

A FUZZY BASED TECHNIQUE FOR MICRO GRID WITH UPQC FOR SEAMLESS RECONNECTION AND INTELLIGENT ISLANDING

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ABSTRACT— This paper clarifies new proposition for the position, integration, and control of unified power quality conditioner (UPQC) in distributed generation (DG)- based grid associated/self-sufficient micro grid/micro generation (μ G) system has been exhibited here alongside fuzzy logic controller. Here we utilizing fuzzy logic controller as opposed to utilizing different controllers. The DG converters (with storage) and the shunt some portion of the UPQC Active Power Filter (APFsh) is set at the Point of Common Coupling (PCC). The upsides of the proposed UPQC μ G-IR over the typical UPQC are to repay voltage interruption notwithstanding voltage sag/swell, harmonic and reactive power compensation in the interconnected mode. The series part of the UPQC (APFse) is associated before the PCC and in series with the grid. The dc link can likewise be coordinated with the storage system. An insightful islanding discovery and reconnection system (IR) are presented in the UPQC as a secondary control. Thus, it is named as UPQC μ G-IR. Amid the interconnected and islanded mode, DG converter with storage will supply the active power just and the shunt some portion of the UPQC will remunerate the reactive and harmonic power of the load. It likewise offers the DG converter to remain associated amid the voltage unsettling influence including phase hop. The simulation was done by utilizing MATLAB/Simulink programming.

Index Terms— Distributed generation (DG), intelligent islanding detection (IsD), micro-grid, power quality, smart grid, unified power quality compensator (UPQC), fuzzy logic controller.

I. INTRODUCTION

The issues of an effective integration of unified power quality conditioner (UPQC) in a distributed generation (DG)- based grid associated micro-generation (μ G) system are basically: 1) control many-sided quality for active power exchange; 2) capacity to remunerate non-active power amid the islanded mode; and 3) trouble in the limit upgrade separately [1]. For a consistent power exchange between the grid-associated operation and islanded mode, different operational changes are included, for example, switching between the

current and voltage control mode, robustness against the islanding location and reconnection deferrals, et cetera [2]. Obviously, these further increment the control many-sided quality of the μ G systems. To stretch out the operational adaptability and to enhance the power quality in grid associated μ G systems, another arrangement and integration method of UPQC have been proposed in [4], which is named as UPQC μ G. In the UPQC μ G coordinated distributed system, μ G system (with storage) and shunt some portion of the UPQC are put at the Point of Common Coupling (PCC). The series part of the UPQC is set before the PCC and in series with the grid. The dc link is likewise associated with the storage, if show. To maintain the operation in islanded mode and reconnection through the UPQC, correspondence process between the UPQC μ G and μ G system is said in [4].

In this paper, the control strategy of the displayed UPQC μ G in [4] is upgraded by executing a shrewd islanding and novel reconnection method with lessened number of switches that will guarantee consistent operation of the μ G without interruption. Subsequently, it is named as UPQC μ G-IR. The advantages offered by the proposed UPQC μ G-IR over the conventional UPQC are as per the following.

1) It can remunerate voltage interruption/sag/swell and non-active current in the interconnected mode. Consequently, the DG converter can in any case be associated with the system amid these twisted conditions. Subsequently, it improves the operational adaptability of the DG converters/ μ G system, all things considered, which is additionally explained in later area.

2) Shunt some portion of the UPQC Active Power Filter (APFsh) can maintain association amid the islanded mode and furthermore remunerates the non-active Reactive and Harmonic Power (QH) power of the load.

3) Both in the interconnected and islanded modes, the μ G gives just the active power to the load. Hence, it can decrease the control unpredictability of the DG converters.

4) Islanding discovery and reconnection strategy are presented in the proposed UPQC as a secondary control. A correspondence between the UPQC and μG is additionally given in the secondary control. The DG converters may not require having islanding identification and reconnection includes in their control system.

5) The system can even work within the sight of a phase hop/contrast (inside farthest point) between the grid and μG .

6) Thus, the UPQC μG -IR will have the total control of the islanding discovery and reconnection for a consistent operation of μG with a brilliant power benefit.

This paper has been sorted out as takes after. The working principle of the proposed system is portrayed in Section II. Based on the working principle, a portion of the plan issues and rating determination have been talked about in Section III. Area IV manages the islanding identification and reconnection methods in detail. Area V demonstrates the ongoing execution contemplate for the proposed control and integration method that has been confirmed utilizing constant test system in equipment synchronization mode.

II. WORKING PRINCIPLE

The integration method of the proposed UPQC μG -IR to a grid associated and DG incorporated μG system is appeared in Fig. 1. S2 and S3 are the breaker switches that are utilized to island and reconnect the μG system to the grid as coordinated by the secondary control of the UPQC μG -IR. The working principle amid interconnected and islanded mode for this configuration is appeared in Fig. 2 and 3. The operation of UPQC μG -IR can be isolated into two modes.

