the DG converters/μG system to a great extent, which is further elaborated in later section.

2) Shunt part of the UPQC Active Power Filter (APFsh) can maintain connection during the islanded mode and also compensates the non active Reactive and Harmonic Power (QH) power of the load.

3) In the interconnected and islanded modes, the μG provides only active power to the load. Therefore, it can reduce the control complexity of the DG converters.

4) Islanding detection and reconnection technique are introduced in the proposed UPQC as a secondary control. A communication between the UPQC and μG is also provided in the secondary control. The DG converters may not require to islanding detection and reconnection.

5) The system can even work in the presence of a phase jump/difference (within limit) between the grid and μG. Thus, the UPQC μG−IR will have control of the islanding detection and reconnection for a seamless operation of μG with a high-quality power service.

2. SYSTEM DEVELOPMENT

2.1 Custom Power Devices (CPDs)

In 1995 the Custom Power concept was first introduced by N.G. Hingorani. [13]. Custom Power embraces a family of power electronic devices, or a toolbox, which is applicable to distribution systems to provide power quality solutions. This technology has been made possible due to the widespread availability of cost effective high power semiconductor devices such as gate turn-off thyristor (GTO) and insulated-gate bipolar transistor (IGBT), low cost microprocessors or microcontrollers and techniques developed in the area of power electronics.

DSTATCOM (Distribution 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 level [14]. The DVR is a series-connected custom power device to protect sensitive loads from supply side disturbances. It can also act as a series active power filter (APFse). In addition, if the DVR and STATCOM are connected on the DC side, the DC bus voltage can be regulated by the shunt connected DSTATCOM while the DVR supplies the required energy to the load in case of the transient disturbances in source voltage. The configuration of such a device (termed as Unified Power Quality Conditioner (UPQC).[15]

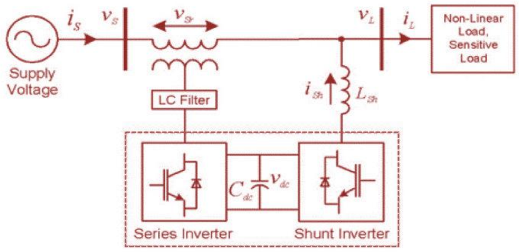


Fig. 2.1 The circuit diagram of the unified power quality conditioner.

Voltage distortions and fluctuations are frequently encountered in the weak grid network systems. The distorted load currents affect to cause non-sinusoidal voltage drops and as a result the network voltages become distorted. On the other hand, voltage sag and swell problems are usually caused by short-circuit current flowing into a fault. Voltage sag and swell are defined as a sudden reduction or rise of grid voltages from its nominal value. Unified Power Quality Conditioner (UPQC) is one of the most advanced custom power devices to solve such power quality problems. Custom power device UPQC is the integration of series and shunt active filters, connected back-to-back on the dc side and sharing a common DC capacitor [16] as shown in Fig 3.1.

The main components of the system are as follows:
a) Series converter is a VSC connected in series with the AC supply line. It acts as a line voltage source to compensate voltage disruptions. It is used for minimizing line voltage fluctuations from the load supply voltage and then feeds to shunt branch of the device to consume current harmonics produced by unbalance load.
b) Shunt converter is a VSC connected in parallel with the AC supply line. It acts as a current source for eliminating current disruptions and also eliminates the reactive current in the load circuit. Main advantage is it improves the power factor of load and acts as DC-link voltage regulator for the reduction of the DC capacitor rating.
c) Energy storage In this the DC capacitor bank is generally used. it is connected between Midpoint-to-ground is divided into two parts, which are arranged in series together. The neutral point's secondary transformer is connected to the DC link midpoint directly.
d) The Low-pass filter (LPF) Because of high-frequency switching mode high frequency components are produced at the output side of series converter to attenuate these LPF is used.
e) High-pass filter (HPF) In current switching mode ripples produced can be consumed by applying HPF at the output of shunt converter.
f) Series and shunt transformers are used to inject the compensating voltages and currents for electrically separation of UPQC converters.

2.2 Control objectives of UPQC

Control Objectives of shunt connected converter are as follows-
1. To balance the source currents by injecting negative and zero sequence components required by the load.
2. The compensate for the harmonics in the load current by injecting the required harmonic currents.
3. To control the power factor by injecting the required reactive current (at fundamental frequency)
4. To regulate the DC bus voltage.

Control Objectives of series connected converter are as follows-
1. To balance the voltages at the load bus by injecting negative and zero sequence voltages to compensate for those present in the source.
2. To isolate the load bus from harmonics present in the source voltages, by injecting the harmonic voltages
3. To regulate the magnitude of the load bus voltage by injecting the required active and reactive components (at fundamental frequency) depending on the power factor on the source side
4. To control the power factor at the input port of the UPQC (where the source is connected) power factor at the output port of the UPQC (connected to the load) is controlled by the shunt converter.[18].

