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CUSTOM POWER DEVICES TO ENHANCE THE IMPROVEMENT OF POWER QUALITY IN GRID CONNECTED RENEWABLE ENERGY SYSTEMS

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Abstract: This paper presents with the r ole of custom power devices in enhancing the integration of renewable means of energy generation by addressing the various power quality problems associated with the renewable based distributed power generation systems through custom power devices such as STATCOM, UPQC and DVC. Which plays a vital role in improvising the quality of power. The IEEE and IEC standards for grid connected renewable energy systems are one of the critical points of interest for the selection of custom power devices. Photovoltaic (PV) and Wind energy systems integration issues and associated power quality problems are enumerated to address the solution to each using custom power devices are discussed.

I. INTRODUCTION

Non-Renewable means of energy generation systems fronting the twin obliges of shortage of raw materials and the need to reduce emissions. Other constrains such as unavoidable electrical power losses in the long transmission lines, requirement of frequent service of various elements in a distributed power system for high efficiency requirement, etc.. Therefore prominence has increased on distributed generation networks with integration of renewable energy systems into the grid, which lead to energy efficiency and reduction in emissions. With the growth of the renewable energy diffusion into the grid, power quality of the medium to low voltage power transmission system is becoming a major area of interest. However the integration of renewable means of energy systems and their network grid takes place with the aid of power electronics converters. The power electronic converters bridges distributed generation to the grid in Acquiescence with power quality standards. However the use of such power electronic circuits for power conversion and inversion can inject additional harmonics to the systems, creating major power quality if not installed properly STATCOM (Static Compensator) (Shunt Active Power Filter), Dynamic Voltage Restorer (DVR) (Series Active Power Filter) and Unified Power Quality Conditioner (UPQC) (Combination of Series and Shunt Active power Filter) are the recent development of interfacing devices between distribution supply and utility appliances to overcome voltage/ current disturbances and improve the quality by compensating the reactive and harmonic power generated or absorbed by load. Renewable energy sources such as Solar and Wind are the most promising distributed generating sources and their infiltration level to the grid is also on the rise. Though there are numerous benefits lies on distributed generation such as reduction of transmission and distribution losses with improved reliability, Diversification of power sources, voltage support, rise of issues related to power quality is also a major concern. This paper concerns with the various research analysis performed over power quality problems related to solar and wind energy integrated to the grid and the impact of degradation power quality. The feasible topol-ogies by custom power devices into the system to overcome the power quality problems are also discussed.

II. VARIOUS ISSUES OF POWER QUALITY IN DIS-TRINUTED GENERATION

Around 80 % of all power quality related problems can be attributed to faculty connections and wiring. Other categories of power quality problems such as Transients, Electromagnetic Interference, Power frequency disturb-ances, harmonics and low power factor are related to the sources of supply and the type of load at utility. Among those mentioned above, harmonics are the most dominant one. The effects of harmonics on power quality according to the IEEE standard, harmonics in the power system should be limited by two different methods: one is the limit of harmonic current that a user can inject into the utility system at the point of common coupling and the other is the limit of harmonic voltage that the utility can supply to any customer at the point of common coupling.

III. ISSUES OF POWER QUALITY IN GRID CONNECTED RENEWABLE ENERGY SYSTEM

A. Solar Photovoltaic Systems:

Though the output of a photo voltaic panel depends on the solar intensity and cloud cover, the power quality problems not only depend on irradiation but also are based on the overall perfor-mance of solar photovoltaic system including photovoltaic modules, inverter, filters controlling mechanism etc. The short fluctuation of irradiance and cloud cover play an important role for low-voltage distribution grids with high penetration of pho-tovoltaic systems. Therefore, special attention should be paid to the voltage profile and the power flow on the line. It also sug-gests that voltage and power mitigation can be achieved using super-capacitors which result in an increase of about 20% in the cost of the photovoltaic system. Voltage swell may also occur when heavy load is removed from the connection. Concerning distributed generation, voltage disturbance can cause the dis-connection of inverters from the grid and therefore result in

