Mitigation of Power Quality Issues in Hybrid Wind/Diesel System using UPQC

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Abstract— The domestic consumers in the remote areas not served by the main electrical grid network, diesel generators are the usual choice for power supply. As a result, plenty of servicing and maintenance needed onto these diesel generators. Thus, we proposed an idea of introducing wind turbine working together with the diesel generators to form a hybrid power system but after connecting wind system with the diesel there are certain power quality issues are created to reduce that issues author proposed a system by introducing UPQC in hybrid system. In such system 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.

Key words: Permanent Magnet Synchronous Generator (PMSG), Maximum Power Point Tracking (MPPT), Matrix Converter, Wind Energy Conversion System (WECS)

I. Introduction

Wind power has become one of the most attractive energy resources as it is almost pollution-free (if noise is not considered as pollution) when used for electricity production A remote power generation system using diesel generation and one or more sources of renewable energy are often referred to as “hybrid” power system. Hybrid power systems are designed for the generation and use of electrical power. They are independent of a large centralized electricity grid, incorporate more than one type of power source, and typically found in remote locations. Diesel generators are portable, modular, and have a high power-to-weight ratio, which makes them an ideal power source for these hybrid power systems. In an effort to conserve expensive diesel fuel, hybrid systems often include some other power source such as wind, solar, or hydropower. To maximize the use of the renewable resource, the size and operation of the hybrid system components need to match with the load and the available renewable resources. In such a hybrid system wind energy is used to reduce the net load (system load minus renewable power) on the diesel generator in order to reduce the fuel consumptions. In general, results indicate that for locations with high wind speed, reduction in Diesel fuel costs more than offset the capital equipment cost of wind turbines but To extend the operational flexibility and to improve the power quality in grid connected distributed systems, a new placement and integration technique of UPQC have been proposed in, which is termed as UPQCμG. In the UPQCμG integrated distributed system, hybrid 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.

II. Proposed System

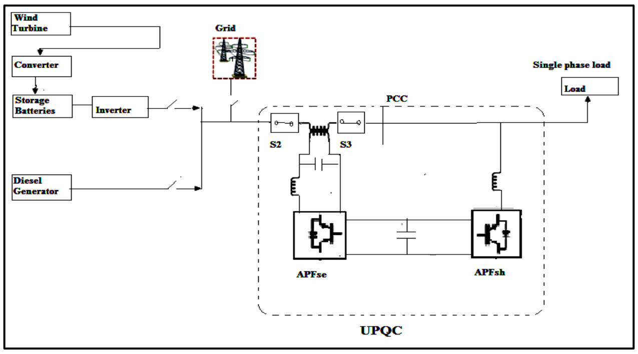

Fig. 1: Proposed System

To maintain the operation in islanded mode and reconnection through the UPQC, communication process between the UPQCμG and hybrid distributed system is mentioned. 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 UPQC*μ*G−IR over the conventional UPQC are as follows

- 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/*μ*G system to a great extent.
- 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
- Both in the interconnected and islanded modes, the *μ*G provide only the active power to the load. Therefore, it can reduce the control complexity of the DG converters
- Islanding detection and reconnection technique are introduced in the proposed UPQC as a secondary control. A communication between the UPQC and *μ*G is also provided in the secondary control. The DG converters may not require to have islanding detection and reconnection features in their control system

III. Working Principle

The integration technique of the proposed UPQC*μ*G−IR to a grid connected and DG integrated *μ*G system is shown in Fig.1. S2 and S3 are the breaker switches that are used to island and reconnect the *μ*G 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 and fig 3.. The operation of UPQCμG−IR can be divided into two modes

A. Interconnected Mode

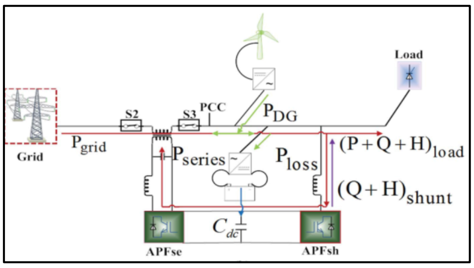

Fig. 2: Interconnected mode

In this mode, as shown in Fig.2, the following holds

- The DG source delivers only the fundamental active power to the grid, storage, and load;
- 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;
- 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;
- If the voltage interruption/black out occurs, UPQC sends a signal within a preset time to the DG converter to be islanded.

