Power quality enhancement using unified power quality conditioner in microgrid system

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Abstract— In this paper, Integration of Unified Power Quality Conditioner in DG connected microgrid system is presented. In this method, the proposed system has UPQC, distribution generation (DG) converters with storage, load. The Shunt active power filter of the UPQC will be connected at PCC after PCC and the series active power filter of the UPQC will be connected before the PCC and it is in series with the grid. DC link is connected to the storage unit. So, it is named as UPQC in microgrid .The advantages of the proposed system are, it compensate voltage interruptions, voltage sag/swell, harmonic and reactive power (QH) compensation in interconnected mode. The DG converter connected to storage will supply the active power and the shunt active filter of the UPQC will compensate reactive and harmonic power of the load during islanded mode. Hence, the proposed system will operates during interconnected and islanded mode. During voltage disturbance, DG converter is not required to be disconnected. Therefore, DG converter only supplies active power to the grid and the load. Hence, it reduces the complexity of controlling DG converter and also enhances the power quality of the system. Simulation work of the proposed topology will be carried out in MATLAB/Simulink.

Keywords—Unified power quality conditioner (UPQC), microgrid , voltage sag/swell, power quality

1. INTRODUCTION

Now a days, there is rise in the demand of renewable energy resources. Penetration of these renewable sources in electrical network will increase many types of disturbances in system. So, maintenance and enhancement of quality of power become more critical. For this reason, custom power device like unified power quality conditioner (UPQC) should be most suitable equipment to increase effective overall working operation of the electrical system. In this paper, interfacing of unified power quality conditioner in distributed generation with micro-grid is proposed. Recently, there are two techniques available. One is (DC-linked)$_{DG-UPQC}$, another is (DC-seperated)$_{DG-UPQC}$

Disadvantages with respect to (DC-linked)$_{DG-UPQC}$ system are 1)There is complexity in controlling the active power transfer.2) In multi-level or multi-module, capacity enhancement is very difficult. The disadvantages of (DC-seperated)$_{DG-UPQC}$ system are 1) Compensation for voltage interruption may not be possible. 2) Not able to give imaginary and harmonic power (QH) compensation at islanding condition. 3) System cost is high.

The above mentioned configurations will increase the complexity in controlling the converter. Therefore, after detecting unintentional islanding, the DG unit either change its control mode or it should be isolated during islanded operation. Considering the enhancement, related to quality of power with grid linked to DG system with microgrid and to increase the flexibility of system, integration of Unified power quality conditioner in microgrid had proposed.

2.PRINCIPLE FOR OPERATION OF UPQC$_{\mu G}$

The UPQC$_{\mu G}$ will integrated in the grid and the DG source connected with microgrid is represented in Fig. 1.

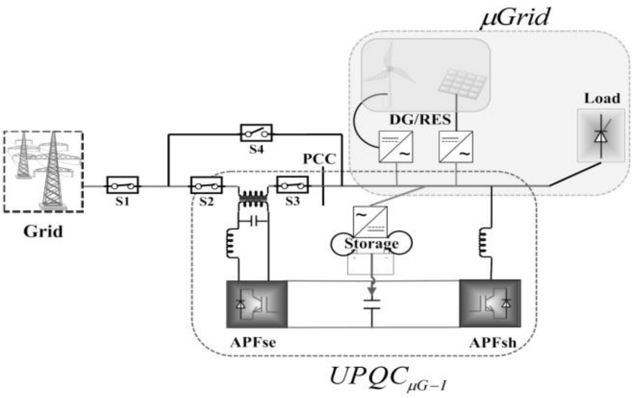


Fig. 1.Integration of UPQC$_{\mu G}$ in DG network

a. Interconnected mode

The distribution generation supplies only active power towards grid, load along with the storage unit. The shunt active filter provides compensation for imaginary and Harmonic power of the load(non-linear). The APF$_{se}$ compensates voltage swell/sag or interrupt by providing active power which is supplied by source/grid or storage unit. Hence, there is no voltage disturbances at DG side and also at PCC.

b. Islanded mode

If failures or blackout occurs, then UPQC send the signal for islanding condition. In the power failure condition, the series filter (APF$_{se}$) is isolated by disconnecting the switches S1,S2,S3. At PCC, the required voltage is maintained by DG converter and it should not be disconnected. The APF_{sh} of the system will provides the compensation for reactive power near load (non-linear). It maintains exact current near point of common coupling. Hence, distribution generation converter distributes only real power for the load.