2.3 UPQC topology and power flow strategy

A 3-phase UPQC consists of two 3-phase voltage source inverters connected in cascade .Inverter 1 (Series Inverter (SEI)) is connected in series with the incoming utility supply through a low pass filter and a voltage injecting transformer. Inverter 2 (Shunt Inverter (SHI)) is connected in parallel with the sensitive load, whose power quality needs to be strictly maintained. The main purpose of SHI is to provide required VAR support to the load, and suppress the load current harmonics from flowing towards the utility and it is operated in current controlled mode. SEI is responsible for compensating the deficiency in voltage quality of the incoming supply, such that the load end voltage remains insensitive to the variation of utility supply. The two models of UPQC have same power circuit configuration. But as the control strategies are different in SEI, the individual loading of SHI and SEI varies and the overall rating of the UPQC differs, which is the thrust of this paper and is explained in the subsequent sections. UPQC also have a few other important components that are essential for interfacing of the equipment.
• The SHI is connected through a boost inductor LSHI, which can boost up the common dc link voltage to the desired value through appropriate control. The size of the inductor L has to be chosen carefully, as increase in size would cause slower response to current control.
• The dc link capacitor C provides the common dc link voltage to both SEI and SHI. Ideally once charged, the dc link voltage should not fall off its charge, but due to finite switching losses of the inverters, inductor and capacitor, some active power is consumed and the charge of the dc link voltage needs to be maintained in a closed loop control, through the SHI. The choice of the reference dc link voltage depends upon the percentage of voltage sag to be mitigated and amount of VAR to be shared. The higher of the two values is to be chosen to comply with all needs. It is to be noted that as the C is charged continuously through SHI, it does not require additional source of voltage support. The online charging also helps UPQC in mitigating voltage unbalance or under-voltage situations for

longer durations, as it is not limited by the storage capacity of separate voltage source.

The integration technique of the proposed UPQCμG−IR to the grid connected and DG integrated μG system is shown in Fig. 2.2(a). breaker switches S2 and S3 are used to island and reconnect the μG system to the grid as directed by the secondary control of the UPQCμG−IR. The working principle during the interconnected and islanded mode for this configuration is shown in Fig. 2.2 (b) and (c). The operation of UPQC μG−IR can be divided into two modes which are as follows-

2.3.1. Interconnected Mode

In this case, as shown in Fig. 2.2(b)-

1) DG Source is delivers the active power to the Storage, grid side and also to the load.

2) Voltage sag/swell/Interruption can be compensated by the active power from the storage and grid through the APFse. The DG Converter having no senses of any voltage disturbances at the point of common coupling and hence remains it connected in any condition.

2) The APFsh compensates the reactive power and harmonic power of the nonlinear load to keep the Total Harmonic Distortion at the PCC within the IEEE standard limit;

4) If the voltage interruption/black out occurs, UPQC sends a signal within a preset time to the DG converter to be islanded condition. [2]

2.3.2 Islanded Mode

In this case, as shown in Fig. 2.2(c)

1) In this mode the APFse is disconnected during the grid failure and DG converters remains connected for maintaining the voltage at PCC.

2) APFse can Compensates the non active power of the nonlinear load to provide and maintain undistorted current at PCC for other linear loads.

3) Hence, DG converter delivers only the active power and hence does not need to be disconnected from the system;

4) APFse is reconnected once when the grid power is available.

From Fig. 2.2(a)–(c), it is clear that the UPQCμG−IR requires two switches compared with four, as required for UPQCμG. A detail of the switching mechanism is discussed in the section of controller design.

The fundamental frequency representation of the system is shown in Fig. 2.2(d).According to the working principle, the APFse is used for working during voltage interruption/sag/swell up to a certain level before it islanded. The APFsh always compensates QH power of the load. Therefore, design and rating selection for the APFse, APFsh, and series transformer.