B. Island Mode

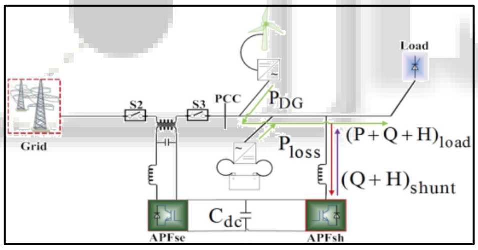

Fig. 3: Island mode

In this case, as shown in Fig.3 the following holds:

- The APFse is disconnected during the grid failure and DG converter remains connected to maintain the voltage at PCC;
- 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);
- Therefore, DG converter (with storage) delivers only the active power and hence does not need to be disconnected from the system;
- The APFse is reconnected once the grid power is available

IV. UNIFIED POWER QUALITY CONDITIONER

A. Shunt part of UPQC (APFsh)

APFsh compensates the non-fundamental current of the load by injecting *I*sh in quadrature to *V*pcc. 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 *I´s* still remains in phase to the *V*pcc. But this changes the magnitude and phase angle of the compensating current, *I´*sh as an additional active component of current (*x*) is added to the shunt compensator current

B. Series part of UPQC (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.

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 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 *C*dc 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 will be

$$C_{dc} = 2\, S_{load}\, n\, T / 4\, C\, V^2_{dc}$$

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}. It indicates that the size of the capacitor can be adjusted by the selection of cycles (*n)* for which the APFse will compensate. One of the purposes of the proposed integration technique of the UPQCμG−IR is to maintain smooth power supply during sag/swell/interruption and extend the flexibility of the DG converters operation during interconnected and islanded modes. For the supply continuity, DG storage system has also been introduced. Therefore, a dc link connection between the capacitor and the DG storage has been proposed for the system. It will help to reduce the size of the capacitor and provide power during the sag/interrupt condition. Therefore, the source current will maintain the required load current active component and the additional current will be provided by the DG converters and storage. Thus, it will ultimately help to reduce the rating of the APFse converter.

V. ISLAND DETECTION

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. 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, 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 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.

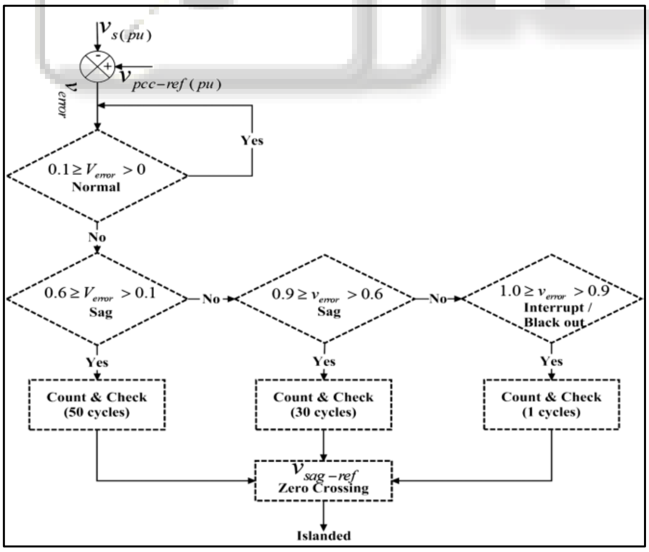

Fig. 4: Island Detection Algorithm

VI. Simulation & Results

Based on the Integration method the signal generation for island detection and the reconnection method fig.5. Shows the switch position (0 for open and 1 for close) during the operation from 0 to 2 second where both interconnected and island modes are observed. The performance of proposed UPQCμG for the voltage sag compensation is shown in fig. 6 and harmonic current compensation is shown in fig.7. Details of performance under different modes of operation are discussed below.

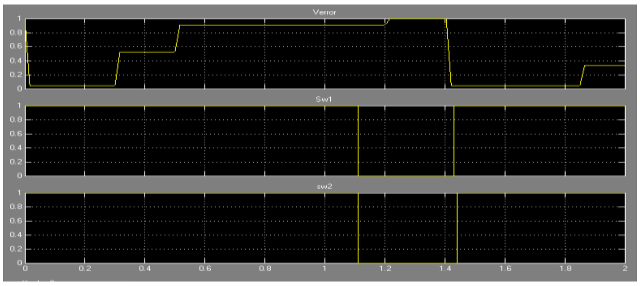

Fig. 5(a):

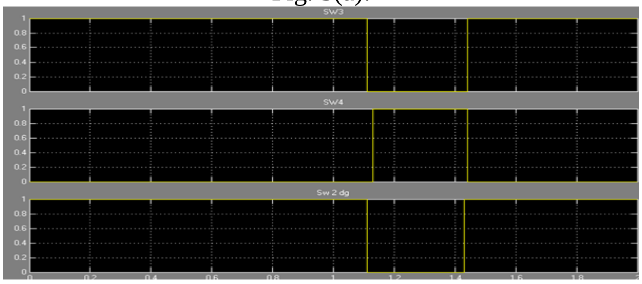

Fig. 5(b):