3. Controller Design of proposed $UPQC_{\mu G}$

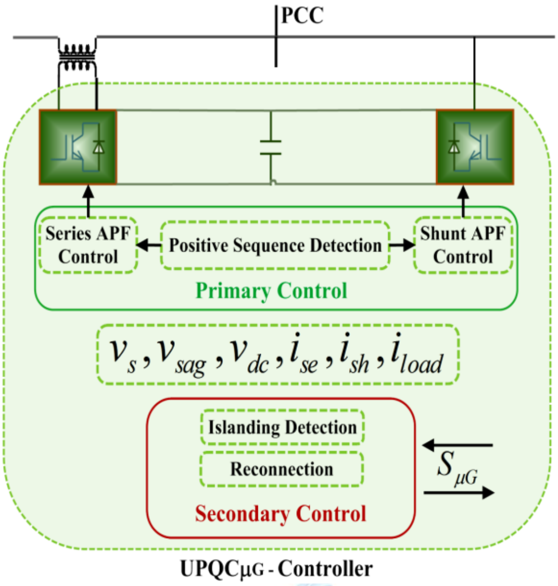


Fig. 2. Representation of $UPQC_{\mu G}$ controller

The proposed system is having works/functions same as the UPQC controller and addition to that, generation of signal for detecting islanding condition and reconnecting of grid is possible. Detection of islanding and reconnecting requires a channel for communicating between proposed system $UPQC_{\mu G}$ and the microgrid (μG). Depending upon voltage sag, interruption, swell in voltage or power deficiency, signal is generated. Above function will included into secondary control or Level 2 of the controlling method in proposed system. Level 1 controls series filter (APF_{se}) along with shunt filter (APF_{sh}) of $UPQC_{\mu G}$ during interconnected mode and the islanded condition for exibit the primary operations. During interconnect and island conditions, above mentioned UPQC which is integrated with microgrid will helps to improve and control the power quality of the system.

3.1. Islanding detection

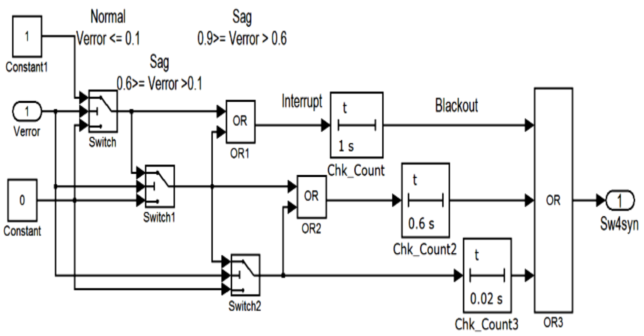


Fig. 3. Generation of signal for islanding detection

In above Fig. 3. different condition are defined with different values of pre-set values and also compensation is also defined. The voltage near Point of common coupling called as reference voltage. Reference voltage is in phase with supply voltage and converter with distribution source. V_{error} is deviation between the V_s and $V_{pcc\text{-}ref}$. The voltage sag/blackout or islanding condition are determined by comparing error voltage to the pre-set values like 0.1, 0.2,......0.9 and waiting period (number of cycles defined by user). If error voltage is greater or equal to 0.9, it is interruption (blackout condition). After one cycle the grid is islanded. This function is carried out in zero crossing condition of series APF.

