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An Integration of an UPQC In Micro-grid With Improving The Power Quality In Both Interconnected And Islanding Modes of Operation

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Abstract: **-- the placement, integration, and control of unified power quality conditioner (UPQC) in distributed generation (DG)-based grid connected/autonomous micro-grid/ micro generation (μG) system has been presented here. The DG converters (with storage) and the shunt part of the UPQC Active Power Filter (APFsh) is placed at the Point of Common Coupling (PCC). The series part of the UPQC (APFse) is connected before the PCC and in series with the grid. The dc link can also be integrated with the storage system. An intelligent islanding detection and reconnection technique (IR) are introduced in the UPQC as a secondary control. Hence, it is termed as UPQCμG−IR. The advantages of the proposed UPQCμG−IR over the normal UPQC are to compensate voltage interruption in addition to voltage sag/swell, harmonic, and reactive power compensation in the interconnected mode. During the interconnected and islanded mode, DG converter with storage will supply the active power only and the shunt part of the UPQC will compensate the reactive and harmonic power of the load. It also offers the DG converter to remain connected during the voltage disturbance including phase jump.**

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

I. INTRODUCTION

The challenging issues of a successful integration of unified power quality conditioner (UPQC) in a distributed generation (DG)-based grid connected micro-generation (μG) system are primarily: 1) control complexity for active power transfer; 2) ability to compensate nonactive power during the islanded mode; and 3) difficulty in the capacity enhancement in a modular way. For a seamless power transfer 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 Clearly, these further increase the control complexity of the μG systems. To extend the operational flexibility and to improve the power quality in grid connected μG systems, a new placement and integration technique of UPQC have been which is termed as UPQCμG. In the UPQCμG integrated distributed system, μG system (with storage) and shunt part of the UPQC are placed at the Point of Common Coupling (PCC). The series part of the UPQC is placed before the PCC and in series with the grid. The dc link is also connected to the storage, if present.To maintain the operation in islanded mode and reconnection through the UPQC, communication process between the UPQCμG and μG system is mentioned in. In this paper, the control technique of the presented UPQCμG in is enhanced by implementing an intelligent islanding and novel reconnection technique with reduced number of switches that will ensure seamless operation of the μG without interruption. Hence, it is termed as UPQCμG−IR. The benefits offered by the proposed UPQCμG−IR over the conventional UPQC are as follows.

1) It can compensate voltage interruption/sag/swell and nonactive current in the interconnected 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 nonactive Reactive and Harmonic Power (QH) power of the load.

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

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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 have islanding detection and reconnection features in their control system.

5) The system can even work in the presence of a phase jump/difference (within limit) between the grid and µG.

6) Thus, the UPQCµG−IR will have the total control of the islanding detection and reconnection for a seamless operation of µG with a high-quality power service.

II. WORKING PRINCIPLE

The integration technique of the proposed UPQCµG−IR to a grid connected and DG integrated µG system is shown in Fig. 1(a). S2 and S3 are the breaker switches that 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. 1(b) and (c). The operation of UPQCµG−IR can be divided into two modes.

A. Interconnected Mode

In this mode, as shown in Fig. 1(b), the following holds: 1) the DG source delivers only the fundamental active power to the grid, storage, and load; 2) the APFsh compensates the reactive and harmonic (QH) power of the nonlinear load to keep the Total Harmonic Distortion at the PCC within the IEEE standard limit; 3) voltage sag/swell/interruption can be compensated by the active power from the grid/storage through the APFse,t. The DG converter does not sense any kind of voltage disturbance at the PCC and hence remains connected in any condition; 4) if the voltage interruption/black out occurs, UPQC sends a signal within a preset time to the DG converter to be islanded.