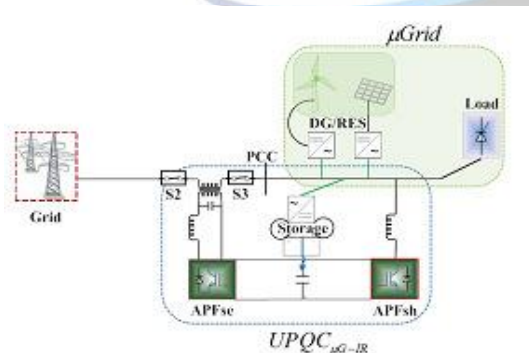


Fig. 1. Integration technique of the UPQC μG -IR

A. Interconnected Mode

In this mode, as appeared in Fig. 2, the accompanying holds:

1) The DG source conveys just the fundamental active power to the grid, storage, and load;

2) The APFsh repays the reactive and harmonic (QH) power of the nonlinear load to keep the Total Harmonic Distortion at the PCC inside the IEEE standard point of confinement;

3) Voltage sag/swell/interruption can be repaid by the active power from the grid/storage through the APFse,t. The DG converter does not detect any sort of voltage aggravation at the PCC and subsequently remains associated in any condition;

4) If the voltage interruption/pass out happens, UPQC sends a signal inside a preset time to the DG converter to be islanded.

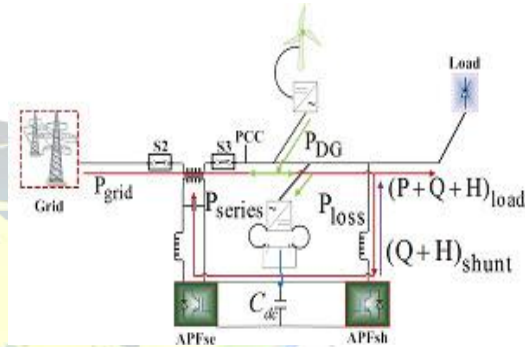


Fig. 2. Interconnected mode

B. Islanded Mode

For this situation, as appeared in Fig.3, the accompanying holds:

1) The APFse is detached amid the grid failure and DG converter remains associated with maintain the voltage at PCC;

2) The APFsh still remunerates the nonactive power of the nonlinear load to give or maintain undistorted current at PCC for other linear loads (assuming any);

3) Therefore, DG converter (with storage) conveys just the active power and consequently does not should be separated from the system;

4) The APFse is reconnected once the grid power is accessible.

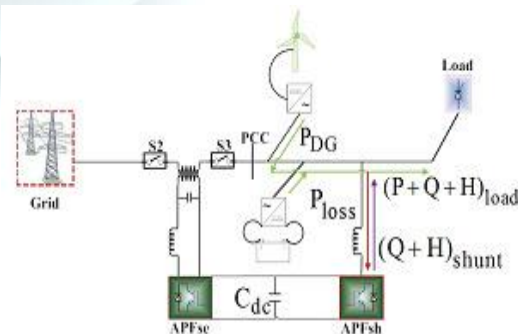


Fig. 3. Islanded mode

From Fig. 1-3, unmistakably the UPQC μG -IR requires two switches contrasted and four, as required for UPQC μG in [4]. A detail of the switching system is examined in the controller configuration segment.

III. DESIGN ISSUES AND RATING SELECTION

The essential recurrence portrayal of the framework is appeared in Fig. 4 and the voltage and current relations are inferred in (1) and (2). As indicated by the working guideline, the APFse can work amid voltage intrusion/list/swell up to a specific level before it is isolated. The APFsh dependably repays QH energy of the load.

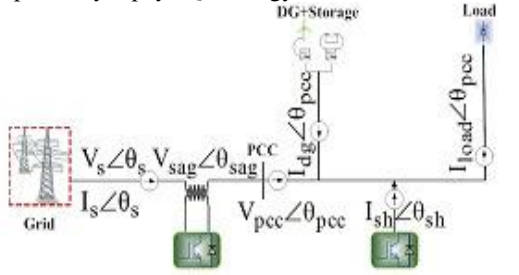


Fig. 4. Fundamental frequency representation.

Therefore, design and rating selection for the APFse, APFsh, and series transformer together with the sizing of dc link capacitor are very important. These are discussed in the following section:

$$V_{PCC} < \theta_{PCC} = V_s < \theta_s + V_{sag} < \theta_{sag} \quad (1)$$

$$I_{load} < \theta_{load} = I_s < \theta_s + I_{dg} < \theta_{pcc} + I_{sh} < \theta_{sh} \quad (2)$$

Under any condition assume that $V_{pcc} = V_{dg} = V_{load}$ and $\theta_{pcc} = 0^\circ$. The phasor diagrams of the proposed system in different conditions are shown in Fig. 5.