Fig. 5(a): & (b): Switching position during operation

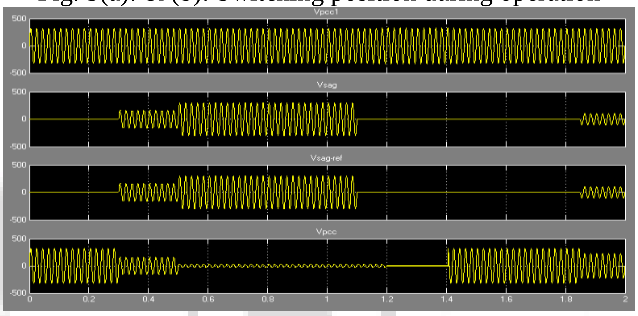

Fig.6. Voltage sag compensation in proposed system

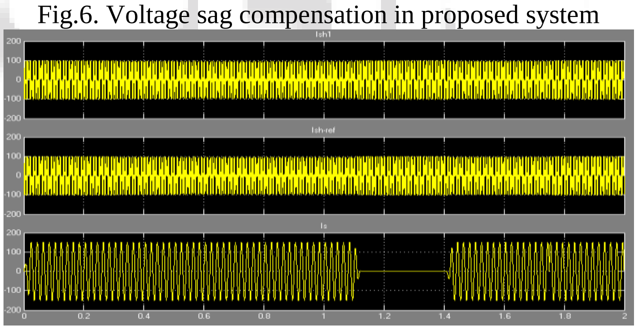

Fig. 7: Current distortion in proposed system

A. *Interconnected mode*

Depending upon the power availability the DG Source can supply the power to the load, grid and storage. Therefore bidirectional power flow can be occurred. Hence performance of the UPQC can be observed in both the cases. for better understanding the according to direction of power flow operation on the interconnected mode can be divide in to two parts (1). Forward flow mode. (2) Reverse flow mode.

1) *Forward Floe Mode*

In case the available DG power is less than the total load demand therefore the utility supplies the rest of the power to load which is not met by the DG supply. Fig. 6 and Fig 7 Shows the performance of APFsh in compensating the reactive and harmonic current generated by the load. The DG Supplies the 0.5 I_{load} (half of the fundamental current) to the load and remaining current is supplied by the storage and utility grid. During the 90% of sag condition total power for the load demand is still met by the micro grid system and utility grid where the storage system provide the power for sag compensation through DC Link.

2) Reverse Flow Mode

When available DG power is more than the required load demand the extra energy is transfer to the grid and storage system this is termed as Reverse flow mode. At this stage, the grid current becomes out of phase whit the voltage at the PCC.

B. Island Mode

According to IsD algorithm APFse compensate the sag up to 0.6 Sec. and then the system goes into Island mode. A utility Disconnection is appear at 1.11 Sec just after completing the 30 Sec count. Then detecting the Zero Crossing of $V_{sag-ref}$. Where S1, S2 and S3 are opened. At disconnection micro grid system operate in island mode. At this stage available DG power is less than Load demad. The required power is supplied by the storage. If DG power is higher thn the load then additional power is supplied to the storage. The APFsh still compensate the non-active power. Therefore DG converter does not disconnected or changes the control strategies to supplied power to load.

1) Power Flow

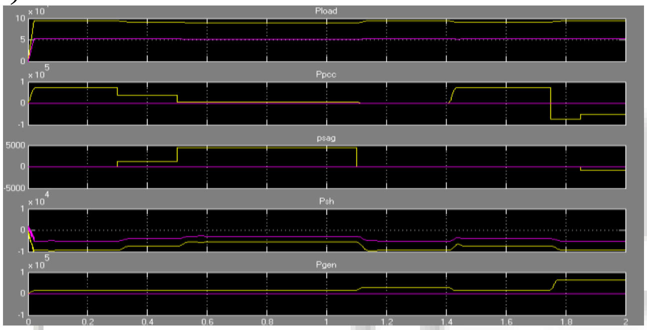

Fig. 8: Power Flow

The power flow diagram is shown in Fig 10 for the complete simulation time where the green line represent the active power (P) and red line (dash) for reactive and harmonic power (QH). This also validates the operation and performance of the APFse and APFsh part of the proposed UPQCμG along with the islanding detection and reconnection.

VII. CONCLUSION

Wind power is characterized by fluctuation due to intermittent primary source, which can damage the electrical network stability because of the imbalance between production and consumption therefore it is necessary to use another source along with the wind generation system therefore by using diesel system along with wind system the generation done and the system becomes hybrid. It is also concluded that the voltage variations and load current harmonics are the two main issues arising when the distributed system is connected to the load or grid. Such types of power quality issues are minimize using UPQC. 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 in any time with any condition.

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