B. Islanded Mode

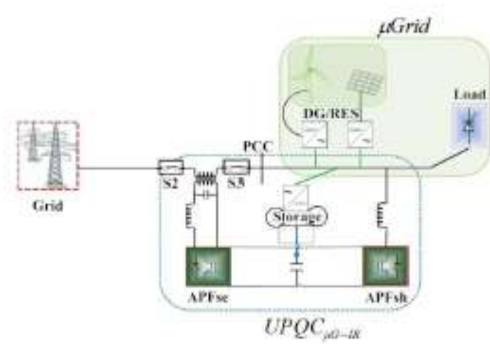
In this case, as shown in Fig. 1(c), the following holds: 1) the APFse is disconnected during the grid failure and DG converter remains connected to maintain the voltage at PCC; 2) the APFsh still compensates the nonactive power of the nonlinear load to provide or maintain undistorted current at PCC for other linear loads (if any); 3) therefore, DG converter (with storage) delivers only the active power and hence does not need to be disconnected from the system 4) the APFse is reconnected once the grid power is available. From Fig. 1(a)–(c), it is clear that the UPQCµG−IR requires two switches compared with four, as required for UPQCµG In. A detail of the switching mechanism is discussed in the controller design section.

III. DESIGN ISSUES AND RATING SELECTION

The fundamental frequency representation of the system is shown in Fig. 1(d) and the voltage and current relations are derived in (1) and (2). According to the working principle, the APFse is able to work during voltage interruption/sag/swell up to a certain level before it is islanded. The APFsh always compensates QH power of the load. Therefore, design and rating selection for the APFse, APFsh, and series transformer.

A. Shunt Part of U PQCµG−I R (APFsh)

It is shown in Fig. 2 that for any condition, APFsh compensates the non fundamental current of the load by injecting Ish in quadrature to Vpcc. When voltage sag appears in the supply side, APFse compensates the sag by injecting the required voltage to maintain the constant voltage and zero-phase at PCC. To complete the task, APFsh draws additional current from the source, to supply power to the APFse. The increased source current Is still remains in phase to the Vpcc. But this changes the magnitude and phase angle of the compensating current, Ish as an additional active power to the APFse.



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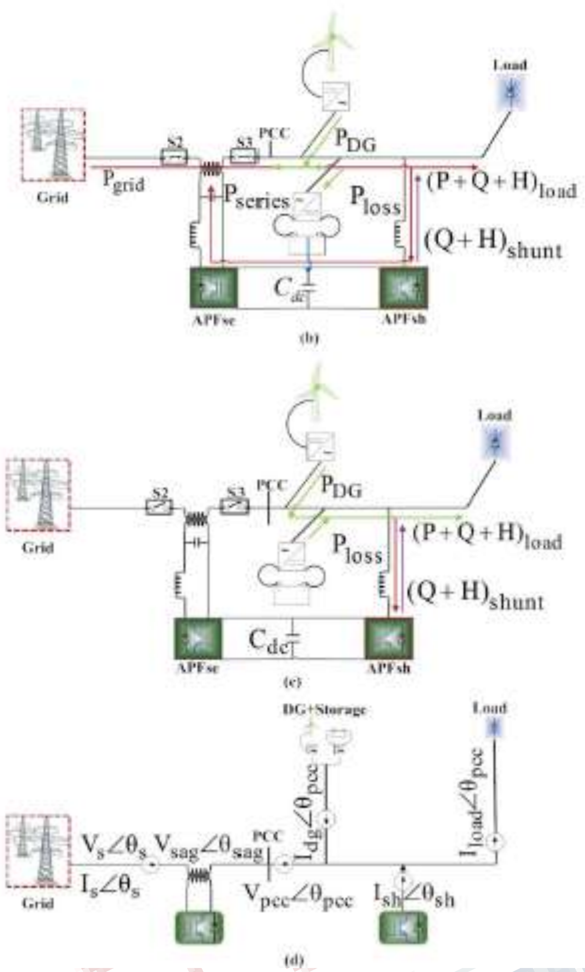

Fig . 1. (a) Integration technique of the UPQCμG−IR. Working principle in (b) interconnected mode,(c) islanded mode, and (d)fundamental frequency representation. together with the sizing of dc link capacitor are very important.

