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Hybrid Wind, Solar & Diesel based UPQC System For Rural Areas

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ABSTRACT

The electric supply is through Grid. The urban and rural divide can be well seen here also. The rural domestic user is usually not connected by the main electric grid. The power availability here is mainly through self installed system which is largely either diesel generator or the popular solar system. The diesel generators usually require large scale maintenance. Thus for smooth working idea of hybrid micro grid system comprising of conventional electric supply and two other sources needs to be integrated. The connection of multi systems has multiple power quality issues for which a novel idea is introduction of unified power quality conditioner in hybrid system.

In the proposed system the DIESEL GENERATOR converters along with storage and the shunt part of the Unified Power Quality Conditioner Active Power Filter (APFsh) is placed at the Point of Common Coupling (PCC). The series part of the Unified Power Quality Conditioner (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 Unified Power Quality Conditioner as a secondary control. Hence, it is termed as Unified Power Quality Conditioner micro grid.

Keywords- *Wind Turbine, Solar System, Diesel Generator, Storage Batteries, Unified Power Quality Controller.*

I. INTRODUCTION

Solar system and wind power has become most popular resources of non conventional energy. The two systems are most environment friendly and are almost pollution-free. The conventional elergy stsm used in the rural or urban area in case of power cuts is the DIESEL GENERATOR sets. The DIESEL GENERATOR sets are the largest source of pollution and needs to have a combinational systems for minimizing its use. The three systems when used in combination will give rise to a hybrid system. This Hybrid power system can met the required power demands of varied order. This local power system is independent of large centralized electricity grid which is a national one. The national grid also includes more than one type of power source. Unlike solar system and wind mill power generator systems Diesel generators are portable, modular, and have comparatively high power-to-weight ratio. The inclusion of these units in reliable power requirements makes DIESEL GENERATOR sets an ideal power source constituent in these hybrid power systems. The petroleum products are costly and have short durability hence fusion of alternate resources, hybrid systems often include some other power source such as wind, solar, or hydropower [4].To lower the continuing cost and maximize the use of the non conventional renewable resource at one hand and to adjust with the varied load and size of the DIESEL GENERATOR sets are used. In such a hybrid system wind energy and solar systems are used to reduce the operational cost for low power requirement which can be met by the renewable sources alone. In case of heavy loads only the DIESEL GENERATOR sets in combination of the other two are put in operation. In general, the availability of solar power everywhere in India and predominantly wind power availability in locations having high wind speed can be used for reduction in Diesel fuel costs more than offset of the capital equipment cost of wind turbines and establishment of solar system [4]. The islanded power requirement and for this power requirements for the isolated functions can be seen Once the solar, wind and diesel model are connected with the load then various power quality issues can be ensured. For the minimization of the power quality problems **Unified Power Quality Conditioner** has used challenging issues of a successful Combination of unified power quality conditioner in a Micro grid generation (DIESEL GENERATOR)-based grid are primarily:
1) 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.

For seamless power transfer between grid-connected operation in 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 In the **Unified Power Quality Conditioner** micro grid integrated distributed system, micro grid system with or without storage and shunt part of the **Unified Power Quality Conditioner** are placed at the Point of Common Coupling (PCC)[6]. The series part of the **Unified Power Quality Conditioner** 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 **Unified Power Quality Conditioner**, communication process between the **Unified Power Quality Conditioner** micro grid and micro grid system is mentioned in. In this paper, the control technique of the presented **Unified Power Quality Conditioner** Micro grid in is enhanced by implementing an intelligent islanding and novel reconnection technique with reduced number of switches that will ensure seamless operation of the micro grid without interruption. Hence, it is termed as **Unified Power Quality Conditioner** micro grid−IR [6]. This paper has

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been focuses on the working principle of the proposed system, Based on the working principle, some of the design issues and rating selection have been and the islanding detection and reconnection techniques in detail.