3.2. Synchronization and reconnection

When the magnitude of voltage, phase control, frequency deviations will within the described value otherwise near to zero, then the connection of grid will be done by S1, S4 that is represented in Fig. 4. The microgrid will send ($S_{\mu G\text{-}R}$) to $UPQC_{\mu G}$ for reconnection of grid . Afterwards, the series active filter is connected through switch S2, S3 towards grid and disconnecting S4. At zero crossing condition of source voltage, Controlling of switch transition from one mode (island) to other (reconnect) is done.

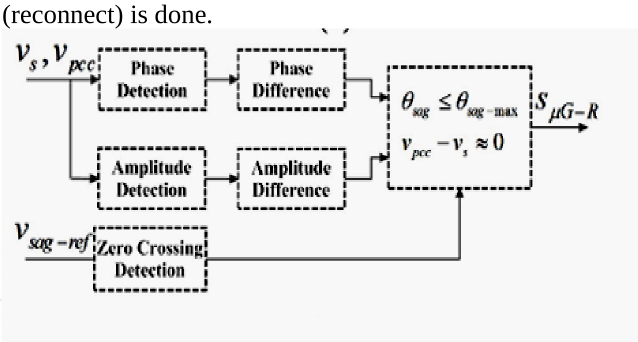


Fig. 4. Block representation of synchronization method

4. SIMULATION STUDY

The proposed structure $UPQC_{\mu G}$ is designed in MATLAB. The structure is modelled as three phase and four wire system. Simulation is conducted to analyze the proposed system and performance in interconnect and islanded mode. Simulation is conducted to 2 seconds.

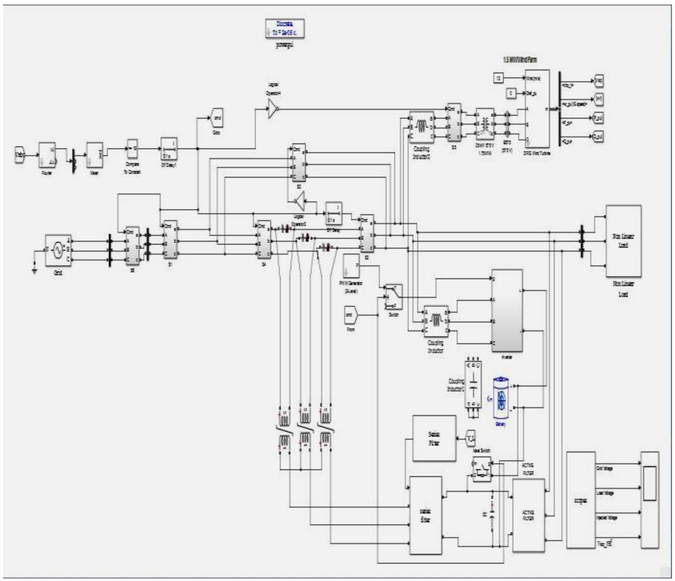


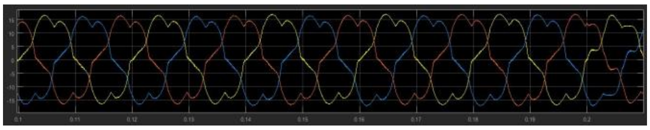
Fig .5. Simulation model for proposed system

Table 1. Simulation parameters of proposed system

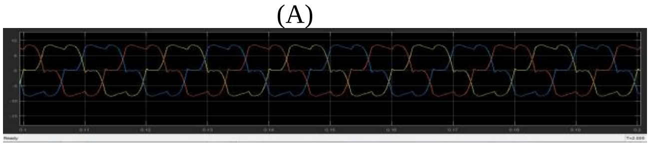
Selection	Parameter	Value
Grid(3 phase)	Voltage(rms)	380$V_{ph\text{-}ph}$
	Line frequency	50Hz
UPQC	DC link voltage	600V
	Series transformer	1:1
	Series RC branch	R=1Ω
		C=100µF
	Series inductor	1.8H
DFIG wind turbine	Nominal power	1.5MW