The increased source current Is still remains in phase to the Vpcc. But this changes the magnitude and phase angle of the compensating current, Ish as an additional active component of current (x) is added to the shunt compensator current now, as shown in Fig. 2 (e).

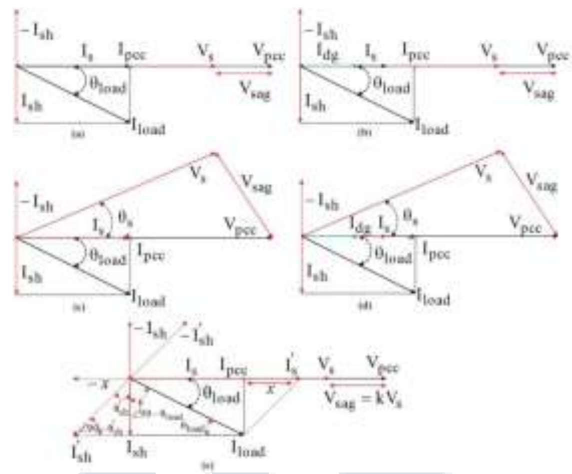

Fig. 2. Phasor diagram of UPQCμG−IR when (a) no DG and θs=θpcc,
(b) with DG and θs=θpcc, (c) no DG and θs≠θpcc, (d) with DG and θs≠θpcc, and (e) in-phase voltage compensation mode.

In this case This ultimately increases the current at PCC and thus creates a VA loading impact on the APFsh, which is also observe.

B. Series Part of U PQCμG−I R (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 (Iloadfp) flows through the APFse. Therefore, the APFse must have at least the same current rating as the active load fundamental requirement

IAPFse,min= Iloadfp.

From Fig. 2(c) and (d), the general equation for voltage sag compensation by The voltage rating of the APFse should be equal to the highest value of the injected sag voltage.

C. DC Link Capacitor

According to the working principle, the APFse should be able to work during a high-sag/swell condition and even in the case of interruption (depending on the interruption time) before it goes to the islanded mode. At this stage, the dc link capacitor should be able: 1) to

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maintain the dc voltage with minimal ripple in the steady state; 2) to serve as an energy storage element to supply the nonactive power of the load as a compensation; and 3) to supply the active power difference between the load and source during the sag/swell or interruption period. For a specific system, it is better to consider the higher value of Cdc so that it can handle all of the above conditions. It also helps to get a better transient response and lower the steady-state ripples. According to the calculation in, for the proposed system, the required capacitor size.

IV. CONTROLLER DESIGN

The block diagram of the proposed UPQCμG−IR controller is shown in Fig. 4. It has the same basic functionality as the UPQC controller except for the additional islanding detection and reconnection capabilities. A communication channel (signals transfer) 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/supply failure conditions. This task is performed in Level 2 (secondary control) of the hierarchical control [13]. Level 1 deals with the primary control of the UPQC to perform their basic functions in the interconnected and the islanded mode. The overall integration technique and control strategy are to improve the power quality during interconnected and islanded modes. 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. The five main elements of the proposed UPQCμG−IR controller are: 1) positive sequence detection;2) series part (APFse) control; 3) shunt part (APFsh) control; 4) intelligent islanding detection (IsD); and 5) synchronization and reconnection (SynRec). As the IsD and SynRec features are new in UPQC, therefore, these have been described in details.