(a)

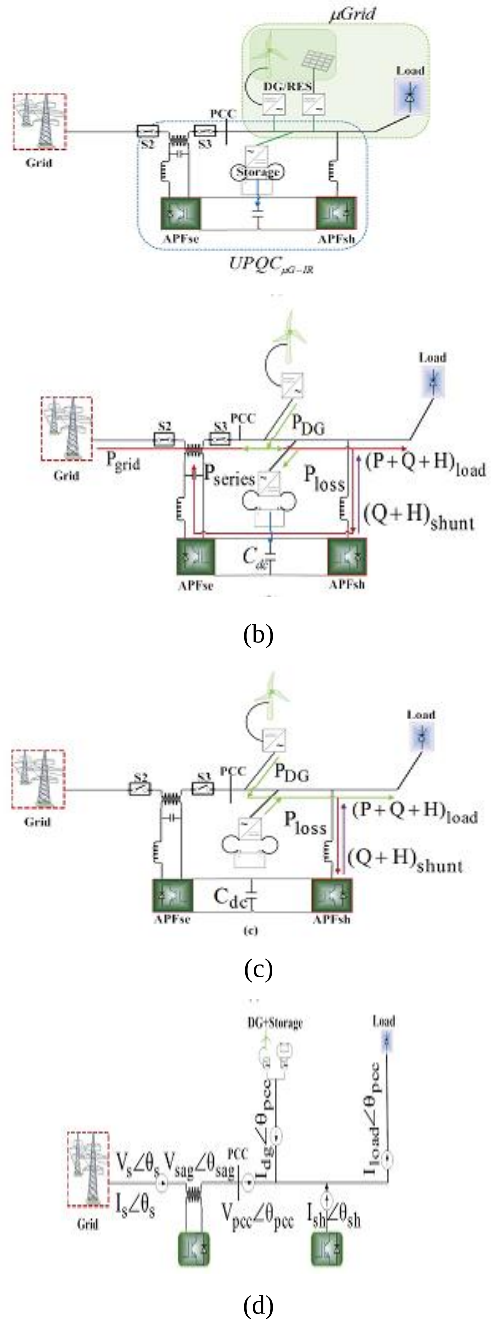
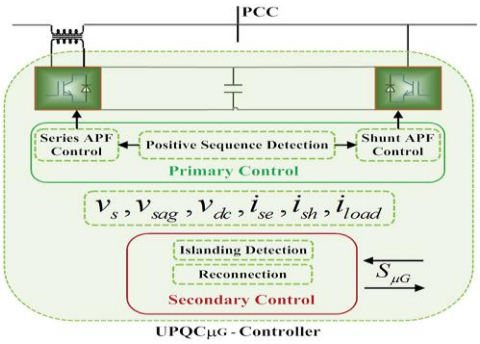


Fig.2.2 a) Integration technique of the UPQCμG−IR. Working principle in (b) interconnected mode, (c) islanded mode, and (d) fundamental frequency representation.

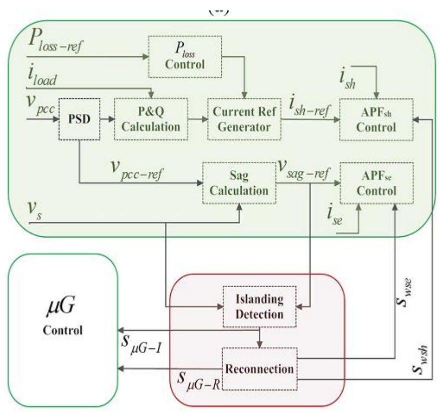
3. METHODOLOGY

3.1 Introduction

The block diagram of the proposed UPQCμG−IR controller is as shown in Fig. 3.1.Controller is same basic functionality as the UPQC controller only additional islanding detection and reconnection capabilities. A communication channel between the proposed UPQCμG−IR and the μG is also required for the smooth operation. These signals generation are based on the sag/swell/interrupt and supply failure conditions. This task is performed in Level 2 (secondary control) of the hierarchical control [13]. Level 1 deal with the primary control of the UPQC to perform their basic functions in the interconnected and the islanded mode [14]. The overall integration technique and control strategy are to improve the power quality during interconnected and islanded modes. In this involves detecting islanding and reconnection that ensures the DG converter remains connected and supply active power to the load. This reduces the control complexity of the converter as well as the power failure possibility in the islanded mode. [15]



(a)



(b)

Fig.3.1 Block diagram of the UPQCµG−IR. (a) Controller. (b) Control algorithm.

There are five main elements of the proposed UPQC µG−IR controller are: 1) positive sequence detection; 2) series part (APFse) control; 3) shunt part (APFsh) control; 4) intelligent islanding Detection (IsD) and 5) synchronation and and reconnection (SynRec). As the IsD and SynRec features are new in UPQC, therefore, these have been described in details.