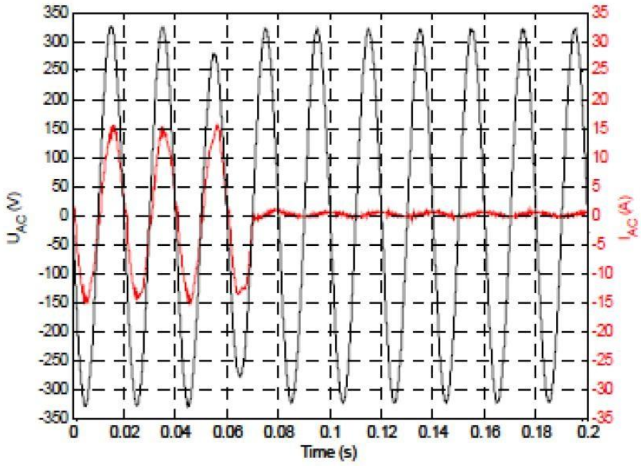

Figure 1: Behavior of a very sensitive inverter

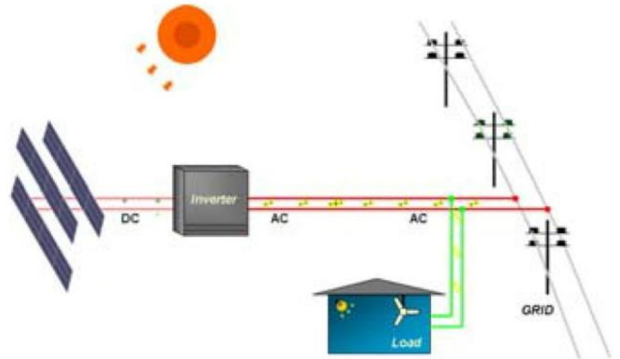

Figure 2: General Structure of Grid-Connected PV system

losses of energy along long term performance of grid connected photovoltaic system shows a remarkable degradation of efficiency due to variation of source and performance of inverter. The general block diagram of grid connected photovoltaic sys-tem is shown in the figure and the system can be a single-phase or three phase depending on the grid connection requirements. The photovoltaic array can be a single or a string of photovoltaic panels either in series or parallel mode connection. Centralized or decentralized mode of photovoltaic systems can also be used. These power electronic converters, together with the operation of non-linear appliances, inject harmonics to the grid, in addition to the voltage fluctuation due to irradiation, cloud cover or shading effects could make the photovoltaic system unstable in terms of grid connection. Therefore, this needs to be considered in the controller design for the inverter. In general, a grid connected photovoltaic inverter is not able to control the reactive and harmonic currents drawn from non-linear loads. This system can also operate in stand-alone mode. But the overall control circuit becomes somewhat more complex. A multifunctional photovoltaic inverter for a grid connected system had been developed recently. This system demonstrates the reliability improvement through UPS functionality, harmonic compensation, reactive power compensation capability together with the connection capability during the voltage sag condition. However, the results show that the power quality improvement remains out of the IEEE range.

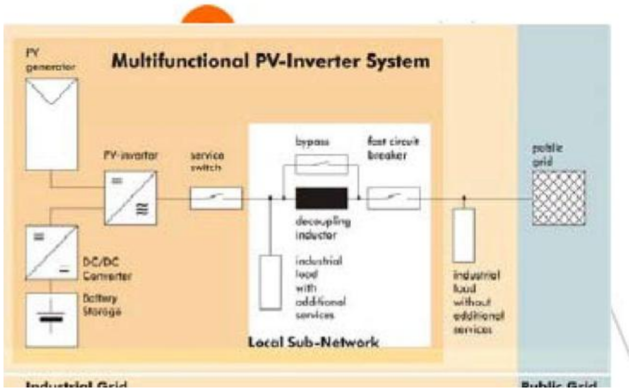

Figure 3: Concept of Multifunctional PV inverter system integrated into an industrial grid

B. Wind Energy System:

A simplified diagram representing some of the common types of wind energy systems are shown in figure 4. from the design perspective it is found that some generators are directly connected to the grid through a dedicated transformer while others incorporate power electronics.