A. Shunt Part of UPQC_μG-IR (APFsh)

It is appeared in Fig. 5 that for any condition, APFsh remunerates the non-principal current of the heap by infusing I_{sh} in quadrature to V_{pcc} . At the point when voltages hang shows up in the supply side, APFse repays the list by infusing the expected voltage to keep up the consistent voltage and zero-stage at PCC.

To finish the undertaking, APFsh draws extra current from the source, to supply energy to the APFse. The expanded source current I_s still stays in stage to the V_{pcc} . Be that as it may, this progressions the extent and stage edge of the remunerating current, I_{sh} as an extra dynamic segment of current (x) is added to the shunt compensator current now, as appeared in Fig. 5(e).

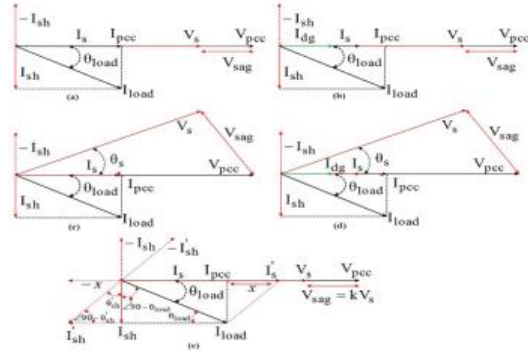


Fig.5. Phasor diagram of UPQC_μG-IR when (a) no DG and $\theta_s = \theta_{pcc}$, (b) with DG and $\theta_s = \theta_{pcc}$, (c) no DG and $\theta_s = \theta_{pcc}$, (d) with DG and $\theta_s = \theta_{pcc}$, and (e) in-phase voltage compensation mode.

In this case

$$I_s^- = I_{PCC} + I_{sh} \sin(\theta_{sh}^-) \quad (3)$$

$$I_{sh}' = \frac{I_{sh}}{\cos(\theta_{sh}')} \quad (4)$$

This ultimately increases the current at PCC and thus creates a VA loading impact on the APFsh.

B. Series Part of UPQC_μG-IR (APFse)

The APFse always appears in series with the grid. In the proposed integration technique when no energy is available from the DG unit and shunt the APF compensates the reactive and harmonic part of the load current, the active fundamental part of the load current (I_{loadfp}) flows through the APFse. Therefore, the APFse must have at least the same current rating as the active load fundamental requirement

$$I_{APFse,min} = I_{loadfp} \quad (5)$$

From Fig. 5(c) and (d), the general equation for voltage sag compensation by the APFse can be written as

$$V_{sag} = \sqrt{V_s^2 + V_{pcc}^2 - 2V_sV_{pcc} \cos(\theta_s - \theta_{pcc})} \quad (6)$$

The voltage rating of the APFse should be equal to the highest value of the injected sag voltage, thus

$$V_{APF, rated} = V_{sag, max} = kV_{load, rater} \quad (7)$$

Assume k is the fraction of V_s that appears as voltage sag. Therefore, the VA rating of the APFse, can be calculated as

$$S_{APFse, rated} = I_{APFse, rated} V_{APFse, rated} = kP_{loadf, rated} \quad (8)$$

From Fig. 5, the active power transfer through the APFse can be calculated for the case when $I_{dg} = 0$

$$P_{APFse} = P_{loadf} \left[\frac{kV_s}{V_{load}} \cos(\theta_s - \theta_{pcc}) \right] \quad (9)$$

Under stable and in-phase operating conditions, assume that $\theta_s = \theta_{pcc} = 0$.

$$P_{APFs} = \frac{kP_{loadf}V_s}{V_{load}} \quad (10)$$

Therefore, during voltage sag compensation, the source current that is transferred through the series transformer of the APFse, as shown in Fig. 5(e), can be calculated as

$$I'_s = \frac{P_{loadf}}{(1-k)V_s} = \frac{1}{(1-k)} I_{loadfp} \quad (11)$$

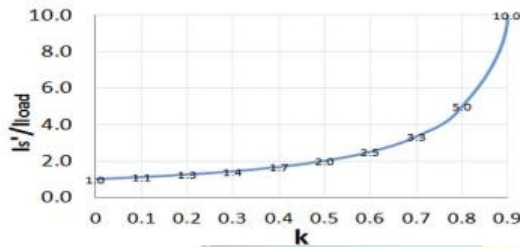


Fig. 6. Relation between source current, load current, and k for voltage sag compensation.

