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ACTIVE POWER FLOW CONTROL OF WIND-PV HYBRID SYSTEM USING AI TECHNIQUE

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ABSTRACT

Scarcity of power has been one of the nightmare issues for mankind in the modern age. Renewable Energy Sources (RES) working parallel with conventional power plants are playing a lead role in narrowing the difference between supply and demand. Among all the available renewable energy sources wind-solar hybrid systems are the most popular one. Due to their natural advantage of being complimentary to each other, they are assuring reliability to the utility. Power quality issues arising due to the usage of non-linear loads at the point of common coupling are addressed with the help of power electronic device interfacing RES to the grid. The proposed architecture of the hybrid system consists of H-bridge multilevel inverter based wind turbine and solar PV. The PV system produces dc output whereas WTG generates ac output voltage. For grid connection of these two sources, different power electronic interfaces are required. The DC-shunted grid connected hybrid PV/wind power system is used. In this system, the output of PV array is connected to DC/DC boost converter and the dc link voltage is regulated. AC output voltage of wind energy system is rectified using uncontrolled rectifier and then a DC/DC boost converter is used to control DC link voltage. The multilevel inverter is incorporated with shunt active power filter functionality is further used to interface the DC shunted wind-solar hybrid model to the grid. The work presented in this paper consists of Modelling and Simulation of wind-solar hybrid energy system and interfacing it to the grid through the interfacing inverter. A suitable control strategy which will add shunt active filter functionality to the RES interfacing device to the grid is also undertaken.

INTRODUCTION

Energy market is directed strongly towards energies. The facts of running out of conventional fuels like coal and oil beside the high rates of carbon-dioxide emissions have forced many countries to concentrate their research and future power generation planes in the field of clean renewable energies. So people are encouraged to use renewable energy sources (e.g. solar energy, wind energy). The reasons are that renewable energy sources are clean and infinite. They can replace some of fossil energy sources to reduce greenhouse gas emissions and air pollution. A drawback of these renewable source in rural countryside is likely a cheap solution in comparison with developing a complete electrical network. The world is facing a major threat of fast depletion of the fossil fuel reserves. Most of the present energy demand is met by fossil and nuclear power plants. A small part is met by renewable energy technologies such as the wind, solar, biomass, geothermal etc. As per the law of conservation of energy, "Energy can neither be created, nor be destroyed, but it can only be converted from

one form to another". Most of the research now is about how to conserve the energy and how to utilize the energy in a better way. Research has also been into the development of reliable and robust systems to harness energy from non conventional energy sources. Among them, the wind and solar power sources have experienced a remarkable rapid growth in the past 10 years. Both are pollution free sources of abundant power. Wind energy is the kinetic energy associated with the movement of atmospheric air. Wind energy systems convert this kinetic energy to more useful forms of power. There is growing awareness that renewable energy such as photovoltaic system and wind power have an important role to play in order to save the situation. Hybrid power system consists of a combination of renewable energy source such as wind generators, solar of charge batteries and provide power to meet the energy demand, considering the local geography and other details of the place of installation. These type of systems are connected to the main utility grid. They are also used in stand-alone applications and operate independently and reliably. The importance of hybrid systems has grown as they appear to be the right solution for a clean and distributed energy production. This paper presents wind-solar hybrid power system that harnesses the renewable energy. Now, more than ever,

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electronic equipment and computing devices are used in all types of industrial processes. This has been pivotal in making these processes more productive, efficient, and safe. However, this trend also makes manufacturing processes and equipment more vulnerable to real world power quality conditions. Power quality is related to fluctuations in the electrical supply in the form of momentary interruptions, voltage sags or swells, transients, harmonic distortion, electrical noise, and flickering lights, among others. The electrical power grid is designed for delivering power reliably, namely maximizing power availability to customers. However, power quality events are largely untracked, and a result, can take out a process as many as 20 to 30 times a year, costing industrial customers millions of dollars. To minimize these costs, it is critical for industrial customers to understand how power quality is impacting their system and how to mitigate its effects. Industrial customers are becoming more aware of the direct costs associated with the electrical energy consumed by their machines and processes as it shows up every month on their utility bill. However, the indirect costs associated with poor power quality, or voltage quality to be more precise, while just as significant, are less obvious. These costs show up in the forms of plant downtime, equipment replacement, lost work in process, additional labour, and possibly missed shipment dates. Without the ability to monitor and gain a comprehensive understanding of the impact power quality has on industrial processes, these costs will continue to go unaddressed. However, with the knowledge to identity and mitigate power quality events, process reliability can be significantly improved. The utility is responsible for the reliability of power, not the quality of power. The supplied power by the utility generally does not have an ideal sinusoidal voltage, and the customer is responsible for protecting their sensitive equipment at their own expensive. Moreover, the electrical equipment and machinery within the plant floor can worsen the quality of power being distributed. There are numerous types of power quality problems; however, the three types that impact industrial customers the most are voltage sags, harmonics and transients.