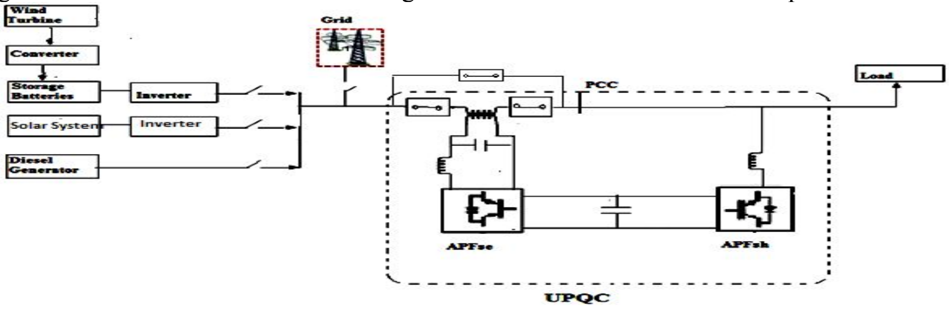

Figure 1 Proposed Power System

Wind turbines are designed for maximum power output and wind speed in the given conditions. These days use of Induction generators are very popular in wind turbine applications since they are reliable, well developed and have loosely coupled devices. Since these loosely coupled devices are heavily damped, they are capable of absorbing slight changes of wind that changes the rotor speed and hence generated power [4]. The operation of the induction machine is determined from the sign of the electromagnetic torque and the slip, that is negative torque and slip correspond to generator operation whereas positive torque and slip correspond to motor operation. The power extracted from the wind is given by

$$P = 0.5 * CpW_v{}^3A_s$$

Where,
P is Power in watt,
W_V is Wind speed in m/s,
C_p is coefficient of performance,
A_s is swept area of the wind turbine blades in m2.

1.1. Wind Generator:

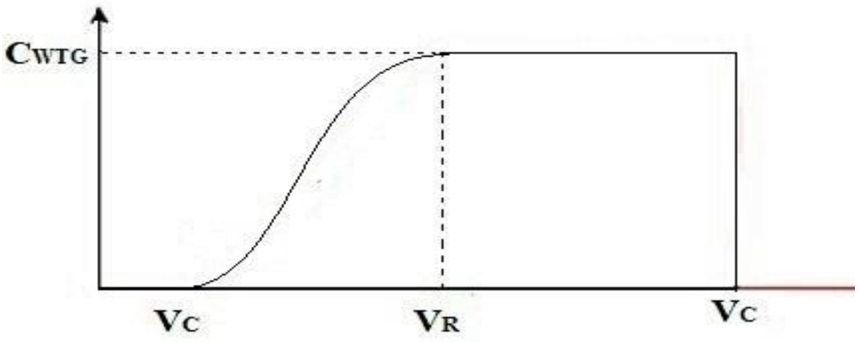

Figure 2 Wind Curve

In wind generator power curve represents a quantitative relationship between wind speed and wind turbine power output and describes the operational characteristics of a wind turbine generator [10]. Thus, for typical output power, a corresponding wind speed can be found on this curve. A typical wind curve of wind turbine generator is shown in figure 2 Where,
V_c is the cut-in speed,
V_R is the rated speed
V_F is the cutout speed
CWTG is the rated Power output

1.2. Diesel Generator

Diesel engines are the best prime movers in remote rural area for power systems and the fuel i.e. diesel availability is less; hence its cost is expensive. This generator for all types of loads, irrespective of the demand and rating, which indicates towards loses when these are run at very low loads. This indicates that the fuel efficiency is very low [4] [9]. The operation on low-load condition results in increased engine maintenance requirements, thereby resulting in fuel use and maintenance as primary concerns. We know that the fuel consumption characteristic of a typical diesel generator is almost quadratic in nature and this linear function can be represented as a simplified model which may be represented mathematically as $F = F_0 + F_{ip}$
Where, F is diesel generator fuel consumption rate, liters/hr.
F_0 : diesel generator fuel consumption at no load in liters/hr.

F_{ip}: incremental diesel fuel consumption rate in liters/hr.
P : diesel generator electrical power output in kW.
The diesel generator efficiency will drop sharply when it operates at less than around 40% of full load and additionally resulting in decreases in life and increased frequency of maintenance. Frequent turning on and turning off will result in increased frequency of maintenance [5].