SIMULATION RESULTS

4.1.Interconnected mode



(A)



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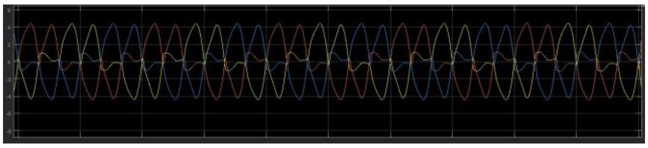
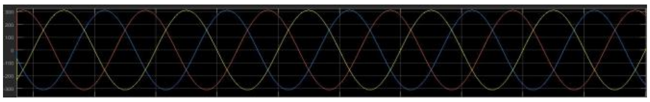


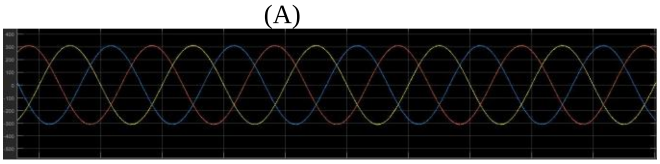
(C)

Fig. 6. (A) Supply Current (B) load Current (C) compensating current in interconnected mode

In Fig. 6. APF_{sh} is compensating harmonic and imaginary current created from load. At current control mode, half of the fundamental load is distributed from DG source. The utility along with storage unit will supplies the remaining current. In this compensation of current is shown from 0.1sec to 0.2sec.



(A)



(B)

(C)

(D)

Fig.7. Voltage waveforms in interconnected mode (A) source voltage (B) load voltage (C) injected voltage (d)V_{sag_ref}

In Fig. 7. source voltage, injected voltage, voltage at load, V_{sag_ref} are shown from time 0.06sec to 0.16sec in the interconnected mode.

4.2.Islanded mode

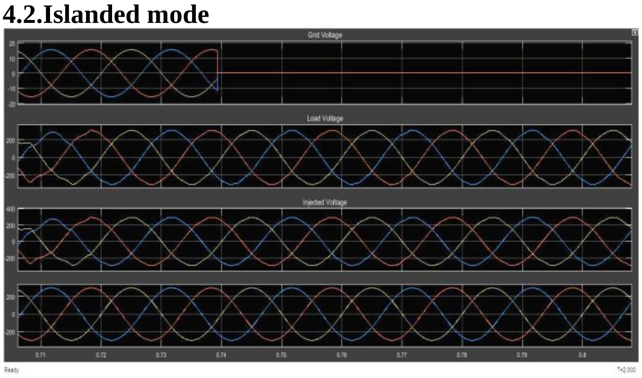
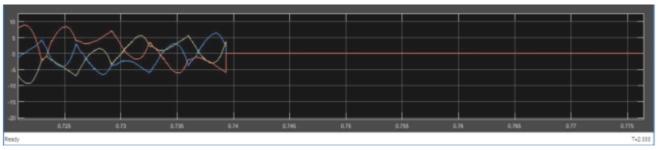
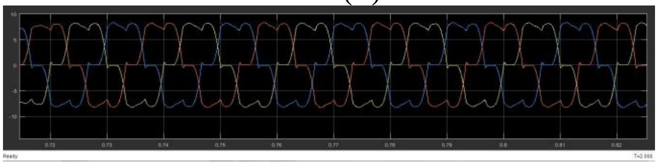


Fig. 8. voltage waveforms for islanded mode

APF_{se} compensates the sag from 0.5 sec to 0.7 sec and then at 0.7 sec blackout occurs. $UPQC_{\mu G}$ detects the blackout and at 0.739sec the system goes to islanded mode. The utility is islanded from 0.739sec to 1.036sec as shown in Fig.8. V_{sag} and utility current is zero at disconnection of APF_{se}.