Proposed System

Renewable energy source based power plants into the action of generating power to the utility is the effect of three major causes. Primary cause is the failure of conventional power plants to satisfy all the loads connected to its terminals. Secondarily, damage created to the environment by burning fossil fuels is enormous. Tertiary cause is the exhaustive nature of fossil fuels and the necessity to find alternative energy source to supply for future demands. Among all the existing RES wind and solar energy sources have attracted investors due to their abundance in capacity.

Wind- Solar hybrid energy sources which are the present day trend in the renewable energy source sector are founding lots of installation across the globe. Main advantage of them being environmental friendly, they have an added advantage of being complimentary to each other. The PV system produces dc output whereas WTG generates ac output voltage. For grid connection of these two sources, different power electronic interfaces are required. The DC shunted grid connected hybrid PV/wind power system is used. In DC shunted grid connected hybrid PV/wind power system, the output of PV array is connected to DC/DC boost converter and the dc link voltage is regulated.
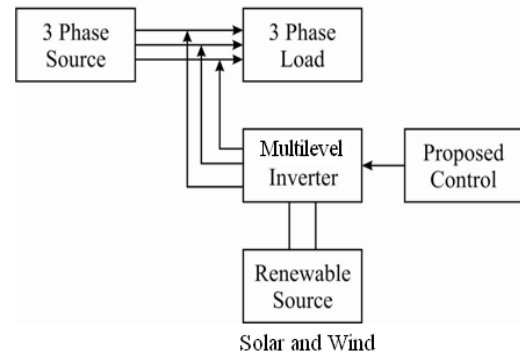
Block diagram description

Figure 1. Block diagram of proposed system

AC output voltage of wind energy system is rectified using uncontrolled rectifier and then a boost converter is used to control dc link voltage. The multilevel inverter is incorporated with shunt active power filter functionality is further used to interface the DC shunted wind-solar hybrid model to the grid. H-bridge multilevel inverter is more efficiency than DFCM. Power quality is a set of electrical boundaries that allow a piece of equipment to function in its intended manner without significant loss of performance or life expectancy. This proposed system used to improve the power quality from the causes like voltage sag, swell etc.
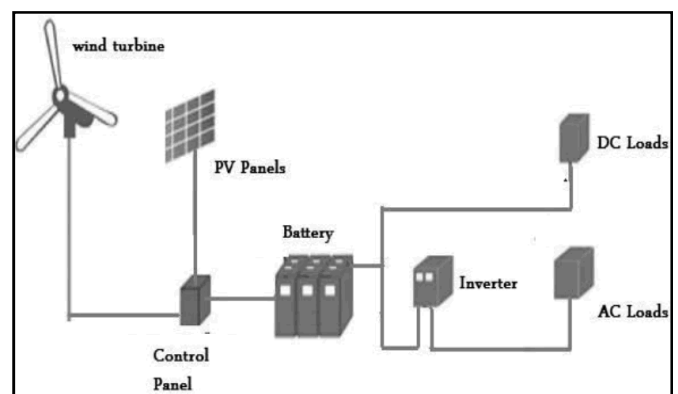
Solar and Wind Hybrid System

Figure 2. Hybrid energy system

Solar-wind power system is the combined power generating system by wind mill and solar energy panel. It also includes a battery which is used to store the energy generated from both the sources. Using this system power generation by windmill when wind source is available and generation from PV module when light radiation is available can be achieved. Both units can be generated power when both sources are available. By providing the battery uninterrupted power supply is possible when both sources are idle.

Implementation of Solar-Wind Hybrid system

Intermittent energy resources unbalance are the most important reason to install a hybrid energy supply system. The solar PV wind hybrid system suits to conditions where sunlight and wind has seasonal shifts. As the wind does not blow throughout the day and the sun does not shine for the entire day, using a single source will not be a suitable choice. A hybrid arrangement of combining the power harnessed from

both the wind and the sun and stored in a battery can be a much more reliable and realistic power source. The load can still be powered using the stored energy in the batteries even when there is no sun or wind. Hybrid systems are usually built for design of systems with lowest possible cost and also with maximum reliability. The high cost of solar PV cells makes it less competent for larger capacity designs. This is where the wind turbine comes into the picture, the main feature being its cheap cost as compared to the PV cells. Battery system is needed to store solar and wind energy produced during the day time. During night time, the presence of wind is an added advantage, which increases the reliability of the system. In the monsoon seasons, the effect of sun is less at the site and thus it is apt to use a hybrid wind solar system.

