DVR AND STATCOM BASED POWER QUALITY IMPROVEMENT METHOD IN HYBRID SYSTEM

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Abstract

Integration of the grid with the non conventional energy system always has been a problematic scenario and with the conventional energy depleting very fast and the power demand increasing every passing day, it has become absolute necessary to focus on renewable energy systems and their integration with the conventional system. Lots and lots of project are being undertaken which are able to harness power from the renewable energy sources like, sun, wind, water, etc . The integration of these systems (wind energy, hydro energy, solar power etc.) created different kinds of problems in the grid like system stability problems or power quality issues which needs to be resolved. Conventionally passive filters were used but nowadays active filters such as Static Synchronous Compensator (STATCOM) and Dynamic Voltage Restorer (DVR) are chosen for the task. STATCOM is a device that regulates the voltage level or the reactive power in the system. It is used to maintain voltage stability, enlargement of critical clearing time. DVR is a voltage restorer that can solve the voltage power quality issues. This objective in this work has been to integrate the STATCOM and the DVR for voltage control and harmonics filtering. The simulation has been carried in MATLAB/SIMULINK and the combined work of the STATCOM and the DVR in improving the power quality has been shown.

Index Terms: STATCOM,DVR, PMSG wind turbine, Harmonics.

I. INTRODUCTION

Power quality has taken a centrestage in the present scenario as there has been a marked increase in the use of electronic equipment used in communication and information technolog, power electronics equipments such as adjustable speed drives (ASD), programmable logic controllers (PLC), energy-efficient lighting, which has led to a complete change of electric loads nature. These loads being non linear in nature are the cause of reduction in power quality. The industrial equipments along with the house hold equipments have become more and more sensitive due to the increase usage of digital components. The most critical areas are the continuous process industry and the information technology services.

Disturbance brings along with itself lots of financial losses and reduction in productivity. This implies that some measures must be taken in order to achieve higher levels of Power Quality. Use of renewable energy has increased through time and integration of renewable energy such as wind, photovoltaic, fuel cell, and tidal to the grid solved many problems and replenished the exceeding and ascending need for electrical energy. Integration of the renewable energy with the grid has lead to a more complex electrical network or "Grid".

This enlargement and enrichment in equipment has caused problems such as stability, reliability and power quality [5], [6], [7] and [8]. The issue of power quality is of great importance to the to the wind turbine [6]. and there's a need to find solutions to these problems, using different technologies such as smart meters, monitoring system, controllers, remote ability.

The integration of wind energy into a weak system is a challenge; voltage fluctuation, voltage dips, swells and swags are created due to the uncontrollable resource and the nature of the DWIG (Distributed Wind Induction Generators) on the already weak system. This causes stability issues, reliability and power quality issues which need to be solved [9].

The rest of this paper is organized as follows. Section II reviews the techniques of harvesting power from renewable energy sources, Section III discusses the power quality issues, Section IV talks about improvement techniques followed by result analysis in Section V and conclusion in Section VI.

II. POWER GENERATION FROM NON CONVENTIONAL ENERGY SOURCES

Wind has long been used as a source of power .Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, and uses little land. The net effects on the environment are far less problematic than those of nonrenewable power sources.

Wind power gives variable power which is very consistent from year to year but which has significant variation over shorter time scales. It is therefore used in conjunction with other electric power sources to give a reliable supply. As the proportion of wind power in a region increases, a need to upgrade the grid, and a lowered ability to supplant conventional production can occur. Power management techniques such as having excess capacity, geographically distributed turbines, dispatchable backing sources, sufficient hydroelectric power, exporting and importing power to neighboring areas, using vehicle-to-grid strategies or reducing demand when wind production is low, can in many cases overcome these problems.

Early days wing power system used y Induction generators, which were often used for wind power projects which required reactive power for excitation so substations used in wind-power collection systems included substantial capacitor banks for power factor correction. These generators have been replaced by variable speed generators combined with partial- or full-scale power converter between the turbine generator and the collector system, which generally have more desirable properties for grid interconnection and have Low voltage ride through-capabilities and off late doubly fed machines with partial-scale converters or squirrel-cage induction generators or synchronous generators (both permanently and electrically excited) with full scale converters are being used increasingly. Since wind speed is not constant, a wind farm's annual energy production is never as much as the sum of the generator nameplate ratings multiplied by the total hours in a year. The ratio of actual productivity in a year to this theoretical maximum is called the capacity factor.