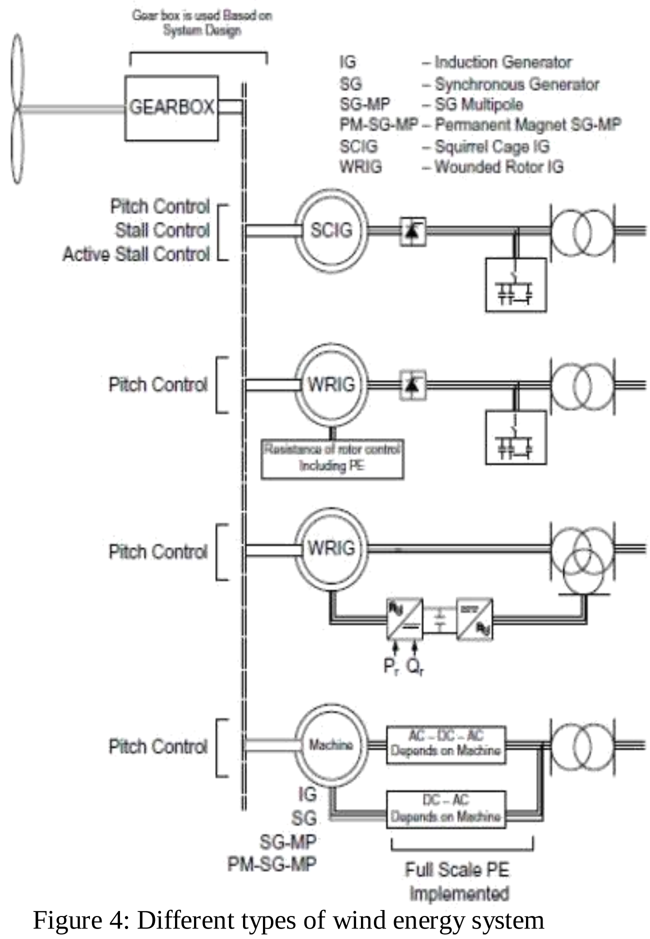

Figure 4: Different types of wind energy system

Many designs, however, include some level of power electronics to improve controllability and operating range. Whatever connection configuration is used, each turbine itself has an effect on the power quality of the transmission system. Recent analysis and study shows that the impact of the yaw error and horizontal wind shear on the power and voltage oscillations is more severe than the effects due to the tower shadow and vertical wind shear. The new grid codes adopted for wind power integration has identified the problems of integrating large amounts of wind energy to the electric grid. It suggests that new wind farms must be able to provide voltage and reactive power control, frequency control and fault ride-through capability in order to maintain the electric system stability. For the existing wind farms with variable speed, double fed induction generators and synchronous generators, a frequency response in the turbine control system can be incorporated by a software upgrade. Wind farms with fixed speed induction generators have to be phased out because they cannot offer the required voltage or frequency control. An overview of the developed controllers for the converter of grid connected system in which it is also been seen that the double fed induction generator has now the most efficient design for the regulation of reactive power and the adjustment of angular velocity to maximize the output power efficiency. These generators can also support the system during voltage sags. However, the drawbacks of converter-based systems are harmonic distortions injected into the system. Being a single-stage buck-boost inverter, the recently proposed Z-source inverter can be a good candidate to mitigate the power quality problems for future distributed generation system connected to the grid.

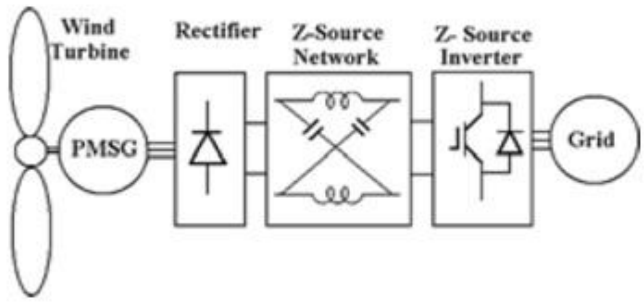

Figure 5: PMSG based WECS with DC boost chopper and ZSI

Anti-islanding is one of the important issues for grid connected distributed generation system. A major challenge for the islanding operation and control schemes is the protection coordination of distribution systems with bidirectional flows of fault current. This is unlike the conventional over-current protection for radial systems with unidirectional flow of fault current. Therefore extensive research in being carried out and an overview of the existing protection techniques with islanding operation and control, for preventing disconnection of distribution generators during loss of grid.