Solar generated electricity

The solar generated electricity is called Photovoltaic (PV). These are solar cells that convert sunlight to DC electricity. Solar cells in PV module are made from semiconductor materials. When light energy strikes the cell, electrons are emitted. The electrical conductor attached to the positive and negative scales of the material allow the electrons to be captured in the form of a DC current. The generated electricity can be used to power a load or can be stored in a battery. Photovoltaic system is classified into two major types: the off-grid (standalone) systems and inter-tied system. The off-grid system are mostly used where there is no utility grid service. It is very economical in providing electricity at remote locations especially rural banking, hospital and ICT in rural environments. PV systems generally can be much cheaper than installing power lines and step-down transformers especially to remote areas. Solar modules produce electricity devoid of pollution, without odour, combustion, noise and vibration. Hence unwanted nuisance is completely eliminated. The major components include PV modules, battery and inverter. The most efficient way to determine the capacities of these components is to estimate the load to be supplied. The size of the battery bank required will depend on the storage required, the maximum discharge rate, and the minimum temperature at which the batteries will be used. When designing a solar power system, all these factors are to be taken into considerations when battery size is to be chosen. Lead-acid batteries are the most common in PV systems because their initial cost is lower and also they are readily available nearly everywhere in the world. Deep cycle batteries are designed to be repeatedly discharged as much as 80 percent of their capacity and so they are a good choice for power systems.

Wind Power: Wind power is energy extracted from the wind, passing through a machine known as the windmill. Electrical energy can be generated from the wind energy. This is done by using the energy from wind to run a windmill, which in turn drives a generator to produce electricity. The windmill in the case is usually called a wind turbine. This turbine transforms the wind energy to mechanical energy, which in a generator is converted to electrical power. An integration of wind generator, wind turbine, aero generators is known as a wind energy conversion system.

Components of a wind energy: Modern wind energy systems consist of the following components:

- A tower on which the wind turbine is mounted.
- A rotor that is turned by the wind

- The nacelle which houses the equipment, including the generator that converts the mechanical energy in the spinning rotor into electricity. The tower supporting the rotor and generator must be strong. Rotor blades need to be light and strong in order to be aerodynamically efficient and to withstand prolonged used in high winds. In addition to these, the wind speed data, air density, air temperature need to be known amongst others.

Wind Turbine: A wind turbine is a machine for converting the kinetic energy in wind into mechanical energy. Wind turbines can be separated into two basic types based on the axis about which the turbine rotates. Turbines that rotate around a horizontal axis are more common. Vertical axis turbines are less frequently used. Wind turbines can also be classified by the location in which they are used as Onshore, Offshore and aerial wind turbines.

H-bridge Multilevel Inverter: Multilevel inverters (MLI) are becoming popular than two level inverter in high power applications. Multilevel output is synthesized by small dc voltage levels. In multilevel inverters all the switches are connected in series which allows operation at higher voltage level. The main advantages of MLI are high voltage capability, low switching losses, low dv/dt, less THD, less electromagnetic compatibility. The main three MLI configurations are neutral point converter, flying capacitor and cascaded H-bridge multilevel inverter. CHMI has more advantages than other two mentioned. CHMI does not have flying capacitors and clamping diodes. Main drawback of CHMI is that the number of devices used increases with the number of levels and this increases the gate drive circuits at control stage itself causing high cost and switching losses. To overcome above disadvantages the choice is hybrid multilevel inverter which is derived from cascaded H-bridge inverter. In order to control the MLI output voltage there are several control techniques in the literature. The most efficient methods are based on sinusoidal PWM techniques because it leads to easy control of inverter's fundamental voltage and as well as eliminates the harmonics. Among various PWM techniques, phase disposition sinusoidal pulse width modulation (PDSPWM) technique is most popular because of its simplicity to apply in CHMI and HMI control with increase in number of levels.

Cascaded H-bridge Multilevel Inverter: The cascaded H-bridge multilevel inverter has drawn tremendous interest due to the greater demand of medium-voltage high power inverters. It is composed of multiple units of single phase H-bridge power cells. The H-bridge cells are normally connected in cascade on their ac side to achieve medium voltage operation and low harmonic distortion. The cascaded H-bridge multilevel inverter requires a number of isolated dc supplies, each of which feeds a H-bridge power cell. The single phase H-bridge cell, which is the building block for the cascaded H-bridge inverter is associated with separate dc sources. An inverter is an electrical device that converts direct current(DC) to alternating current(AC) the converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching and control circuits. Static inverters have no moving parts and are used in a wide range of applications, from small switching power supplies in computers, to large electric utility high-voltage direct current applications that transport bulk power. Inverters are commonly

used to supply AC power from DC sources such as solar panels or batteries.
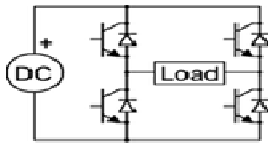