Therefore, the size and VA rating of the series transformer relies upon the measure of sag to be adjusted. Fig. 6 demonstrates how the source current increments with the estimation of k. Based on (6)–(11), and for a given estimation of k, there can be of various answers for V_{sag} , I_s , and P_{APFse} . Control procedures are based on the minimization of the energy trade amid compensation or by lessening the voltage rating. [3] discussed about Improved Particle Swarm Optimization. The fuzzy filter based on particle swarm optimization is used to remove the high density image impulse noise, which occur during the transmission, data acquisition and processing. The proposed system has a fuzzy filter which has the parallel fuzzy inference mechanism, fuzzy mean process, and a fuzzy composition process. In particular, by using no-reference Q metric, the particle swarm optimization learning is sufficient to optimize the parameter necessitated by the particle swarm optimization based fuzzy filter, therefore the proposed fuzzy filter can cope with particle situation where the assumption of existence of “ground-truth” reference does not hold. The merging of the particle swarm optimization with the fuzzy filter helps to build an auto tuning mechanism for the fuzzy filter without any prior knowledge regarding the noise and the true image. Thus the reference measures are not need for removing the noise and in restoring the image. The final output image (Restored image) confirm that the fuzzy filter based on particle swarm optimization attain the excellent quality of restored images in term of peak

signal-to-noise ratio, mean absolute error and mean square error even when the noise rate is above 0.5 and without having any reference measures.

The voltage rating of the APFse is a vital plan parameter, as it decides some different qualities, for example, the repaying range, the need to incorporate (and size of) energy storage devices, and the general size of the series transformer. What's more, losses tend to increment if the voltage rating of the APFse is expanded. Accordingly, the voltage infusion ability ought to be picked as low as important to lessen gear cost and standby losses.

C. DC Link Capacitor

As indicated by the working principle, the APFse ought to have the capacity to work amid a high-sag/swell condition and even on account of interruption (contingent upon the interruption time) before it goes to the islanded mode. At this stage, the dc link capacitor ought to be capable: 1) to maintain the dc voltage with negligible swell in the steady state; 2) to fill in as an energy storage component to supply the non-active power of the load as a compensation; and 3) to supply the active power contrast between the load and source amid the sag/swell or interruption period. For a particular system, it is smarter to consider the higher estimation of C_{dc} with the goal that it can deal with the majority of the above conditions. It additionally improves transient reaction and lowers the steady-state swells.

According to the calculation in [12], for the proposed system, the required capacitor size will be

$$C_{dc} = \frac{2S_{load} \cdot n \cdot T}{4 \cdot c \cdot V_{dc}^2} \quad (12)$$

Where S_{load} is the total VA rating of the load, n is the number of cycles to perform the task, T is the time period, and c is the percentage of V_{dc} .

IV. CONTROLLER DESIGN

The block diagram of the proposed UPQCμG-IR controller is appeared in Fig. 7. It has an indistinguishable essential functionality from the UPQC controller with the exception of the extra islanding recognition and reconnection capabilities. A correspondence channel (signals exchange) between the proposed UPQCμG-IR and the μG is likewise required for the smooth operation. These signals generation are based on the sag/swell/interrupt/supply failure conditions. This assignment is performed in Level 2 (secondary control) of the various leveled control [13]. Level 1 manages the primary control of the UPQC to play out their fundamental functions in the interconnected and the islanded mode [14].