3.1.1Intelligent Islanding Detection

Consider the future trends toward the smart-grid and µG operation in connection with the distribution grid, the capability of: 1) Automatically detecting the islanded condition; 2) To maintaining connection during grid fault condition; and 3) Reconnecting after the grid fault are the most important features of the µG system. In that case, the placement of APFse in the proposed integration method of the system plays an important role by extending the operational flexibility of the DG converter in the µG system. Also include the islanding detection, changing the control strategy from current to voltage control may result in serious voltage deviations and it becomes severe when the islanding.[13]

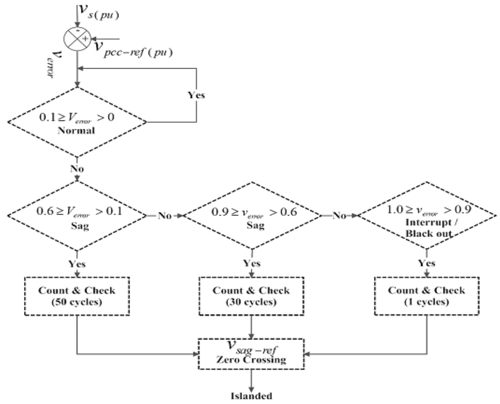


Fig.3.2. Algorithm for Is D method in UPQCµG−IR.

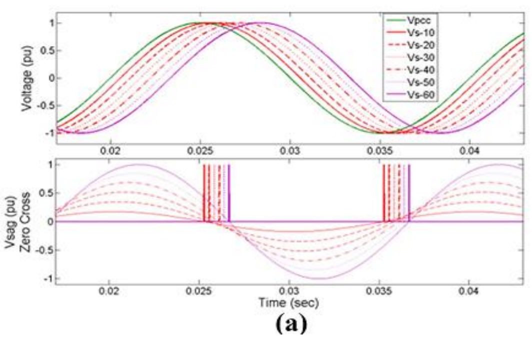
Detection is delayed in the case of hierarchical control [15]. Hence, seamless voltage transfer control between the grid connected mode and isolated controlled modes is very important[5] . Both direct and indirect current control techniques are proposed in [2] and [4] to mitigate the voltage transients in transition mode, but because of these increase the control complexity of the µG converters. In the case of power quality problems, it is reported that more than 95% of voltage sags can be compensated by injecting a voltage of up to 60% of the nominal voltage, with a maximum duration of 30 cycles. Therefore, based on the islanding detection requirement and sag/swell/interrupt compensation, islanding is detected and a signal SµG− I. [15]

As the APFse takes the responsibility for compensating voltage sag/swell/unbalance disturbances, IsD algorithm in the proposed UPQCµG−IR can be simply and flexible. On the other hand, it will also help to reduce the complexity of islanding detection technique or even can be removed from all the DG converters in a µG system. Fig. 3.2 shows a simple algorithm that has been used to detect the islanding condition to operate the UPQC in islanded mode. The voltage at PCC is taken as the reference and it is always in phase with the source and the DG converters, the difference between the V pcc-ref (pu) and Vs (pu) is Verror. This Verror is then compared with the preset values (0.1–0.9) and a waiting period (user defined n cycles) issued to determine the sag/interrupt/islanding condition. In this e.g: 1) if Verror is less than or equal to 0.6, then 60% sag will be compensated for up to 50 cycles; 2) if Verror is in between 0.6 and 0.9, then compensation will be for 30 cycles; and 3) otherwise (if Verror ≥ 0.9) it will be interrupt/black out for islanding after 1 cycle. This signal generation method is simple and can be adjusted for any time length and Verror condition. Thus, the intelligence can be achieved by introducing the operational flexibility of time and control of sag/interrupt compensation before islanding. the seamless voltage transfer from grid connected to isolated mode is one of the critical tasks in transition period, the transfer is completed at the zero-crossing position of the APFse. Hence, there is no voltage fluctuation or abrupt

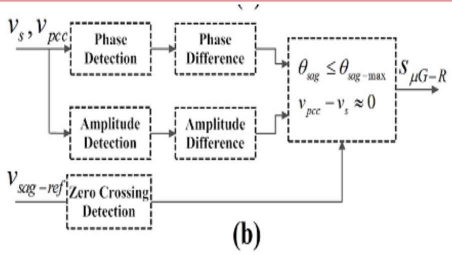
conditions occur. It is to be noted that, this is the first time the algorithm and islanding techniques are introduced in the control part of the UPQC, which are intelligent and flexible in operation. According to Fig. 3.1, the proper control and operation of the switches are very important for intelligent islanding and seamless reconnection. In that case, presents a topology that represents a step forward compared with the use of intelligent connection agents (ICA) as presented in [16], an additional module named ICA is connected to an existing Microgrid with a number of current sources. The ICA module acts as voltage source to fix the voltage and frequency in islanding mode and is able to guarantee seamless connection / disconnection of the µG from the main grid. The UPQCµG−IR presented in this is not only able to perform these seamless transitions, but also improve the power quality with some operational
flexibility. In addition, the UPQC having a series element (APFse) can perform the role of voltage source of the µG, and easily PCC voltage observation-based anti-islanding algorithm can be implemented. Notice that using conventional equipment, e.g., in grid connected PV systems, the non detection zone (NDZ) increases with the number of PV inverters, since they are not able to distinguish between the external grid or other PV inverters output voltage, thus may remain connected for a dangerously long time. [10].