Electricity generated from wind power can be highly variable at several different timescales: hourly, daily, or seasonally. Annual variation also exists, but is not as significant. Because instantaneous electrical generation and consumption must remain in balance to maintain grid stability, this variability can present substantial challenges to incorporating large amounts of wind power into a grid system. Where a suitable head of water is not available, pumped-storage hydroelectricity or other forms of grid energy storage such as compressed air energy storage and thermal energy storage can store energy developed by high-wind periods and release it when needed.

Another non conventional energy source which has gained a lot of attention is the solar enery. Solar energy is radiant light and heat from the Sun harnessed using a range of ever-evolving technologies such as solar heating , photovoltaic , solar thermal energy, solar architecture and artificial photosynthesis.

The amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined, The potential solar energy that could be used by humans differs from the amount of solar energy present near the surface of the planet because factors such as geography, time variation, cloud cover, and the land available to humans limits the amount of solar energy that we can acquire.

However, the use of photovoltaics that can follow the position of the sun can significantly increase the solar energy potential in areas that are farther from the equator. Time variation effects the potential of solar energy because during the nighttime there is little solar radiation on the surface of the Earth for solar panels to absorb. This limits the amount of energy that solar panels can absorb in one day. Cloud cover can affect the potential of solar panels because clouds block incoming light from the sun and reduce the light available for solar cells.

In addition, land availability has a large effect on the available solar energy because solar panels can only be set up on land that is unowned and suitable for solar panels. Roofs have been found to be a suitable place for solar cells, as many people have discovered that they can collect energy directly from their homes this way. Other areas that are suitable for solar cells are lands that are unowned by businesses where solar plants can be established.

Active solar techniques use photovoltaics, concentrated solar power, solar thermal collectors, pumps, and fans to convert sunlight into useful outputs. Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun. Active solar technologies increase the supply of energy and are considered supply side technologies, while passive solar technologies reduce the need for alternate resources and are generally considered demand side technologies.

In the last two decades, photovoltaics (PV), also known as solar PV, has evolved from a pure niche market of small scale applications towards becoming a mainstream electricity source. A solar cell is a device that converts light directly into electricity using the photoelectric effect. The first solar cell was constructed by Charles Fritts in the 1880s.Off-grid PV systems have traditionally used rechargeable batteries to store excess electricity. With grid-tied systems, excess electricity can be sent to the transmission grid, while standard grid electricity can be used to meet shortfalls. Pumped-storage hydroelectricity stores energy in the form of water pumped when energy is available from a lower elevation reservoir to a higher elevation one. The energy is recovered when demand is high by releasing the water, with the pump becoming a hydroelectric power generator.

III. POWER QUALITY ISSUES

With power comes the issues which are concerned with its quality. With the non conventional energy being used at a large scale ,power quality issues have taken a centre stage and has necessitated a need to know the root cause of the power quality issues . Various power quality issues that normally occur in a power system are listed in Table I below .

Table I Table showing Various Power Quality Issues

Issue	Nature	Causes	Effects
Voltage Sag	Voltage decrease between 10 and 90% of the nominal rms voltage for durations of 0,5 cycle to 1 minute.	Faults on the transmission or distribution network , Connection of heavy loads and start-up of large motors.	Malfunction of digital equipment , that may lead to a process stoppage.
Very Short Interruptions	Total interruption of electrical supply for few millisecond	Insulation failure, lightning and insulator flashover.	Tripping of protection devices, loss of information
Long Interruptions	Total interruption of supply for duration upto 2 seconds	Equipment failure in the power system network, storms, fire etc.	Stoppage of all equipment .
Voltage Spike	Very fast variation of the voltage value upto few millisecond	Lightning, switching of lines or power factor correction	Destruction of components (particularly electronic components) .
Voltage Swell	Momentary increase of the voltage, at the power	Start/stop of heavy loads, badly	Data loss, flickering of lighting