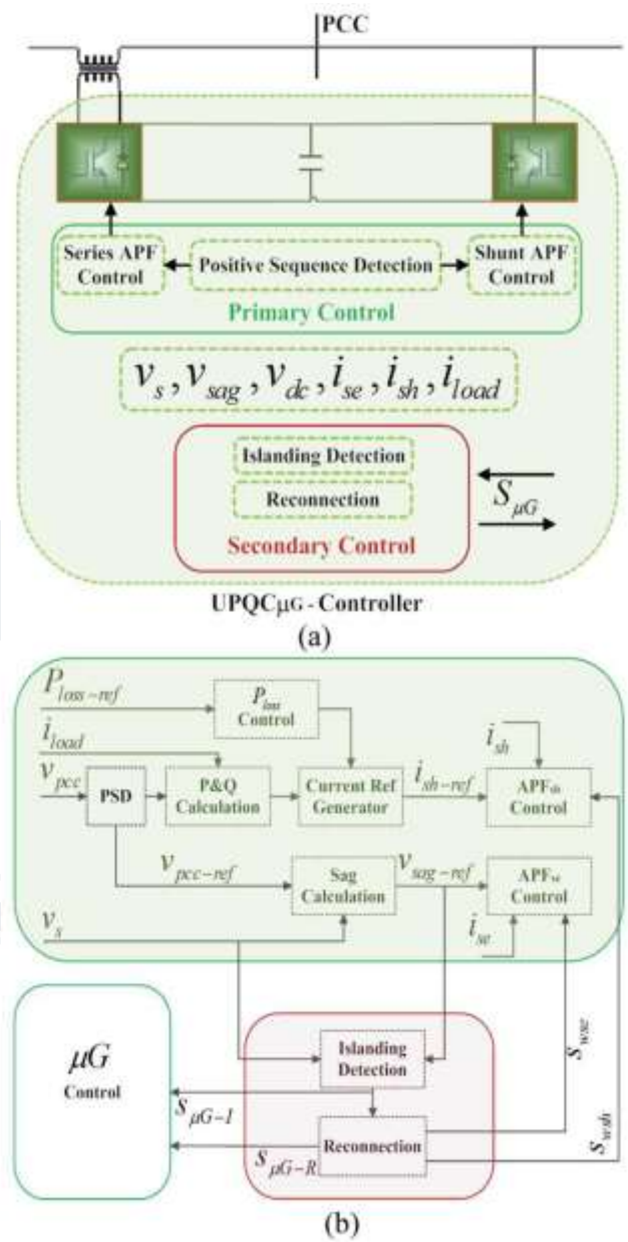

Fig. 4. Block diagram of the UPQCμG−IR. (a) Controller. (b) Control algorithm

A. Intelligent Islanding Detection

Considering the future trends toward the smart-grid and μG operation in connection with the distribution grid, the capability of: 1) maintaining connection during grid fault condition; 2) automatically detecting the islanded

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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. In addition to 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 detection is delayed in the case of hierarchical control Therefore, seamless voltage transfer control between the grid connected and isolated controlled modes is very important. Both indirect and direct current control techniques are proposed mitigate the voltage transients in transition mode, but these then 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, as shown in Fig. 4(b), is also generated in the proposed UPQCμG−IR to transfer it to the DG converters. As the APFse takes the responsibility for compensating voltage sag/swell/unbalance disturbances (depending on the controller), IsD algorithm in the proposed UPQCμG−IR can be simple yet quite flexible. On the other hand, it will help to reduce the complexity of islanding detection technique or even can be removed from all the DG converters in a μG system.