3.1.2 Synchronization and Reconnection:

Here Once the grid system is restored, the µG may be reconnected to the main grid and to return its pre disturbance condition. The seamless reconnection also depends on the accuracy and performance of the synchronization methods [1]–[5].Smooth reconnection can be achieved when the difference between the voltage magnitude, phase, and frequency of the two buses are minimized or close to zero. In case of UPQC µG−IR, reconnection is performed by the APFse. In addition, due to the control of sag/swell by the APFse, this UPQCµG−IR has the advantage of reconnection even in case of phase jump/difference between the voltage of the utility and at the PCC. This obviously increases the operational flexibility of the µG system with high-power quality. The phase difference limit depends on the rating of the APF se and the level of V sag-max required for compensation. This limit can be calculated using (1) and (2).



(a)



(b)

Fig.3.3. (a) Position of Vs and Vpcc for different phase differences to measure the V sag and Vsag-ref. (b) SynRec θsag-max can be found as

$$\theta_{\text{sag-max}} = \cos\left[(\theta_s - \theta_{\text{pcc}})\right]^{-1} = 1/2 = 60°.$$

It additionally shows the zero-crossing point of the Vsag-ref depending upon the phase. This zero-crossing detection also indicates the point at which the instantaneous voltage difference between the utility and the PCC becomes zero. Detection of this zero-crossing point and activation of the switches S2 and S3, as shown in Fig. 2.1, at the same time are the key control of this reconnection method for a seamless transfer from the off-grid to the on-grid condition as well as changing the controller of the DG inverter from voltage to current control mode. Conditions for reconnection are set as: 1) assuming the phase difference between the utility grid and DG unit should be within θ sag-max; 2) instantaneous value of the two bus voltages becomes equal; and 3) these should occur at the zero-crossing condition. Once the utility supply is available after a blackout, a synchronization pulse (generated in reconnection process) is enabled to start synchronization. A simple logic sequence is then created, to generate the active pulse for S2 and S3 to return the system in the interconnected mode. At the same time SµG− R, as shown in Fig. 4(b) is also transferred to the µG system for reconnection. The other advantage is that, IsD and SynRec methods have been carried out as a secondary control in Level 2, i.e., these can also be added in conventional UPQC system as an additional block to convert it to UPQCµG−IR. It is to be noted that the proposed UPQCµG−IR will be helpful to meet the required advanced grid integration features as mentioned in [12]

4. PERFORMANCE ANALYSIS

3-phase, 3-wire active distribution network (230VL-N) with the proposed UPQCµG and µG, as shown in Fig 2.3, has been developed in the MATL AB environment. The system specifications are as follow; UPQCµG (capability: 100% sag and 100Amax harmonic current compensation) and the µG (Load: 200Amax with harmonic 100Amax; DG: 0.5 to 1.5 times of load fundamentals). Details of the performance with the simulation results are given below. All the simulations have been performed for up to 2 sec. Table 4.1 shows the timeline for the respective operating conditions. Based on the integration method and signal generation for islanding detection and the reconnection method, Graph 4.1 shows the switch positions (0 for open and 1 for close) during the operation from 0 to 2 sec where both the interconnected and islanded modes are observed. The performance of the proposed UPQCµG for voltage sag compensation is shown in Graph 4.2 and harmonic current compensation is shown in Graph 4.3

based on the Table 4.1. Performance during the reverse current flow due to the high penetration of DG is also shown in waveform 5.3. Details of the performance at different conditions are discussed below. Generally waveforms are shown for phase A only.

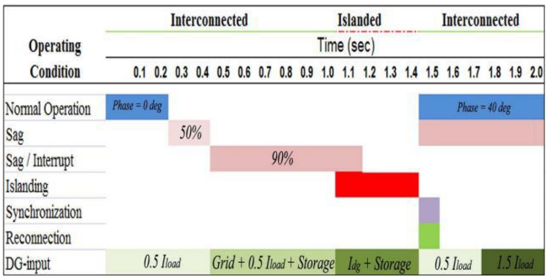


Table 4.1 Timeline of the Operating condition.