Figure 4. Inverter logic circuit

Grid tie inverters can feed energy back into the distribution network because they produce alternating current with the same wave shape and frequency as supplied by the distribution system. They can also switch off automatically in the event of a blackout. Electronic circuits which process information encoded as one of a limited set of voltage or current levels. Logic circuits are the basic building blocks used to realize consumer and industrial products that incorporate digital electronics.
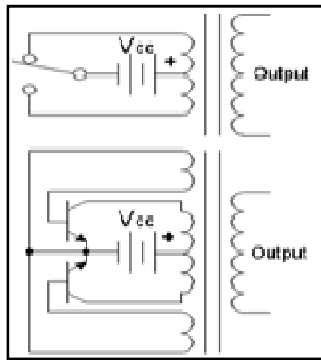

Figure 5. Operation of the inverted circuit

An inverter converts the DC electricity from sources such as batteries, solar panels, or fuel cells to AC electricity. The electricity can be at any required voltage in particular it can operate AC equipment designed for mains operation or rectified to produce DC at any desired voltage.
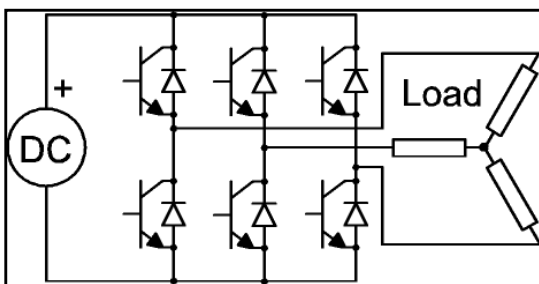

Figure 6. Model of tie inverter

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RESULT ANALYSIS AND DISCUSSION

The simulation result shows that the proposed system helps hybrid wind-solar system H-bridge multilevel inverter for the power quality improvement. Three phase balanced and undistorted supply voltage is considered to represent ideal grid supply. Three phase diode bridge rectifier with RL load is

considered as a non-linear load. Wind-solar hybrid model is connected to the grid at the point of common coupling. H-bridge multilevel inverter is used as an interface between RES and grid and is incorporated with shunt active filter functionality. Simulation is carried out as per practical conditions i.e. for RES=0, load demand>RES>0, RES>load demand.
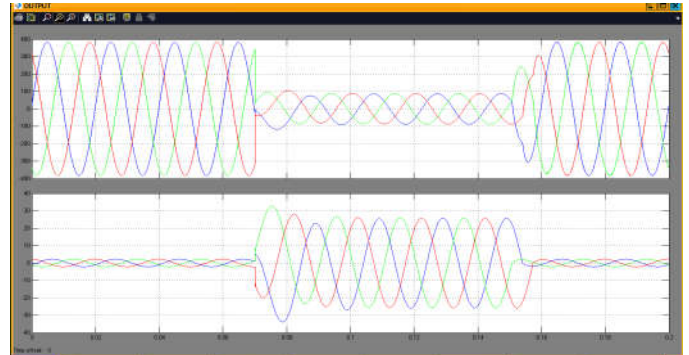

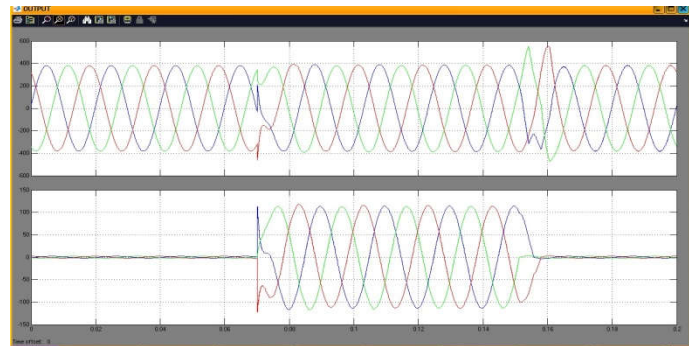**Figure 7. Output Waveform of wind-solar without interconnection**

Figure 8. Output waveform of wind-solar with interconnection

Conclusion

Model of wind turbine and photovoltaic energy system are developed using MATLAB. The models of wind and photovoltaic energy systems are integrated with the grid through H-bridge multilevel inverter using DC shunted grid connected scheme. Id-Iq based control strategy is used to add shunt active power filter functionality to the interfacing inverter. Model is tested for all practical cases of load demand. For all the cases the model is working as per IEEE standards on power quality. Hence with the help of suitable control strategy shunt active filter can be added to the grid interfacing inverter.

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