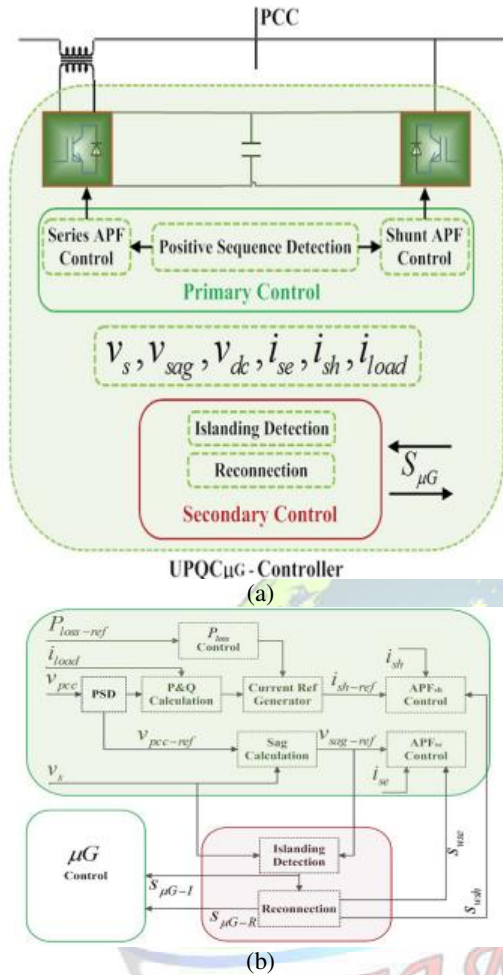


Fig. 7. Block diagram of the UPQCμG-IR. (a) Controller. (b) Control algorithm

The general integration method and control procedure are to enhance the power quality amid interconnected and islanded modes. This includes identifying islanding and reconnection that guarantees the DG converter remains associated and supply active power to the load. This decreases the control multifaceted nature of the converter and in addition the power failure probability in the islanded mode. The five main components of the proposed UPQCμG-IR controller are: 1) positive sequence discovery; 2) series part (APFse) control; 3) shunt part (APFsh) control; 4) smart islanding location (IsD); and 5) synchronization and reconnection (SynRec). As the IsD and SynRec highlights are new in UPQC, thusly, these have been depicted in points of interest.

A. Intelligent Islanding Detection

Considering the future patterns toward the smart-grid and μG operation, regarding the distribution grid and the capacity of: 1) maintaining

association amid grid fault condition; 2) consequently identifying the islanded condition; and 3) reconnecting after the grid fault are the most vital highlights of the μG system. All things considered, the arrangement of APFse in the proposed integration technique for the system assumes a vital part by expanding the operational adaptability of the DG converter in the μG system.

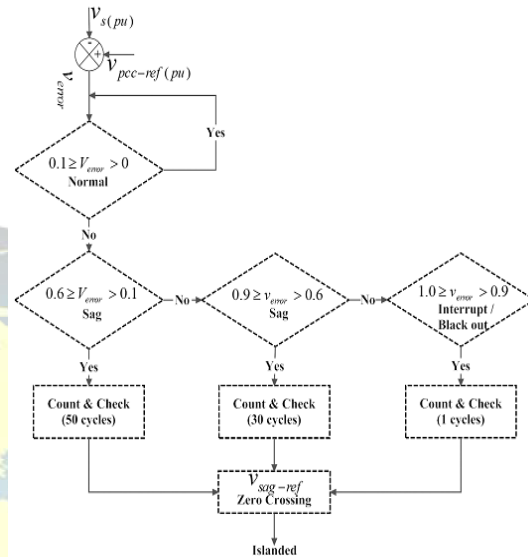


Fig. 8. Algorithm for IsD method in UPQCμG-IR

Fig. 8 demonstrates a basic calculation (with illustration) that has been utilized to identify the islanding condition to work the UPQC in islanded mode. The voltage at PCC is taken as the reference and it is dependably in phase with the source and the DG converters, the contrast between the $V_{pcc-ref}$ (pu) and V_s (pu) is V_{error} . This error is then contrasted and the preset esteems (0.1– 0.9) and a holding up period (client characterized n cycles) is utilized to decide sag/interrupt/islanding condition. In this case: 1) if V_{error} is not exactly or equivalent to 0.6, at that point 60% sag will be made up for up to 50 cycles; 2) if V_{error} is in the middle of 0.6 and 0.9, at that point compensation will be for 30 cycles; and 3) generally (if $V_{error} \geq 0.9$) it will be interrupt/pass out for islanding after 1 cycle.

B. Synchronization and Reconnection

Once the grid system is reestablished, the μG might be reconnected to the main grid and come back to its pre-unsettling influence condition. A smooth reconnection can be accomplished when the distinction between the voltage extent, phase, and frequency of the two busses are limited or near zero. The consistent reconnection likewise relies upon the exactness and execution of the synchronization strategies [21] – [25].

In the event of UPQC_μG-IR, reconnection is performed by the APFse. Also, because of the control of sag/swell by the APFse, this UPQC_μG-IR has the upside of reconnection even if there should be an occurrence of phase bounce/distinction (up to a specific point of confinement) between the voltage of the utility and at the PCC. This clearly expands the operational adaptability of the μ G system with high-power quality. The phase distinction constrain relies upon the rating of the APFse and the level of Vsag-max required for compensation. This farthest point can be figured utilizing (1) and Fig. 2. It is additionally talked about in [26]. Accepting that the conceivable Vsag-max = Vs = Vpcc, the $\theta_{sag-max}$ can be found as

$$\theta_{sag-max} = \cos[(\theta_s - \theta_{pcc})]^{-1} = \frac{1}{2} = 60^\circ \quad (13)$$

The connection for the phase distinction and size between Vs, Vpcc, and Vsag are likewise appeared in Fig. 9(a). It likewise demonstrates the zero-intersection point of the Vsag-ref relying on the phase. This zero-intersection identification additionally shows the point at which the instantaneous voltage distinction between the utility and the PCC winds up noticeably zero. Identification of this zero-intersection point and actuation of the switches S2 and S3, as appeared in Fig. 1, in the meantime are the key control of this reconnection technique for a consistent exchange from the off-grid to the on-grid condition and also changing the controller of the DG inverter from voltage to current control mode.