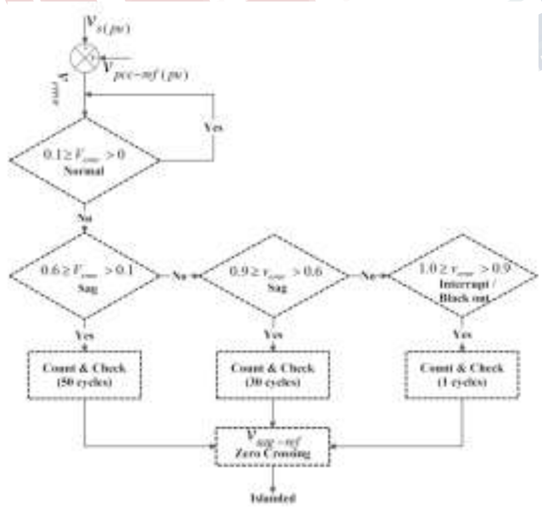

Fig. 5. Algorithm for IsD method in UPQCμG−IR

Fig. 5 shows a simple algorithm (with example) 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 Vpcc-ref (pu) and Vs (pu) is Verror. This error is then compared with the preset values (0.1–0.9) and a waiting period (user defined n cycles) is used to determine the sag/interrupt/islanding condition. In this example: 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. As 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. Therefore, 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. 1, the proper control and operation of the switches are very important for intelligent islanding and seamless reconnection. In that case, this paper presents a topology that represents a step forward compared with the use of intelligent connection agents (ICA) as presented in, an additional module named ICA is connected to an existing μG 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 paper 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, as shown in Fig. 5. 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. With the

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proposed UPQC control strategy, we can add it in an existing PV plant, and this unit will be the only one responsible of the voltage support and islanding detection, thus being more effective and reducing drastically the NDZ.

B. Synchronization and Reconnection

Once the grid system is restored, the μG may be reconnected to the main grid and return to its predisturbance condition. A 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. The seamless reconnection also depends on the accuracy and performance of the synchronization methods. In case of UPQCμG−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 (up to a certain limit) 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 APFse and the level of Vsag-max required for compensation. This limit can be calculated using (1) and Fig. 2. It is also discussed in. Assuming that the possible

Vsag-max= Vs = Vpcc

The reconnection method is shown in Fig. 6(b). Conditions for reconnection are set as: 1) assuming the phase difference between the utility grid and DG unit should be within θsag-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, based on the condition shown in Fig. 6(b), 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.

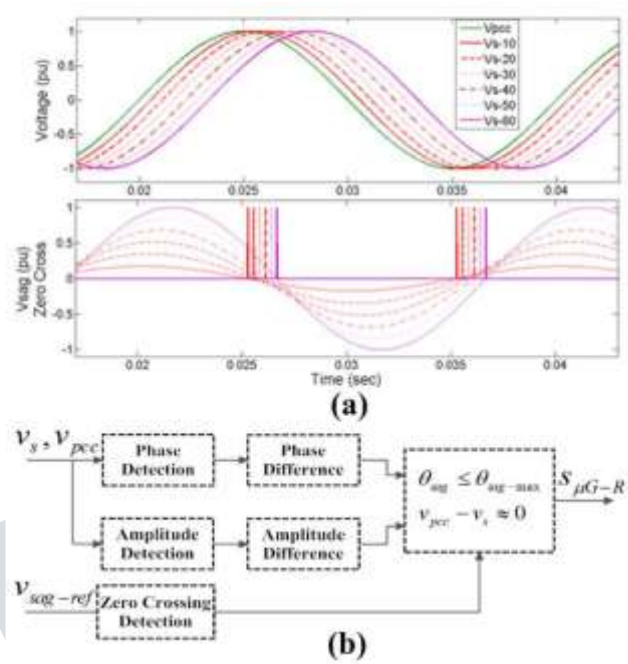

Fig. 6. (a) Position of Vs and Vpcc for different phase differences to measure the Vsag and Vsag-ref . (b) SynRec Interconnected Mode:

In this case, two possible mode of operation can be observed: 1) forward and 2) reverse flow. In the forward flow mode, the available DG power is less than the required load demand. The utility supplies rest of the power to the load. When the DG power becomes higher than the required load demand, the extra energy is transferred to the grid and storage and this is termed the reverse-flow mode. At this stage, the grid current becomes out of phase with the voltage at PCC. Fig. 9(a) and (b) shows the real-time performance of the APFsh part during interconnected mode in compensating the reactive and harmonic current (ish) generated by the load (iload) in the μG system. Here, iload contains active, reactive, and harmonic part of the total load demand of the μG system. Fig. 9(a) shows the performance in forward flow mode, when idg < iloadf . Therefore, additional active current is provided by the grid (is). Similarly, Fig. 9(b) shows the results for reverse flow mode when idg > iloadf . Therefore, additional current from the DG source is transmitted back to the grid and hence (is) phase is reversed. Fig. 9(c) and (d) shows the response of APFse during presage and postsag condition and the performance is obtained in reverse flow mode.and bidirectional power flow condition during a voltage sag