1.3. Battery model

Since solar and wind power generates electrical energy which in turn has to stored for future use and this will require typical methods for storing energy Batteries are the most common and simplest form of storing energy [4].
Energy storage in a hybrid power system is used for a number of purposes. The most common uses purposes are
1) To reduce the number of diesel stop/starts by using storage to meet high frequency fluctuations in the net load caused by wind turbulence
2) To store excess wind energy so that it may be used later to Reduce fuel consumption
3) For cycle charging in order to reduce diesel running time
4) Stored energy in idle conditions for peak conditions
5) Routine and maintenance work energy requirements
The battery model used here is an expanded form of Kinetic Battery Model illustrated in Figure3. Here battery is viewed as a voltage source in series with a resistance which is internal resistance of battery. The internal resistance Ro is assumed to be constant and the internal voltage E varies with current state of charge.
The terminal voltage V given by $V=E-IR_0$ the model allows the simulation of a variety of types of batteries; both lead acid and nickel cadmium [16]. It accounts for voltage level as a function of state of charge and charge or discharge rate, as well the apparent change of capacity as affected by charge or discharge rate[9,11]. Lead -acid batteries are used in hybrid power systems due to its lower capital costs. Because the expected lifetime of lead -acid batteries are less compare to the other components of a hybrid power system, and because battery wear is related to the operating strategy, the cost associated with battery replacement is considered as an operating cost

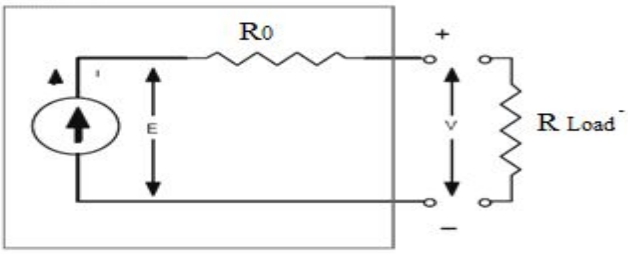

Figure 3: Battery Model

1.4. Discharge Strategies

The aim of the various discharge strategies that is to minimize the operating cost of the system. The operating cost of the system is assumed to be the sum of the hourly fuel costs and battery wear costs. An improved discharge strategy is to set a fixed discharge thresh old at a net power level less than the frugal threshold. Below this fixed threshold, storage would be used to meet the net load if the batteries have sufficient energy. Above this threshold, diesel power would be used. By setting a low threshold, battery discharge would be limited to low net loads where cost savings are greatest. Above the fixed threshold, stored energy is used to meet higher loads at the expense of future low loads where savings could be increased. Below this threshold, the batteries would frequently not have been completely discharged before excess wind power charges the batteries again. This means that opportunities to save costs by using the stored energy at higher power levels are missed.
The objective of fuzzy discharge strategy is to design a practical discharge controller that can perform better in terms of reducing operating costs than the practical discharge strategies. There are two factors that are to be considered in implementing an improved discharge strategy: the current state of charge of the storage batteries and future wind predictions. In general, as the state of charge of the batteries decreases, so too should the threshold of net loads to be met by storage. In this implementation current battery SOC is defined in terms of the three fuzzy sets: Low, Medium, and High the output of the fuzzy controller is the discharge threshold. If the net load is below the discharge threshold and the storage batteries have sufficient energy, then the net load met by the storage alone, allowing the diesel generator to turn off. Otherwise, the diesel generator is used to meet the net load. The important thing is to operate the diesel generator minimally in order to reduce the diesel
consumption. The role of the fuzzy threshold controller is to adjust continuously the discharge threshold for optimal performance based on battery SOC and expected wind conditions