IV. IMPACT OF POWER QUALITY PROBLEMS

The impacts of power quality are usually divided into three broad categories: direct, indirect and social. Documentary reports satiate that the cost of power quality due to the effect of voltage dips and swells, sustained interruptions, interruptions, harmonics, surges and transients, flicker, unbalance, earthling and electromagnetic compatibility problems. It is found that the annual cost of waste caused by poor power quality for India according to this analysis exceeds 140 crores where industry accounts for over 90% of this wastage. Dips and short interruptions account for almost 60% of the over-all cost to industry and 57% for the total sample. The study also shows that the economic impact of inadequate power quality costs industry and service sector some 4% and 0.15% of their annual turnover. At the same time it is necessary to consider the impact of distributed generation in terms of the cost of power quality. The problem of wastage cost evaluation due to dip and interruption on distributed generation has been estimated. Based on the operating hours, the frequencies of power quality events occur and cost of power quality events indicates the positive or negative impact of distributed generation.

V. MITIGATION OF POWER QUALITY PROBLEMS

There are two ways to mitigate the power quality problems either from the customer side or from the utility side. The first approach is called load conditioning, which ensures that the equipment is less sensitive to power disturbances, allowing the operation even under significant voltage distortion. The other solution is to install line conditioning systems that suppress or counteracts the power system disturbances. Several devices including flywheels, super-capacitors, other energy storage systems, constant voltage transformers, noise filters, isolation transformers, transient voltage surge suppressors, harmonic filters are used for the mitigation of specific power quality

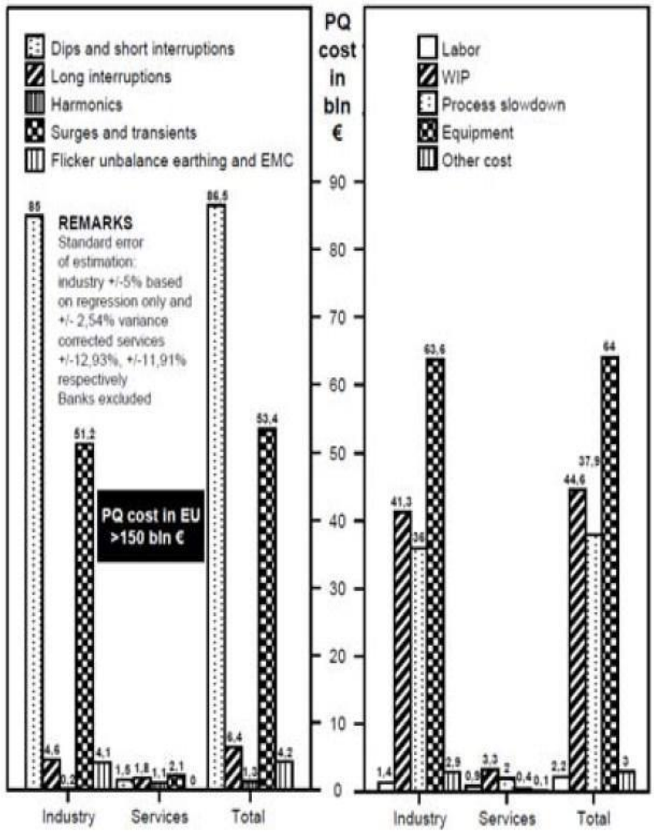

Figure 6: Extrapolation of Power Quality cost to economy

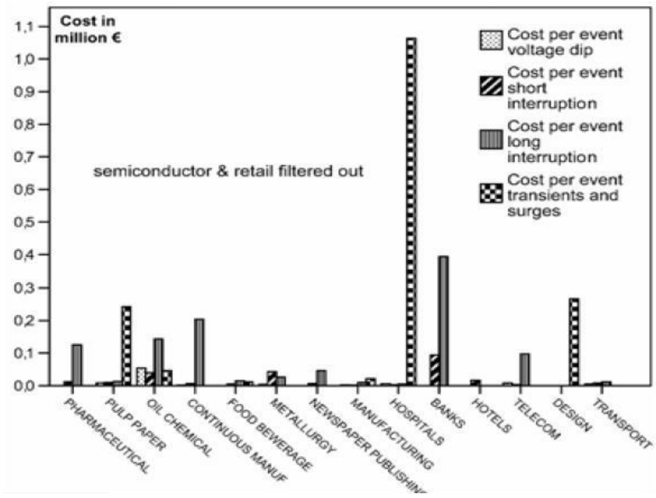

Figure 7: The cost per event identification by the survey

problems. Custom power devices like DSTATCOM, DVR and UPQC are capable of mitigating multiple power quality problems associated with utility distribution and the end user appliances. The following section of the paper looks at the role of custom power devices in mitigating power quality problems in relation to grid integrated solar and wind energy systems.