(A)



(B)

Fig. 9. Current waveforms for islanded condition (A) supply current (B) load current

In Fig. 9. APF_{sh} continues to operate in islanding condition and compensates reactive power. The Load is supplied by DG source and storage. Hence, in islanding condition the DG will not be separated by removing its connection to grid and also changing of control action will not required for meeting demand of load.

4.3. Reconnection of grid

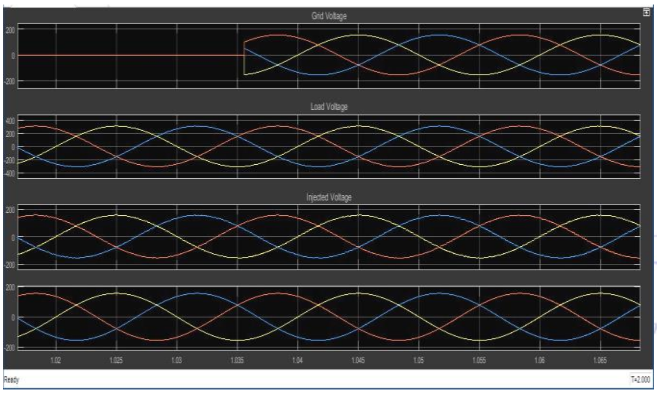
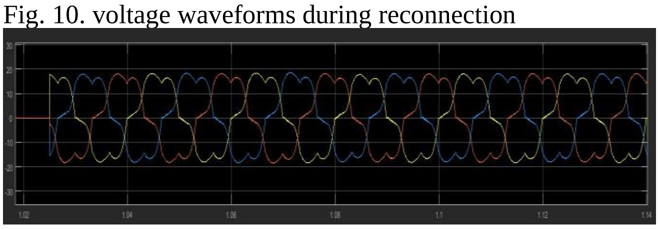
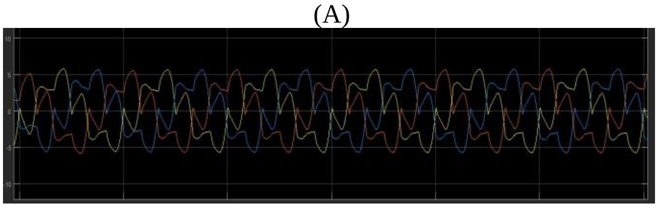


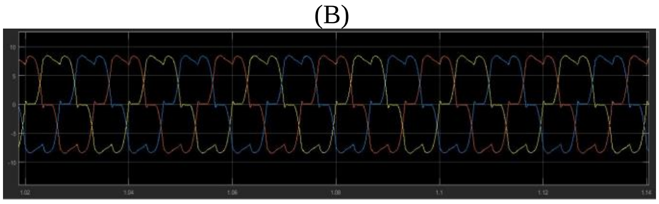
Fig. 10. voltage waveforms during reconnection



(A)



(B)



(C)

Fig. 11. (A) Source Current (B) Compensation Current (C) Load Current during reconnection

Fig. 11. shows reconnection process. Grid voltage will again obtained at 1.036 sec. Therefore, DG unit sends the signal of reconnection to $UPQC_{\mu G}$. During reconnection, the switch S1 is connected. After synchronization of DG unit, the S2 and S3 are activated and S4 is disconnected simultaneously. During this process, series active filter (APF_{se}) is reactivated instantly when grid voltage is obtained at 1.036sec.

5.CONCLUSION

In this paper, integration of $UPQC_{\mu G}$ in grid connected µG condition is shown by simulating the system in MATLAB. During interconnected mode, proposed $UPQC_{\mu G}$ will compensates the sag voltage along with voltage swell or other interruptions at PCC. It will also provide harmonic current compensation during interconnected mode. During islanded condition, real power is distributed by DG for the load. The main grid will be reconnected when grid voltage is available. So, DG converter need not be disconnected during the islanded condition. Therefore, the proposed system operates both in interconnected and islanded condition. Hence, it should reduce the difficulty in controlling the distribution generation converter and enhances the power quality of network.

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