	frequency, outside the normal tolerances.	dimensioned power sources, badly regulated transformers.	and screens, stoppage or damage of sensitive equipment.
Harmonic Distortion	Voltage or current waveforms assume non-sinusoidal shape.	Electric machines working above the knee of the magnetization curve, all non-linear loads.	Increased probability in occurrence of , loss of efficiency in electric machines, electromagnetic interference with communication systems etc
Voltage Fluctuation	Oscillation of voltage value.	Arc furnaces, frequent start/stop of electric motors .	The most perceptible consequence is the flickering of lighting and screens.
Noise	Imposition of high frequency signals on the waveform of the power-system frequency.	Interferences provoked by Hertzian waves such as microwaves, television diffusion, and radiation due to welding machines.	Disturbances on sensitive electronic equipment, usually not destructive
Voltage Unbalance	A voltage variation in a three-phase system in which the three voltage magnitudes or the phase angle are different	Large single-phase loads ,incorrect distribution of all single-phase loads by the three phases of the system	The most affected loads are three-phase induction machines.

IV. Power Quality Mitigation Techniques

The mitigation of PQ problems may take place at different levels: transmission, distribution and the end use equipment. Several measures can be taken at these levels.

Table II Table showing the issue areas and probable mitigation measures

Issues Areas	Remedial Measure
Transmission	Assure Grid Adequacy
Distribution	Assure Grid Adequacy
Distributed Resources	Develop Advanced Distributed Resources Develop Codes and Standards
Power Quality Interface	Develop Codes and Standards Develop Enhanced Interface Devices
End User Devices	Make End Use Device less sensitive

1. Grid Adequacy

Many PQ problems have origin in the transmission or distribution grid. Thus, a proper transmission and distribution grid, with adequate planning and maintenance, is essential to minimize the occurrence of PQ problems.

2. Distributed Resources – Energy Storage Systems

Interest in the use of distributed energy resources (DER) has increased substantially over the last few years because of their potential to provide increased reliability. These resources include distributed generation and energy storage systems. Energy storage systems, also known as restoring technologies, are used to provide the electric loads with ride-through capability in poor PQ environment.

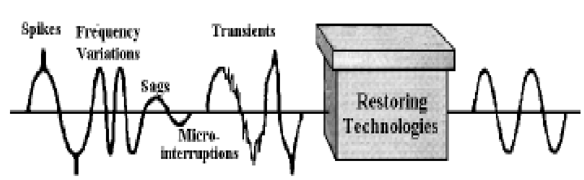


Figure 1 principle of power restoration

Recent technological advances in power electronics and storage technologies are turning the restoring technologies one of the premium solutions to mitigate PQ problems.

The first energy storage technology used in the field of PQ, yet the most used today, is electrochemical battery. Although new technologies, such as flywheels, super capacitors and superconducting magnetic energy storage (SMES) present many advantages, electrochemical batteries still rule due to their low price and mature technology.

A. Flywheels

A flywheel is an electromechanical device that couples a rotating electric machine (motor/generator) with a rotating mass to store energy for short durations. The flywheel provides power during a period between the loss of utility supplied power and either the return of utility power or the start of a back-up power system (i.e., diesel generator). Flywheels typically provide 1-100 seconds of ride-through time, and back-up generators are able to get online within 5-20 seconds.

B. Supercapacitors

Supercapacitors (also known as ultracapacitors) are DC energy sources and must be interfaced to the electric grid with a static power conditioner, providing energy output at the grid frequency.

C. SMES

A magnetic field is created by circulating a DC current in a closed coil of superconducting wire. The path of the coil circulating current can be opened with a solid-state switch, which is modulated on and off. Due to the high inductance of the coil, when the switch is off (open), the magnetic coil behaves as a current source and will force current into the power converter which will charge to some voltage level.

3.Distributed Resources – Distributed Generation

Distributed Generation (DG) units can be used to provide clean power to critical loads, isolating them from disturbances with origin in the grid. DG units can also be used as backup generators to assure energy supply to critical loads during sustained outages. Additionally DG units can be used for load management purposed to decrease the peak demand.

4. Enhanced Interface Devices

Besides energy storage systems and DG, some other devices may be used to solve PQ problems. Using proper interface devices, one can isolate the loads from disturbances deriving from the grid.