VI. ROLE OF CUSTOM POWER DEVICES

Custom power embraces a family of power electronic devices, or a toolbox, which is applicable to distribution systems to pro-vide power quality solutions. This technology has been made possible due to the widespread availability of cost effect e high power semiconductor devices such as GTOs and IGBTs, low cost microprocessors or microcontrollers and techniques developed in the area of power electronics. DSTATCOM is a shunt-custom power device specially de-signed for power factor correction, current harmonics filtering, and load balancing. It can also be used for voltage regulation at a distribution bus. It is often referred to as a shunt or parallel active power filter. It consists of a voltage or a current source PWM converter. It operates as a current controlled voltage source and compensates current harmonics by injecting the harmonic components generated by the load but phase shifted by 180 degrees. With an appropriate control scheme, the DSTATCOM can also compensate for poor load power factor.

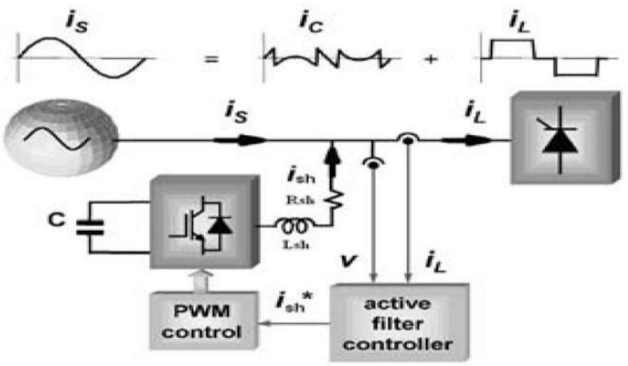

Figure 8: System configuration of DSTATCOM

The DVR is a series-connected custom power devices to protect sensitive loads from supply side disturbances. It can also act as a series active filter, isolating the source from harmonics generated by loads. It consists of a voltage-source PWM converter equipped with a dc capacitor and connected in series with the utility supply volt-age through a low pass filter (LPF) and a coupling transformer as shown in figure. This device injects a set of controllable ac voltages in series and in synchronism with the distribution feeder voltages such that the load-side voltage is restored to the desired amplitude and wave-form even when the source voltage is unbalanced or distorted.

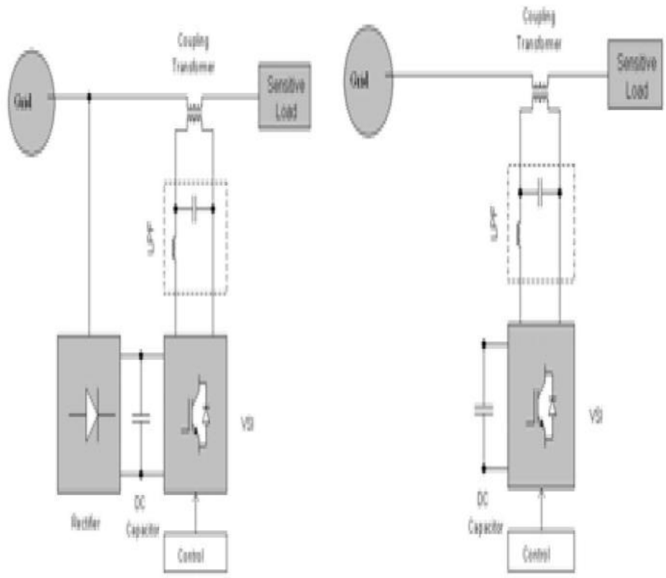

Figure 9: Rectifier supported, DC capacitor supported DVR

UPQC is the integration of series and shunt active filters, connected back to back on the dc side and share a common DC capacitor as shown in figure below. The series component of the UPQC is responsible for mitigation of the supply side disturb