II. 3UNIFIED POWER QUALITY CONDITIONER

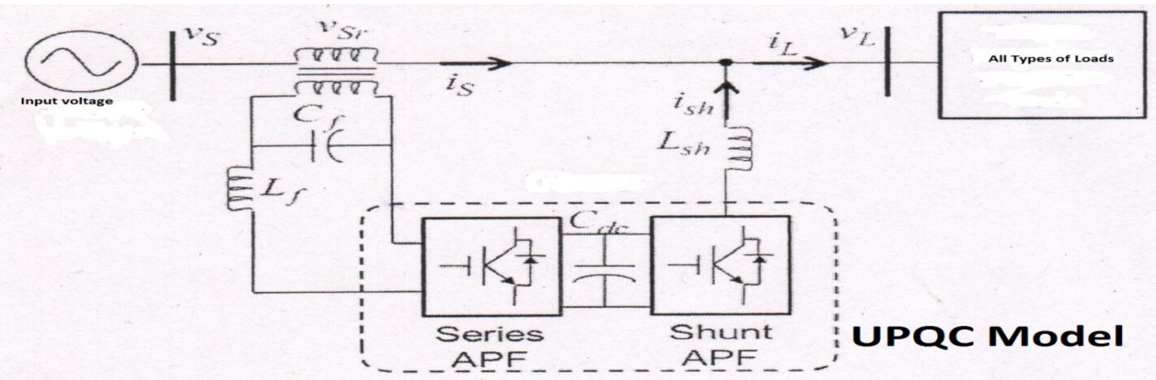

Figure 4: UPQC Structure

To provide balanced, distortion-free, and constant magnitude power to sensitive loads with proper restriction to harmonic, unbalanced, and reactive power demands of loads the **Unified Power Quality Conditioner** is the best solution provider system. **Unified Power Quality Conditioner** is equally applicable for shunt and series active power filters. The series part of the **Unified Power Quality Conditioner** is known as Dynamic Voltage Restorer (DVR) is used to maintain voltage at the terminals of load. The shunt part of the **Unified Power Quality Conditioner**, known as Distribution Static Compensator, is used to compensate load reactive power, harmonics and balance the load currents. This makes the source current balanced and distortion free with unity power factor [12]. Voltage rating of dc-link capacitor largely influences the compensation performance of an active **Unified Power Quality Conditioner** contains two IGBT based Voltage Source Converters, one shunt and one series cascaded by a common DC bus. **Unified Power Quality Conditioner** is adaptable to different activities which contain of two voltage source converters (VSC) connected back-to back through a common dc -link capacitor [9]. The series active filter fed a voltage, which is added at the point of the common coupling (PCC) such that the load ends voltage remains constant due to any voltage disturbance. The main Purpose of the shunt active filter are

1) To compensate for the load reactive power demand and unbalance,
2) to reduce the harmonics from the supply current, and
3) to maintain the common dc link voltage.

The system configuration of a single phase **Unified Power Quality Conditioner** is shown in Figure 4 Whenever the supply voltage undergoes sag then series converter fed suitable voltage with supply. Thus UNIFIED POWER QUALITY CONDITIONER improves the power quality by preventing load current harmonics and improve the input power factor

2.1. Shunt Active Power Filter

Active power filters are devices which generates the same amount of harmonics which are generated by load but at 180 degree phase shifted. Active power filters are devices such as amplifiers etc. Shunt APF injects the compensating current in the line at the point of common coupling (PCC) so that the current at source sides become completely sinusoidal and free from distortions. Generally due to presence of non -linear load there is harmonics & distortions in load current due to which source current also get affected and source current becomes non-sinusoidal and distorted. So to remove this non-sinusoidal behavior of source current we use Shunt APF which provides the compensating current which is same as harmonic generated by load but 180 degree phase shifted and this compensating current is given at PCC which helps in removing distortions from source current and makes source current completely sinusoidal. Shunt APF is also used for reactive power compensation & it also removes all problems which arise due to current harmonics.

The control scheme used in Shunt APF is instantaneous reactive power theory also known as ―p-q theory. p-q theory is used to generate the reference current and this reference current is given to Hysteresis current controller along with compensating current of Shunt APF. Hysteresis current controller is used to generate gating signal which is then given to voltage source inverter.

2.2. Series Active Power Filter

A series active power filter is equipment which is used to mitigate the problems which are caused due to voltage distortions and voltage unbalance in source voltage. The voltage distortions and unbalance means voltage dip, voltage rise, voltage fluctuations, voltage flicker these are removed from the source voltage by means of Series APF. A series APF injects a voltage component in series with supply voltage and removes harmonic component and

distortions, unbalance present in voltage waveform. The series APF is used to remove all these voltage problems from supply voltage and make load voltage perfectly balanced and regulated. Series APF is connected in series with transmission line with a
series transformer. The turns ratio of series transformer should be proper so that the injected voltage should come properly. Here three phase reference voltage is calculated by transforming − − to − −0 reference frame and again by transforming − −0 to − − frame. After that the reference voltage is given to hysteresis voltage controller with the actual output voltage of series APF (voltage we got across series transformer) and the PWM signal is generated which is given to voltage source inverter. The DC voltage is given across VSI so to get real power difference between source and load.