4.1 Interconnected Mode

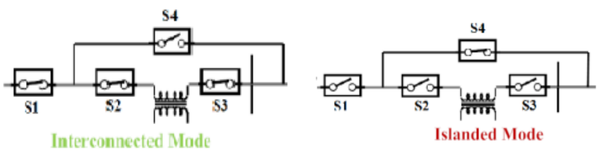
As per the power availability, the DG source supply power to the load and grid side, and therefore occurs by-directional power flow. Hence, the performance of the proposed UPQC should be observed in both cases. For a better understanding, according to the direction of power flow, operation in the interconnected mode can be divided into following two parts: (1) forward-flow mode and (2) reverse-flow mode.

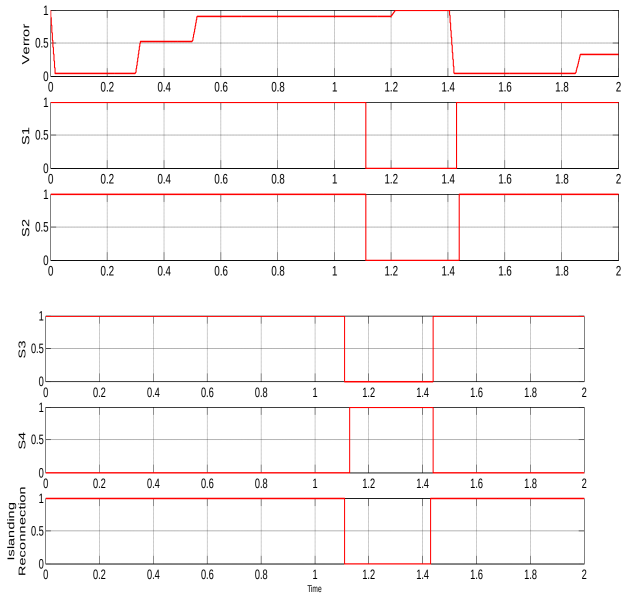
i) Forward-flow mode

In this case of Forward flow mode, Availability of required load demand is greater than the available DG power. Hence, the utility supplies rest of the power to the load which is not met by the DG supply. Performance of the APFsh in compensating the reactive and harmonic current generated by the load. As is mentioned in the timeline table, the DG unit supplies 0.5 (half of load fundamental in current control mode) during this time frame. Therefore the remainder of the current is supplied by the utility grid and storage. During a 90% sag condition, the total power for the load demand and is still met by the µG system (as shown in Graph 4.3) and the utility where the storage system provides the power for sag compensation through the DC link. [16]

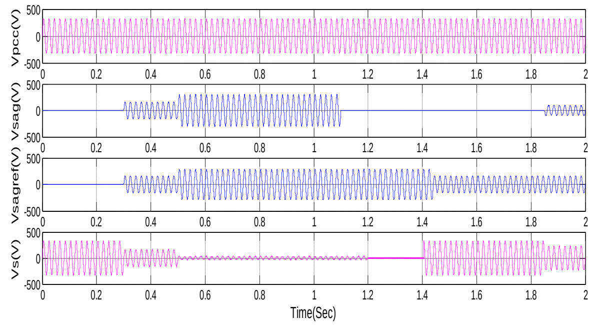
ii) Reverse-flow mode

When the available DG power becomes higher than the required load demand, then in that case the extra energy is transferred to the grid and storage and this is the reverse-flow mode. At this stage, the grid current becomes out of phase with the voltage at PCC. Graph 4.4 shows the performance of the system. When DG current becomes 1.5 at 1.75 sec and 30% sag is also applied at 1.85 sec. [15, 16]

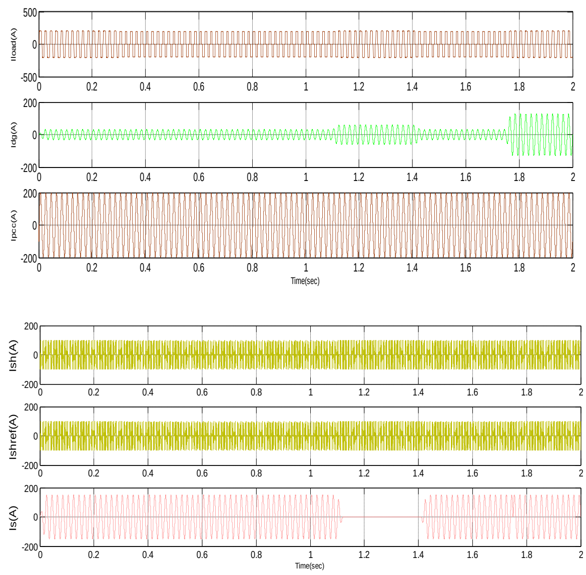




Graph.4.1 Switching positions during the operation



Graph 4.2 Voltage and at different conditions and positions in the network



Graph.4.3 current waveforms at different conditions and positions in the network

4.2 Islanded Mode

According to the Sig-IsD method, the APFse compensates the sag for up to 0.6 sec (30 cycles) and then the system goes into islanded mode. A utility disconnection is applied at 1.11 sec just after completing the 30 cycle count and then detecting the zero crossing of where the switches S1, S2 and S3 are opened. At the time of disconnection, the μG operates in islanded mode. At this stage, if the available DG power is lower than the load demand, the required power is supplied by the storage. If the DG power is higher than the load, then the additional power goes to the storage. The APFsh still performs the compensation of non active power. Hence, DG converter does not need to be disconnected or change the control strategy (supply only the fundamental active power) to supply power to the load