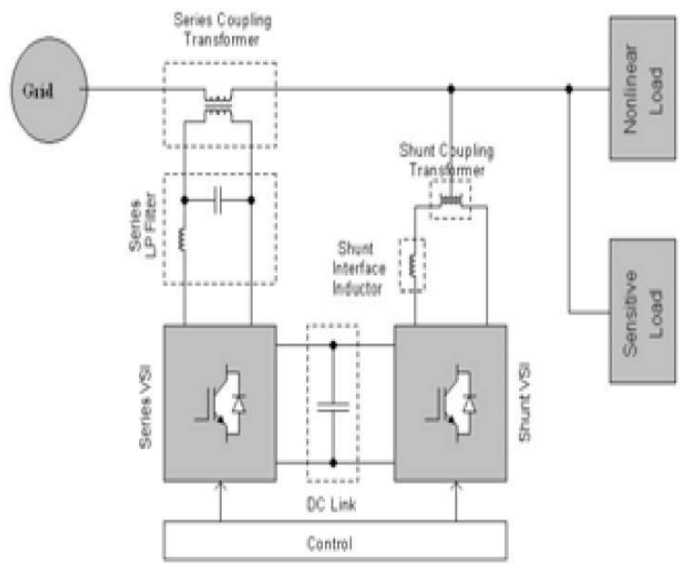

Figure 10: System configuration of UPQC

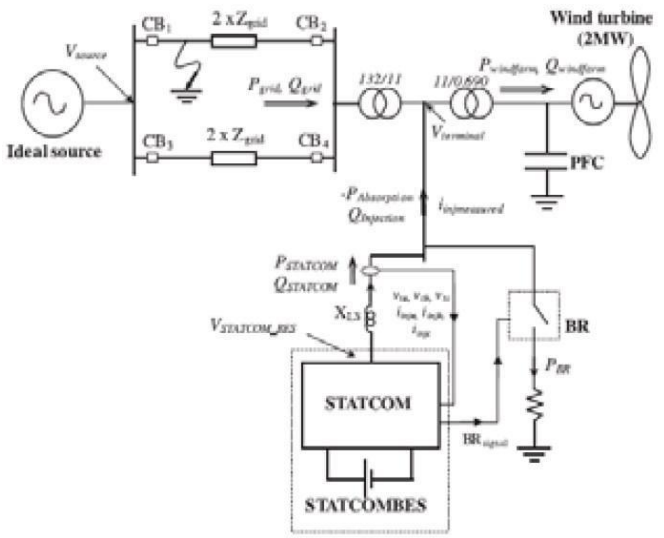

Figure 11: STATCOM BESS and BR to improve PQ

ances: voltage sags/swells. Flicker, voltage unbalance and harmonics. It inserts voltages so as to maintain the load voltages at a desired level; balanced and distortion free. The shunt component is responsible for mitigating the current quality problems caused by the consumer: poor power factor, load harmonic currents, loads un-balance etc. it injects currents in the ac system such that the source currents become unbalanced sinusoids and in phase with the source voltages. The application of the STATCOM is already reported for wind power applications in stability enhancement, transient, flicker mitigation etc. as the traditional STATCOM works only in leading and lagging operating mode, its application is therefore limited to reactive power support only. The fluctuating power due to the variation of wind cannot be smoothed by using a STAT-COM, because it has no active power control ability. To over-come this problem, Battery Energy Storage System (BESS) has been incorporated with STATCOM (STATCOM/BESS), which has both real and reactive power control ability. Similarly the DVR can also be used with BESS to control the reactive and active power flow with harmonic voltage mitigation for a grid-connected, distributed generation system.