2.3. 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 $C_{dc}= 2S_{load}\, n\, T/4\, C\, V^2_{dc}$
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 **Unified Power Quality Conditioner** micro grid−IR is to maintain smooth power supply during sag/swell/ interruption and extend the flexibility of the DIESEL GENERATOR converters operation during interconnected and islanded modes. For the supply continuity, DIESEL GENERATOR storage system has also been introduced. Therefore, a dc link connection between the capacitor and the DIESEL GENERATOR 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 DIESEL GENERATOR converters and storage. Thus, it will ultimately help to reduce the rating of the APFse converter.

III. WORKING PRINCIPAL

The integration technique of the proposed **Unified Power Quality Conditioner** micro grid−IR to a grid connected and DIESEL GENERATOR integrated micro grid system is shown in Figure1. 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 **Unified Power Quality Conditioner** micro grid−IR. The working principle during the interconnected and islanded mode for this configuration is shown in Figure2 and fig 3.. The operation of **Unified Power Quality Conditioner** micro grid−IR can be divided into two modes

3.1. Interconnected mode

1. The DIESEL GENERATOR 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 DIESEL GENERATOR 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, **Unified Power Quality Conditioner** sends a signal within a preset time to the DIESEL GENERATOR converter to be islanded

3.2. Island Mode

1. The APFse is disconnected during the grid failure and DIESEL GENERATOR 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, DIESEL GENERATOR 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

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3.3. 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 DIESEL GENERATOR converter in the micro grid 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 90 % 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 S micro grid−I, in the proposed **Unified Power Quality Conditioner** micro grid−IR to transfer it to the DIESEL GENERATOR converters. As the

APFse takes the responsibility for compensating voltage sag/swell/unbalance disturbances. On the other hand, it will help to reduce the complexity of islanding detection technique or even can be removed from all the DIESEL GENERATOR converters in a micro grid system. Suitable flow chart can be developed for proper operation to operate the **Unified Power Quality Conditioner** in islanded mode. The voltage at PCC is taken as the reference and it is always in phase with the source and the DIESEL GENERATOR converters, the difference between the Vpcc-ref (pu) and Vs (pu) is V_{error}. 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 V_{error} is less than or equal to 0.6, then 60% sag will be compensated for up to 50 cycles 2) if V_{error} is in between 0.6 and 0.9, then compensation will be for 30 cycles; and 3) otherwise (if $V_{error} \geq 0.9$) 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 V_{error} 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.

IV. SIMULATION & RESULT

Based on the Integration method the signal generation for island detection and the reconnection method for the typical algorithm developed can be framed for 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 **Unified Power Quality Conditioner** micro grid for the voltage sag compensation is shown in figure6 and harmonic current compensation is shown in figure7. Details of performance under different modes of operation are discussed below