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(80%) compensation. The performance is obtained with the dynamic change of idg, which is reflected in the changes of is . From reverse to forward is created by decreasing idg during the sag compensation

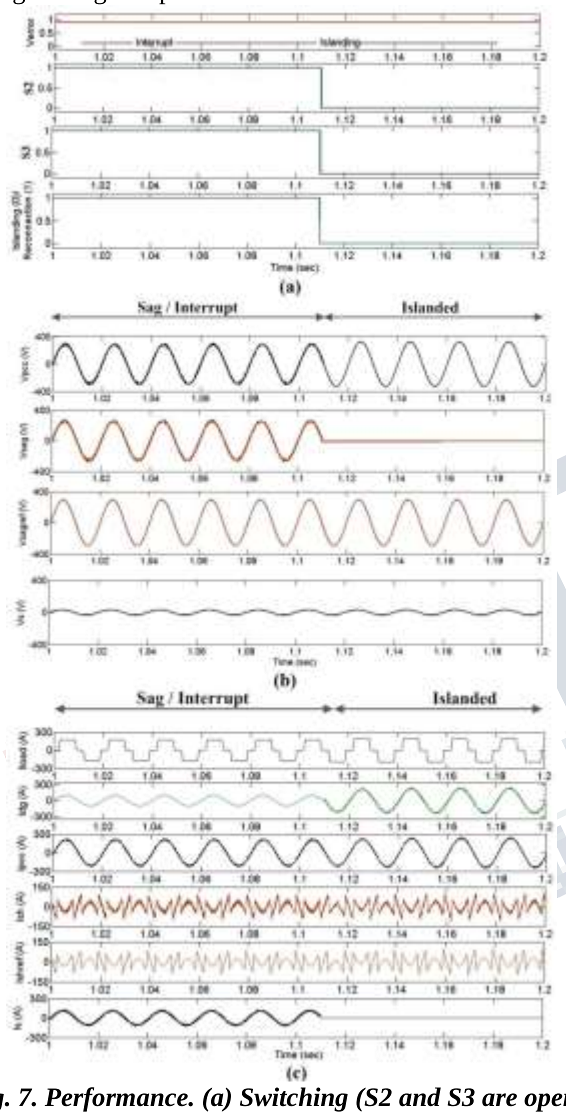

Fig. 7. Performance. (a) Switching (S2 and S3 are open). (b) APFse. (c) APFsh during islanded mode

Islanding Detection:

According to the IsD method, the APFse compensates the sag for up to 0.6 s (30 cycles) and then the system goes into islanded mode. A utility disconnection is applied at 1.11 s just after completing the 30 cycle count and then detecting the zero-crossing of Vsag−ref where S2 and S3 are opened. At 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 nonactive power. Therefore, 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.