A. Dynamic Voltage Restorer

A dynamic voltage restorer (DVR) acts like a voltage source connected in series with the load. The output voltage of the DVR is kept approximately constant voltage at the load terminals by using a step-up transformer and/or stored energy to inject active and reactive power in the output supply trough a voltage converter.

B. Transient Voltage Surge suppressors (TVSS)

Transient voltage surge suppressors are used as interface between the power source and sensitive loads, so that the transient voltage is clamped by the TVSS before it reaches the load.

C. Constant Voltage Transformers

Constant voltage transformers (CVT) were one of the first PQ solutions used to mitigate the effects of voltage sags and transients. To maintain the voltage constant, they use two principles that are normally avoided: resonance and core saturation.

D. Noise Filters

Noise filters are used to avoid unwanted frequency current or voltage signals (noise) from reaching sensitive equipment. This can be accomplished by using a combination of capacitors and inductances that creates a low impedance path to the fundamental frequency and high impedance to higher frequencies, that is, a low-pass filter.

E. Isolation Transformers

Isolation transformers are used to isolate sensitive loads from transients and noise deriving from the mains. In some cases (Delta-Wye connection) isolation transformers keep harmonic currents generated by loads from getting upstream the transformer..

F. Static VAR Compensators

Static VAR compensators (SVR) use a combination of capacitors and reactors to regulate the voltage quickly. Solid-state switches control the insertion of the capacitors and reactors at the right magnitude to prevent the voltage from fluctuating.

G. Harmonic Filters

Harmonic filters are used to reduce undesirable harmonics. They can be divided in two groups: passive filters and active filters.

Passive filters consist in a low impedance path to the frequencies of the harmonics to be attenuated using passive components (inductors, capacitors and resistors).
Active filters analyse the current consumed by the load and create a current that cancel the harmonic current generated by the loads..

5. Develop Codes and Standards

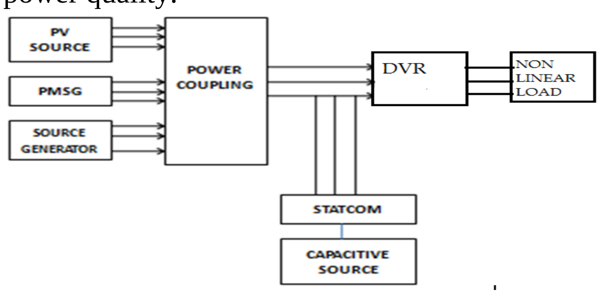
Some measures have been taken to regulate the minimum PQ level that utilities have to provide to consumers and the immunity level that equipment should have to operate properly when the power supplied is within the standards. One major step in this direction was taken with the CBEMA curve , created by the Computer and Business Equipment Manufacturer's Association..

6. Make End-use Devices Less Sensitive

Designing the equipment to be less sensitive to disturbances is usually the most cost effective measure to prevent PQ problems. Some manufacturers of end-use equipment are now recognising this problem, but the competitive market means that manufacturers should reduce costs and only respond to customers requirements.

V. Proposed Hybrid Model

The The proposed system explores the effect of using STATCOM and DVR to improve the power quality.



Figure(2) Proposed Hybrid Model.

The Above block shows the proposed scheme in which the DVR and STATCOM. The figure above shows the grid or the infinite bus connected to the grid, it shows the WTIG, a non-linear load for harmonics generation. The DVR and STATCOM are used for Active filtering. They cancel the effect of voltage sags and swells by injecting a voltage into the system, and remove the harmonics by injecting a current into the system.

STATCOM operation

After the wind turbine is initialized and will be running and when the Non-Linear load will be connected to the system, the voltage and current at the Grid will be distorted and will need to be filtered. Here the STATCOM (Active filter) will be activated and will inject the exact current into the system needed to cancel the effect of the harmonics. This reference injected current will be generated by the hysteresis control technique.

DVR operation

When a wind turbine will be initially connected to the grid, it will needs reactive power for the induction generator to start producing electric power. This will causes the voltage to drop at the Grid. At this instant the DVR should start its operation and compensate for the voltage drop at the critical load.