Graph 4.4 shows the performance of the proposed UPQCμG during 1.0 to 1.2 sec where the islanding is detected just immediately after 1.1 sec at zero crossing detection. The islanding mode is observed between 1.11 and 1.405 sec. During this period the APFse is disconnected, as shown in Graph 4.4 (b) where Vsag = 0, utility current become zero, as shown in Graph 4.4 (c). The APFsh continues to operate, as shown in Graph 4.4 (c), and the load demand is met by the DG with the storage unit. €[16]

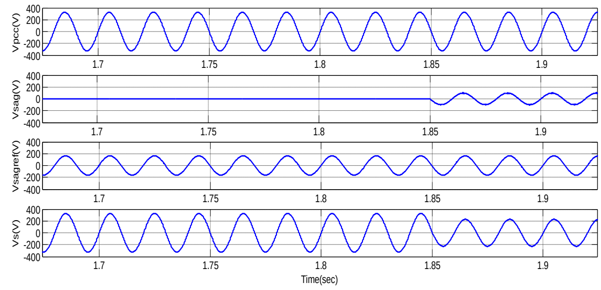
4.3 Reconnection

To check the performance of the reconnection process for the worst condition, the utility grid is powered on at 1.405 sec where the magnitude is at a maximum. The DG unit sends a reconnection signal, to the UPQCμG unit. The actual switch S1 is activated at 1.43 sec and it starts operation shown in Graph. Switches S2 and S3 are activated after the synchronization by the DG unit. S4 is disconnected simultaneously at 1.44 sec. Zero crossing detection is also shown. Algorithm for combined logic gate ensures the utility connects with the μG smoothly after the utility system is restored.

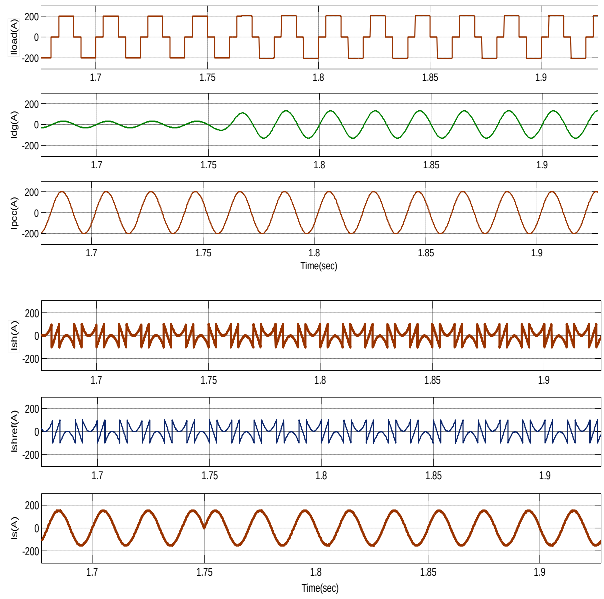
APFse unit is immediately reactivated when the grid voltage is available at 1.405 sec but it starts operation when the switches S2 and S3 are closed at 1.43 sec. It is expected that, according to the smooth reclosing condition, no power flow will occur at the point of reclosing. The switching operation is complete within the limiting condition. Here DG converter changes its control from voltage to current control mode but only transfers the active fundamental current. The performance of the APFsh is also uninterrupted during the transition period. [16]

4.4Power Flow

Power flow diagram is shown in Graph 4.5, for the complete simulation time where the green line represents the active power (P) and pink line (dash) for reactive and harmonic power (QH). In this performance of the APFse and APFsh part of the proposed UPQCμG along with the islanding detection and reconnection. [16]