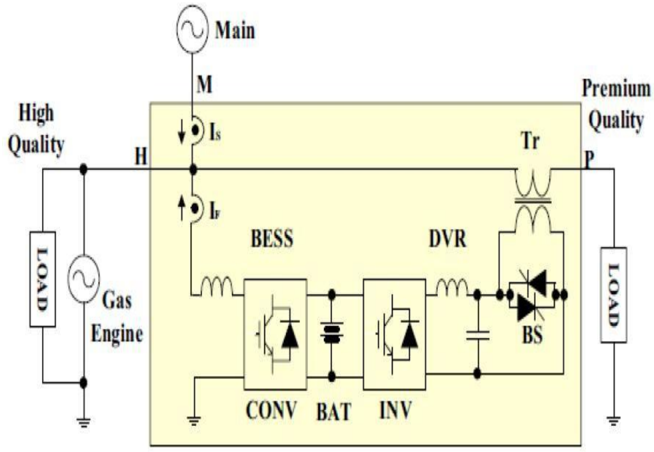

Figure 12: Power Quality control using DVR and BESS

Very recent research reports show that significant research and development has been carried out on the application of UPQC to grid-connected PV and wind energy systems. As the UPQC can compensate for almost all existing grid, placement of a UPQC in the distributed generation network can be multipurpose. A structure has been proposed in where PV is connected to the DC link in the UPQC as an energy source. It works both in inter-connected and islanded mode. UPQC has the ability to inject power using PV to sensitive loads during source voltage interruption. The advantage of this system is voltage interruption compensation and active power injection to the grid in addition to the other normal UPQC abilities, but the system's functionality may be comprised if the solar resource is not sufficient during the voltage interruption condition The application of UPQC to overcome the grid integration problems of the FSIG is investigated in figure 14. the FSIG fails to remain connected to the grid in the event of grid voltage dip or line fault due to excessive reactive power requirement the drop in voltage created over speeding or turbine, which causes a protection trip. With the aid of the UPQC, this fault ride through capability is achieved, which greatly enhances system stability. Result show that the UPQC as one of the best devices for the integration of wind energy system to the grid.

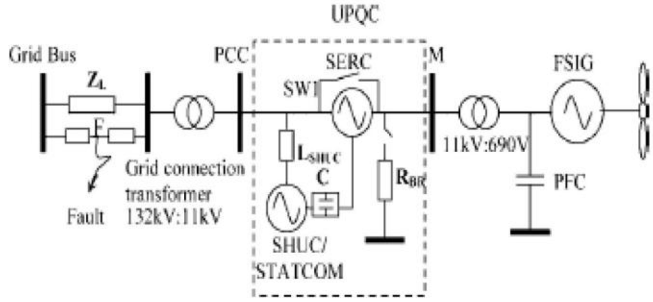

Figure 13: Grid connected wind energy system with UPQC

The concept of a custom power park has been proposed using CPDs, to provide quality power at various level. It has been ex-tended further by using supervisory control techniques to coordinate the custom power devices by providing the pre specified quality of power.

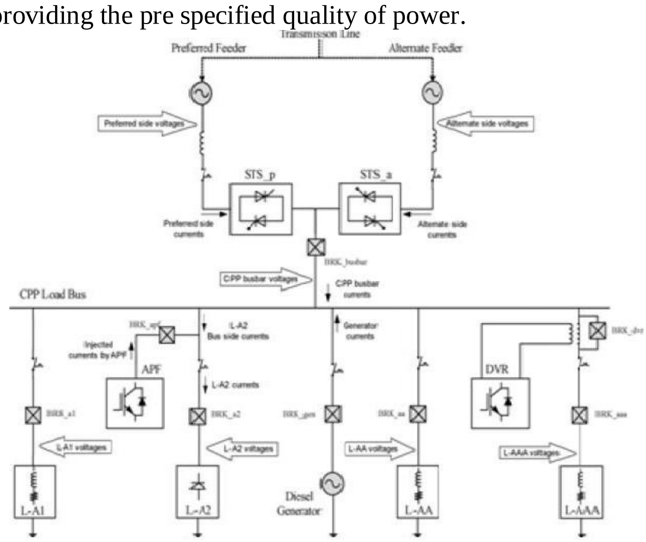

Figure 14: Single line diagram of CPP

VII. CONCLUSION

Recent trends in the power generation and distribution system shows that penetration level of DG into the grid has increased considerably. End user appliances are becoming more sensitive to the power quality condition. Extensive research on CPEs for the mitigation of power quality problems are also carried out. CPDs are found to be very capable in integrating solar and wind energy sources to the grid. They play an important role in the concept of custom power park in delivering quality power at various levels.

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