The reconnection method is shown in Fig. 9(b). Conditions for reconnection are set as: 1) assuming the phase difference between the utility grid and DG unit should be within $\theta_{sag-max}$; 2) instantaneous value of the two bus voltages becomes equal; and 3) these should occur at the zero-crossing condition.

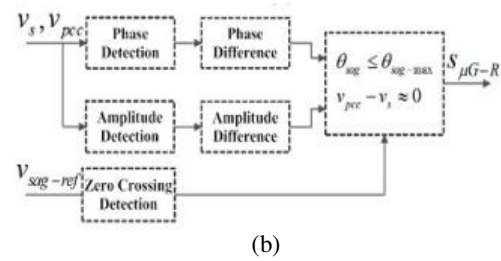
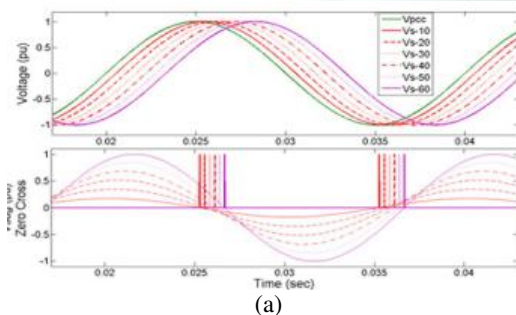


Fig. 9. (a) Position of Vs and Vpcc for different phase differences to measure the Vsag and Vsag-ref. (b) SynRec.

V. FUZZY LOGIC CONTROLLER

In FLC, basic control action is determined by a set of linguistic rules. These rules are determined by the system. Since the numerical variables are converted into linguistic variables, mathematical modeling of the system is not required in FC.

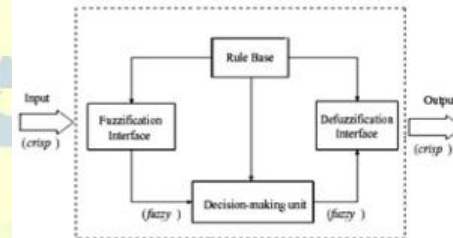


Fig.10. Fuzzy logic controller

The FLC comprises of three parts: fuzzification, interference engine and defuzzification. The FC is characterized as i. seven fuzzy sets for each input and output. ii. Triangular membership functions for simplicity. iii. Fuzzification using continuous universe of discourse. iv. Implication using Mamdani's, 'min' operator. v. Defuzzification using the height method.

Fuzzification: Membership function values are assigned to the linguistic variables, using seven fuzzy subsets: NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium), and PB (Positive Big). The partition of fuzzy subsets and the shape of membership CE(k) E(k) function adapt the shape up to appropriate system. The value of input error and change in error are normalized by an input scaling factor.

TABLE III: FUZZY RULES

Change in error	Error						
	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PB	PM	PM	PS	Z
NM	PB	PB	PM	PM	PS	Z	Z
NS	PB	PM	PS	PS	Z	NM	NB
Z	PB	PM	PS	Z	NS	NM	NB

PS	PM	PS	Z	NS	NM	NB	NB
PM	PS	Z	NS	NM	NM	NB	NB
PB	Z	NS	NM	NM	NB	NB	NB

In this system the input scaling factor has been designed such that input values are between -1 and +1. The triangular shape of the membership function of this arrangement presumes that for any particular $E(k)$ input there is only one dominant fuzzy subset. The input error for the FLC is given as

$$E(k) = \frac{P_{ph(k)} - P_{ph(k-1)}}{V_{ph(k)} - V_{ph(k-1)}} \quad (9)$$

$$CE(k) = E(k) - E(k-1) \quad (10)$$

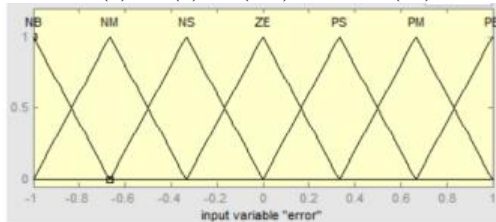


Fig. 11. Membership functions

Inference Method: Several composition methods such as Max-Min and Max-Dot have been proposed in the literature. In this paper Min method is used. The output membership function of each rule is given by the minimum operator and maximum operator. Table 1 shows rule base of the FLC.