VI. Results

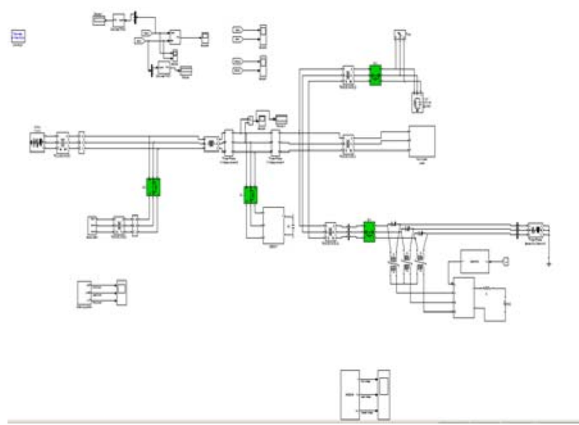


Figure 3 The proposed simulation model

We have connected a STATCOM for removal of harmonics and DVR for injecting compensation voltage. The fault is injected in the system at time t = 0.4 to t= 0.6 and the result of the simulation are given below.

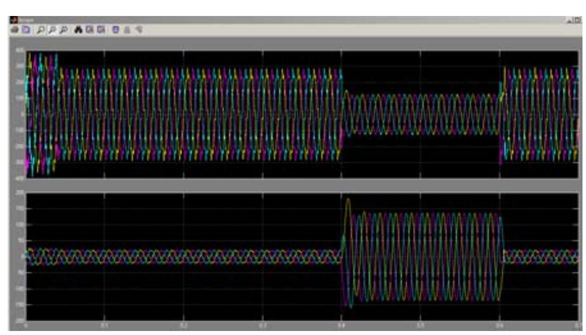


Figure 4 System Load voltage and current

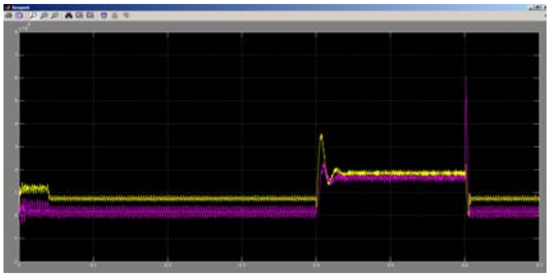


Figure 5 Active reactive power of the system

STATCOM

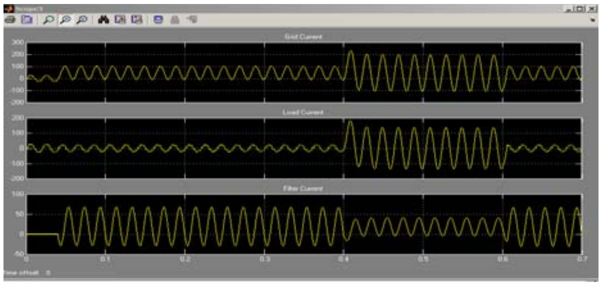


Figure 6 STATCOM removing harmonics

DVR

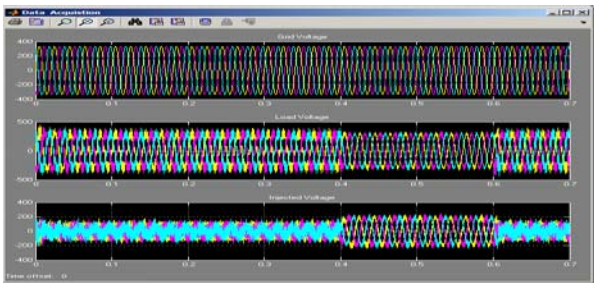


Figure 7 DVR Injecting voltage

In figure 4 above we observe that when the STATCOM comes into play at time t = 0.4 to t=0.6 and the harmonics are reduced. And similarly we observe that the DVR comes into play at time t = 0.4 to t=0.6 and injects suitable amount of voltage to make the system stable.

VI CONCLUSION

In this work non-linear load like simple AC to DC rectifiers have been used. In this work we have examined the combined usage of the STATCOM and the DVR. We also observe that the STATCOM removes the harmonics from the system in presence of fault and similarly the DVR maintains the voltage whenever that system encounters fault.

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