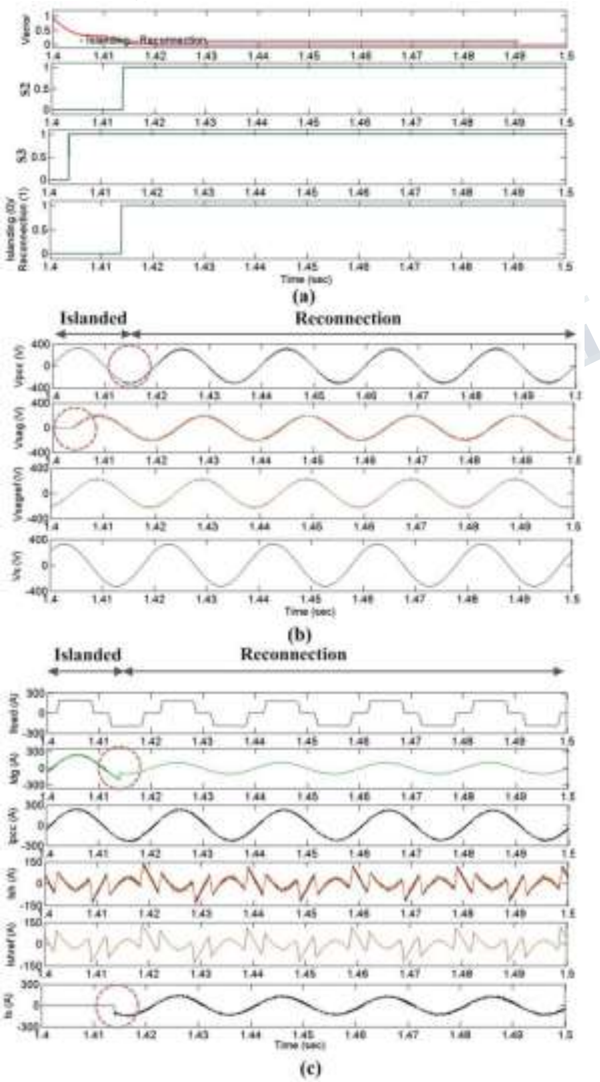

Fig.8. Reconnection. (a) Switching (S2 and S3 instances are shown). (b) APFse (S3 is closed). (c) APFsh (S2 is closed as shown in switching diagram).

Fig.7 shows the performance of the proposed UPQCμG−IR during 1.0–1.2 s, where the islanding is detected just immediately after 1.1 s at zero-crossing detection. The islanding mode is observed between 1.11 and 1.405 s. During this period the APFse is disconnected, as shown in Fig.7(b) where Vsag = 0, and Is becomes zero, as shown in Fig.7(c). The APFsh continues to operate, shown in Fig.7(c), and the load fundamental is met by the DG and storage.

Reconnection (SynRec):

Fig.8 shows the signals for reconnection process. To check the performance for one of the worst conditions, the utility grid (Vs) is powered on at 1.40 s with a 40° out of phase from the PCC. Immediately, the reconnection algorithm is activated and it starts generating active pulses when the phase and amplitude differences are within the required limits.Zero-crossing detection is also shown. UPQCμG−IR sends a reconnection signal to the DG unit. Based on the logic the actual switch S3 and S2 are activated at 1.405 and 1.415 s, respectively. Fig.8(a) shows that the APFse is immediately reactivated and starts operation when Vs is available and S3 is connected at 1.405 s, as shown by the circle in Vsag waveform in Fig.8(b). The power transfer starts when the S2 is closed at 1.415 s, as shown in Fig.8(c). It is expected that, according to the smooth reclosing condition, no power flow will occur at the point of reclosing. The switching is carried out successfully within the limiting condition as shown in Fig.8(b). The circle at 1.415 s for Idg and Is in Fig.8(b) shows the smooth transition from islanded to interconnected mode. The DG inverter also changes its control from voltage to current control mode, but only transfers active fundamental current. The performance of APFsh is also uninterrupted during the transition period.

V. CONCLUSION

This paper describes a powerful control and integration technique of the proposed UPQCμG−IR in the grid connected μG condition. The real-time performance with off-line simulation has been obtained using MATLAB and RT-LAB in real-time simulator by OPAL-RT. The results show that the UPQCμG−IR can compensate the voltage and current disturbance at the PCC during the interconnected mode. Performance is also observed in bidirectional power flow condition. In islanded mode, the DG converters only supply the active power. Therefore, the DG converters do not need to be disconnected or change their control strategy to keep the μG operating in any time with any condition. Islanding detection and seamless reconnection technique by the UPQCμG−IR and the dynamic change with bidirectional power flow are validated in real-time for a DG integrated μG System without compromising on power quality.