Defuzzification: As a plant usually requires a non-fuzzy value of control, a defuzzification stage is needed. To compute the output of the FLC, „height“ method is used and the FLC output modifies the control output. Further, the output of FLC controls the switch in the inverter. In UPQC, the active power, reactive power, terminal voltage of the line and capacitor voltage are required to be maintained. In order to control these parameters, they are sensed and compared with the reference values. To achieve this, the membership functions of FC are: error, change in error and output.

The set of FC rules are derived from

$$u = -[\alpha E + (1-\alpha)C] \quad (11)$$

Where α is self-adjustable factor which can regulate the whole operation. E is the error of the system, C is the change in error and u is the control variable. A large value of error E indicates that given system is not in the balanced state. If the system is unbalanced, the controller should enlarge its control variables to balance the system as early as possible. Set of FC rules is made using Fig. (9) is given in Table 3.

V. SIMULATION RESULTS

A 3-phase, 3-wire active distribution network (230 VL-N) with the proposed UPQC μ G-IR and μ G, as shown in Fig.1, has been developed

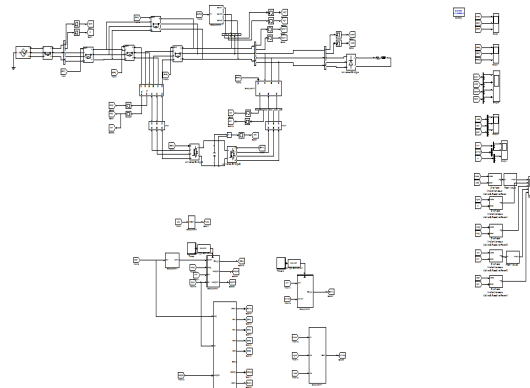


Fig.12. Matlab model for proposed method

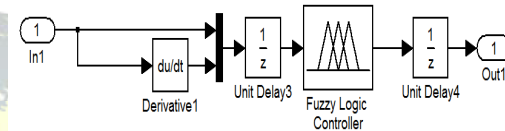


Fig.13. Fuzzy logic controller

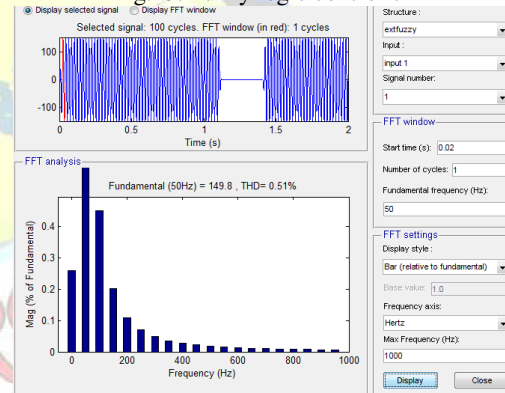
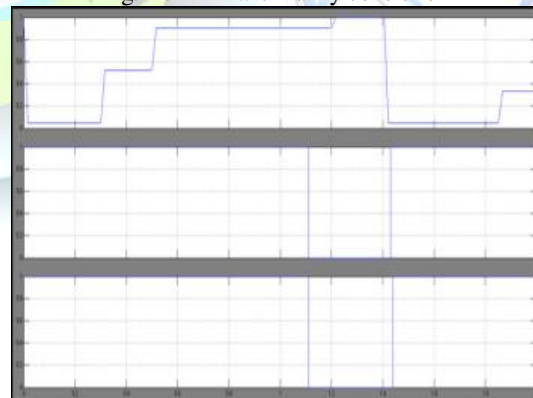
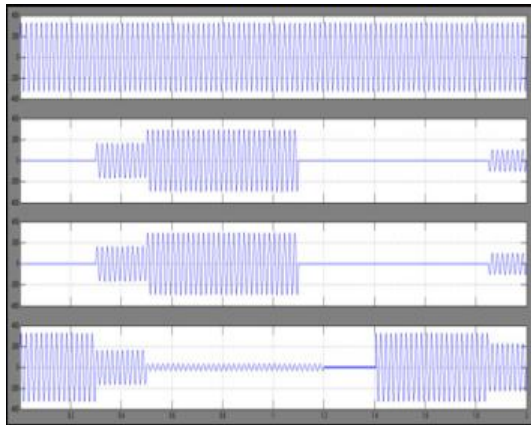