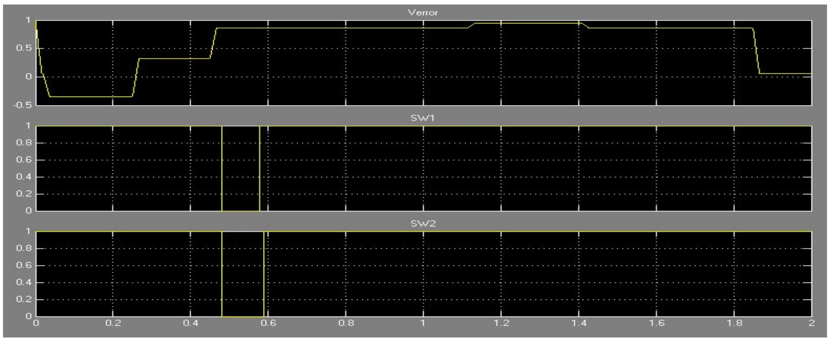

Figure 5(a): Waveform of V_{error} and switch1&2positions during operation

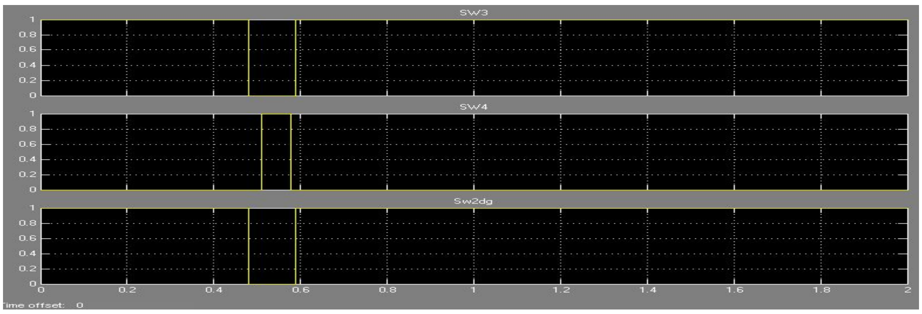

Figure 5(b): waveform for Switch 3,4% Diesel Generator switch operation.

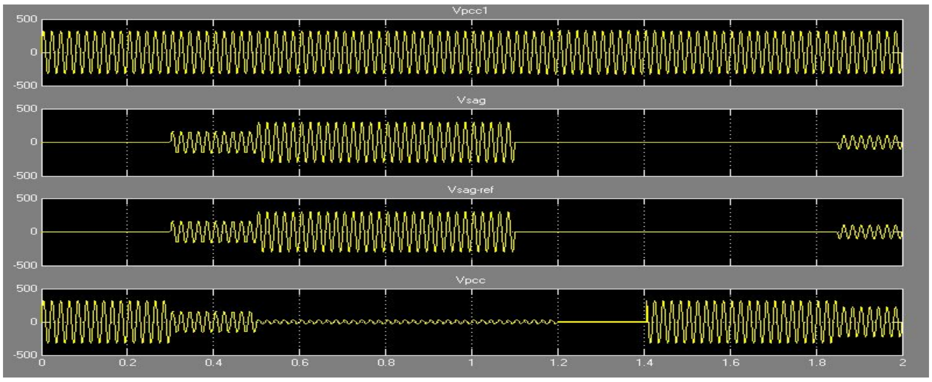

Figure 6: Voltage Sag Compensation in Proposed system

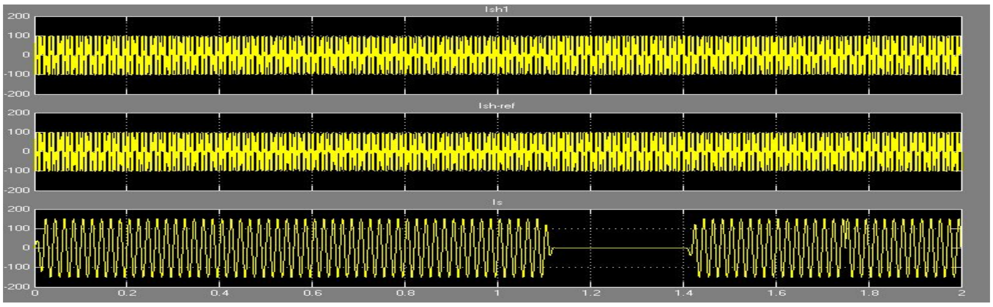

Figure 7 Harmonic Current Distortion in system

4.1. Interconnected mode

Depending upon the power availability the DIESEL GENERATOR Source can supply the power to the load, grid and storage. Therefore bidirectional power flow can be occurred. Hence performance of the **Unified Power Quality Conditioner** 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 Flow mode.

In case the available DIESEL GENERATOR 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 DIESEL GENERATOR supply. Figure6. and Fig7. Shows the performance of APFsh in compensating the reactive and harmonic current generated by the load. The DIESEL GENERATOR Supplies the 0.5 (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 DIESEL GENERATOR 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.

4.2. Island mode

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

V. 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 **Unified Power Quality Conditioner**. The results show that the **Unified**

Power Quality Conditioner micro grid−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 DIESEL GENERATOR converters only supply the active power. Therefore, the DIESEL GENERATOR converters do not need to be disconnected or change their control strategy to keep the micro grid operating in any time with any condition. Islanding detection and seamless reconnection technique by the **Unified Power Quality Conditioner** micro grid−IR and the dynamic change with bidirectional power flow are validated in real time for a DIESEL GENERATOR integrated micro grid system without compromising on power quality

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