REFERENCES

1] S. K. Khadem, M. Basu, and M. F. Conlon, "UPQC for power quality improvement in DG integrated smart grid network—A review," Int. J. Emerg. Electr. Power Syst., vol. 13, no. 1, p. 3, 2012.

[2] A. Kahrobaeian and Y.-R. Mohamed, "Interactive distributed generation interface for flexible micro-grid operation in smart distribution systems," IEEE Trans. Sustainable Energy, vol. 3, no. 2, pp. 295–305, Apr. 2012.

[3] X. Yu, A. M. Khambadkone, H. Wang, and S. Terence, "Control of parallel-connected power converters for low-voltage microgrid—Part I: A hybrid control architecture," IEEE Trans. Power Electron., vol. 25, no. 12, pp. 2962–2970, Dec. 2010.

[4] S. K. Khadem, M. Basu, and M. F. Conlon, "A new placement and integration method of UPQC to improve the power quality in DG network," in Proc. 48th UPEC, vol. 1. Sep. 2013, pp. 1–6.

[5] T. Jimichi, H. Fujita, and H. Akagi, "Design and experimentation of a dynamic voltage restorer capable of significantly reducing an energy-storage element," IEEE Trans. Ind. Appl., vol. 44, no. 3, pp. 817–825, May/Jun. 2008.

[6] M. Basu, S. P. Das, and G. K. Dubey, "Comparative evaluation of two models of UPQC for suitable interface to enhance power quality," Electr. Power Syst. Res., vol. 77, no. 7, pp. 821–830, 2007.

[7] J. Nielsen, F. Blaabjerg, and N. Mohan, "Control strategies for dynamic voltage restorer compensating voltage sags with phase jump," in Proc. 16th APEC, vol. 2. 2001, pp. 1267–1273.

[8] D. M. Vilathgamuwa, A. R. Perera, and S. S. Choi, "Voltage sag compensation with energy optimized dynamic voltage restorer," IEEE Trans. Power Del., vol. 18, no. 3, pp. 928–936, Jul. 2003.

[9] S. S. Choi, J. D. Li, and D. M. Vilathgamuwa, "A generalized voltage compensation strategy for mitigating the impacts of voltage sags/swells," IEEE Trans. Power Del., vol. 20, no. 3, pp. 2289–2297, Jul. 2005.

[10] M. R. Banaei, S. H. Hosseini, S. Khanmohamadi, and G. B. Gharehpetian, "Verification of a new control strategy for dynamic voltage restorer by simulation," Simul. Model. Pract. Theory, vol. 14, no. 2, pp. 112–125, 2006.

[11] M. Moradlou and H. R. Karshenas, "Design strategy for optimum rating selection of interline DVR," IEEE Trans. Power Del., vol. 26, no. 1, pp. 242–249, Jan. 2011.

[12] S. K. Khadem, M. Basu, and M. F. Conlon, "Harmonic power compensation capacity of shunt active power filter and its relationship with design parameters," IET Power Electron., vol. 7, no. 2, pp. 418–430, 2013.

[13] J. M. Guerrero, J. C. Vasquez, J. Matas, L. G. de Vicuña, and M. Castilla, "Hierarchical control of droop-controlled AC and DC microgrids—A general approach toward standardization," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 158–172, Jan. 2011.

[14] B. Han, B. Bae, H. Kim, and S. Baek, "Combined operation of unified power-quality conditioner with distributed generation," IEEE Trans. Power Del., vol. 21, no. 1, pp. 330–338, Jan. 2006.

[15] H. Kim, T. Yu, and S. Choi, "Indirect current control algorithm for utility interactive inverters in distributed generation systems," IEEE Trans. Power Electron., vol. 23, no. 3, pp. 1342–1347, May 2008.

[16] J. Rocabert, G. M. S. Azevedo, A. Luna, J. M. Guerrero, J. I. Candela, and P. Rodríguez, "Intelligent connection agent for three-phase gridconnected microgrids," IEEE Trans. Power Electron., vol. 26, no. 10, pp. 2993–3005, Oct. 2011.