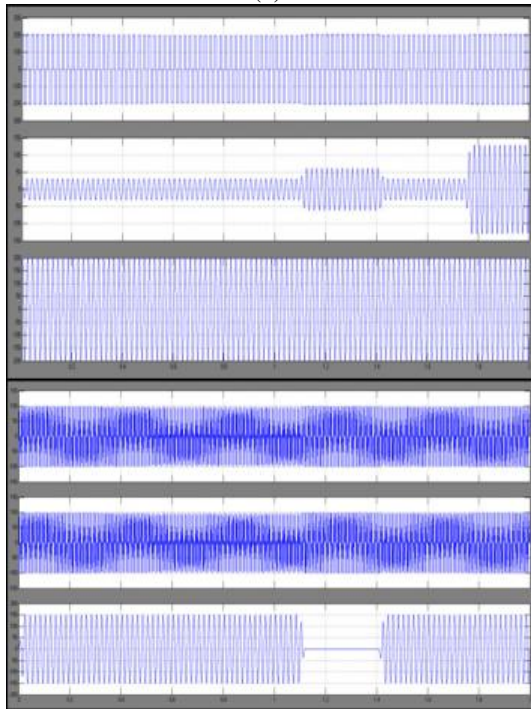
Fig.14. THD with fuzzy controller



(a)

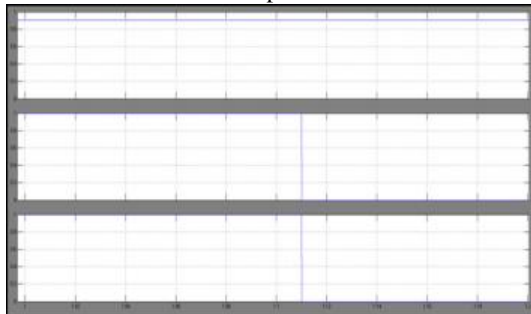


(b)

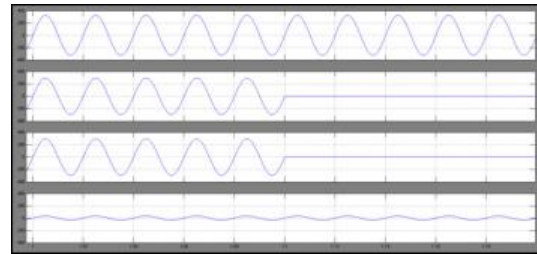


(c)

Fig. 14. (a) Switching positions during the operation. (b) Voltage and (c) current waveforms at different conditions and positions in the network.



(a)

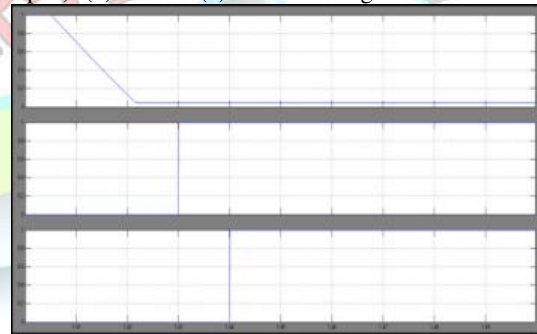


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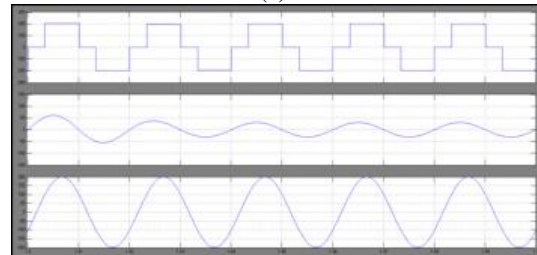


(c)

Fig. 15. Performance. (a) Switching (S2 and S3 are open). (b) APFse. (c) APFsh during islanded mode.



(a)



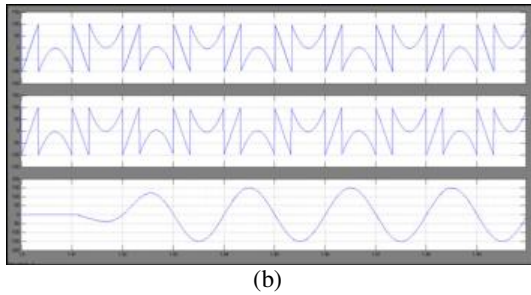


Fig. 16. Reconnection. (a) Switching (S2 and S3 instances are shown). (b) APFsh (S2 is closed as shown in switching diagram).

VI. CONCLUSION

This paper portrays a powerful control and integration procedure of the proposed UPQC μ G-IR in the grid associated μ G condition utilizing fuzzy logic controller. The ongoing execution with disconnected simulation has been acquired utilizing MATLAB and RT-LAB continuously test system by OPAL-RT. The results demonstrate that the UPQC μ G-IR can remunerate the voltage and current unsettling influence at the PCC amid the interconnected mode. Execution is additionally observed in bidirectional power flow condition. In islanded mode, the DG converters just supply the active power. Islanding identification and consistent reconnection procedure by the UPQC μ G-IR and the dynamic change with bidirectional power flow are approved continuously for a DG coordinated μ G System without bargaining on power quality.

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