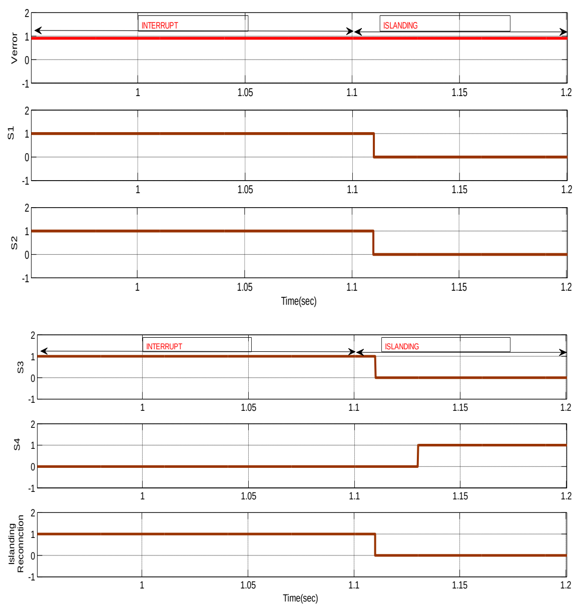


(a)



(b)

Graph 4.4 Performance; a) APFse; b) APFsh; interconnected and reverse flow



(a)

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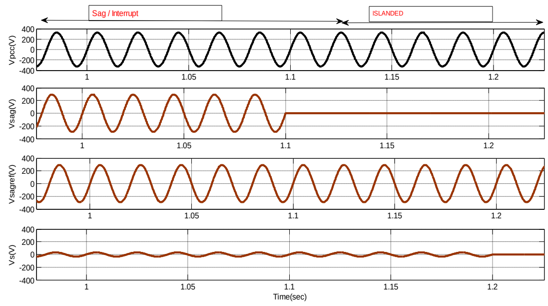
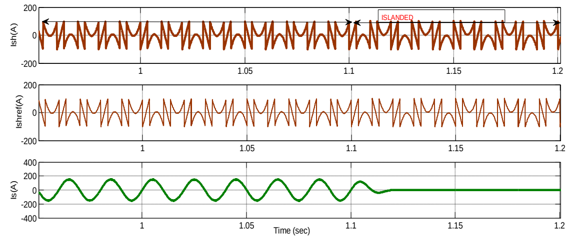
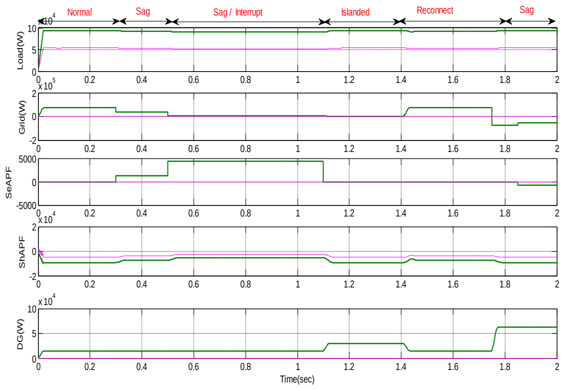


(b)



(c)

Graph 4.5 Performance -(a) switching, b) APFse, c) APFsh h during islanded mode.



Graph 4.6 Power flow during the simulation time

5. CONCLUSION

5.1 **Conclusion**

Based on the study and analysis for the placement of UPQC in DG connected µGrid/µGen network, it can be concluded that the network arrangement of PCC-UPQC-DG-Load can be a better choice for the overall performance of a UPQC and DG connected grid network. In terms of sensor placement, control and performance study. While designing a system, µGrid designer needs to maintain the condition that the measured current THD at PCC will be higher than the IEEE / EU limit while DG in connected to the network and provides 0.5 to 1.5 times of the load fundamental current. Finally, in a DG connected µGrid/µGen system, strategic positioning of UPQC can provide some control flexibility for DG inverters for islanding detection and reconnection.

As a part of design and capacity enhancement, detailed switching dynamics with a parameter selection procedure of shunt APF units has been studied. Power flow between the shunt APF unit and the PCC has been derived and an equation for reactive and harmonic current compensation capacity has been acquired. Active power loss associated with the design parameters has also been analyzed as a rating requirement of the shunt APF unit.. Implementation of the proposed integration and capacity enhancement methods, and the modification in design with an advanced and real time control strategy have been developed. The performance of the proposed UPQC (UPQCµG and D-UPQC) in an active DG integrated microgird network has been studied.

5.2 Future Scope

There are several important points which need to be investigated but could not be included in the scope of this research work. The following issues have been identified as possible topics of work in future in this area:

1. The proposed integration technique of UPQCµG along with the control of islanding detection and reconnection techniques can be tested with real controllable hardware switches as a validation of their effectiveness in the next step.
2. A control method should be developed to reduce the circulating current flow in DUPQC system based on hysteresis current control.
3. A droop control method can be developed for reactive and harmonic current compensation for implementation in a D-UPQC system. The independent operation of a droop control based APFsh can further increase the operational flexibility of the proposed D-UPQC.
4. The proposed D-UPQC can be integrated as D-UPQCµG to check the performance of the system in DG integrated microgrid system.

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