A FUZZY LOGIC CONTROLLER FOR A PWM INVERTER IN A HYBRID PV/WIND TURBINE SYSTEM CONVERSION SCHEME

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Abstract
The paper work addresses the method of controlling wind turbine connected to the grid and state the use of wind energy as a distributed generation in a power system. A fuzzy logic controller regulates the modulation index of PWM inverter in an AC-DC- AC converter. An controllable battery connected to DC bus is use where even if input from wind during changing wind speed or unbalance condition, the output to the load will remain stable. The control system uses the rule-base defined at the point of common coupling to determine the instantaneous value of modulation index and battery amount. The technique provides flexibility to the grid to provide power from wind turbines, gives this ability to have more control on a system. As a power electronics technique, it also can be used in hybrid PV/Wind energy systems. Performance of the proposed method is illustrated by simulation results.
Keywords: PIC, Fuzzy, Distribution generation, Smart grid, Modulation index

1. Introduction

Distributed generation (DG) is expected to become more important in the future generation system. The purpose of distributed generation is to provide a source of active electric power A hybrid energy system is a photovoltaic array coupled with a wind turbine[1,2].This would create more output from the wind turbine during the winter, whereas during the summer, the solar panels would produce their peak output. Hybrid energy systems often yield greater economic and environmental returns than wind, solar, geothermal or tri generation stand-alone systems by themselves. To get constant power supply, the output of the renewable may be connected to the rechargeable battery bank and then to the load. If the load is alternating current (AC), then an inverter is used to convert the direct current (DC) supply from the battery to the AC load. Increasing in load demand, the large distances between generation and consumption centers as well as the state of transport and distribution networks turns the power system operating close to its stability limit.

With the addition of a fuzzy controller that regulates the modulation index of PWM inverter in an AC-DC- AC converter, and controllable battery storage connected to DC Bus, output of voltage even during changing wind speed or unbalanced load will remain stable. The control system uses the rule-base defined on the load voltage error of the point of common coupling to determine the instantaneous value of modulation index and battery amount . This technique can give a full flexibility to the grid to provide power from wind turbines, an extra control factor for smart grids and gives this ability to have more control on a system. The proposed system controlled the voltage even during changing sunlight voltage condition or unbalanced load. This paper utilizes the wind turbine driven doubly-fed induction generator using an AC/DC/AC converter as distributed generation to feed the load in the grid. The output voltage of DG will be remain stable and balanced via the controller even when the load or input is unbalanced and nonlinear.

2. Wind

Since earliest times, man has harnessed the power of the wind, with the first mill recorded as long ago as the 6th century AD. The technology has diversified over the years to include pumping water, grinding grain, powering sawmills and most recently generating electricity, now the fastest growing energy sector worldwide. Wind turbine technology has developed rapidly in recent years and Europe is at the hub of this high-tech industry. Wind turbines are becoming more powerful, with the latest turbine models having larger blade lengths which can utilise more wind and therefore produce more electricity, bringing down the cost of renewable energy generation. The first commercial wind farm in the UK, built in 1991 at Delabole in Cornwall, used 400 kilowatt (kW) turbines, while the latest trials have involved turbines ten times more powerful, of four megawatts (MW) and above. The average size of an onshore wind turbine installed in 2005 was approximately 2 MW. Wind turbines have an average working life of 20-25 years, after which the turbines can be replaced with new ones or decommissioned. Old turbines can be sold in the second hand market and they also have a scrap value which can be used for any ground restoration work.

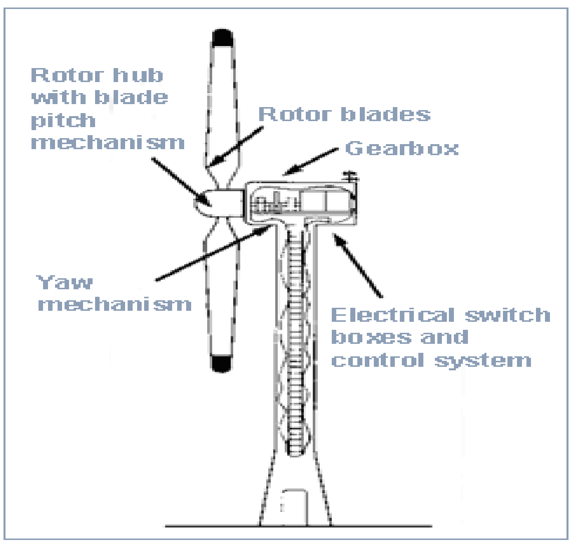

Figure 1. Wind turbine

Wind turbine shown in figure 1 produce electricity by using the natural power of the wind to drive a generator. The wind is a clean and sustainable fuel source, it does not create emissions and it will never run out as it is constantly replenished by energy from the sun. In many ways, wind turbines are the natural evolution of traditional windmills, but now typically have three blades, which rotate around a horizontal hub at the top of a steel tower. Most wind turbines start generating electricity at wind speeds of around 3-4 metres per second (m/s), (8 miles per hour); generate maximum _rated' power at around 15 m/s (30mph); and shut down to prevent storm damage at 25 m/s or above (50mph). Wind Turbine Technology Generating electricity from the wind is simple[1] Wind passes over the blades exerting a turning force. The rotating blades turn a shaft inside the nacelle, which goes into a gearbox. The gearbox increases the rotation speed for the generator, which uses magnetic fi elds to convert the rotational energy into electrical energy. The power output goes to a transformer, which converts the electricity from the generator at around 700 Volts (V) to the right voltage for the distribution system, typically between 11 kV and 132 kV. The regional electricity distribution networks or National Grid transmit the electricity around the country, and on into homes and businesses.

3. Photovoltaic Cell

PV cells are made of semiconductor materials, such as silicon. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current - that is, electricity. This electricity can then be used to power a load . A PV cell can either be circular or square in construction shown in figure 2

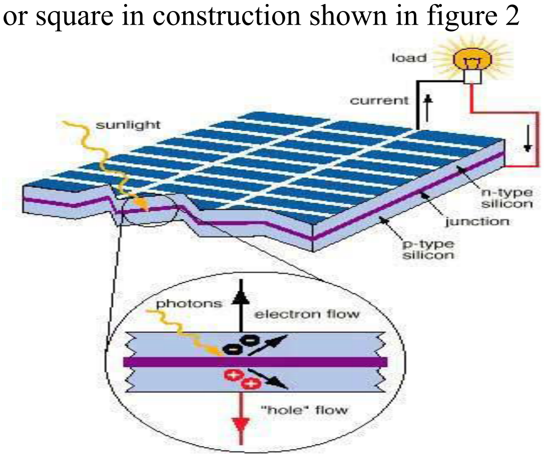

Figure 2. PV Cell working

Characteristics of PV cell

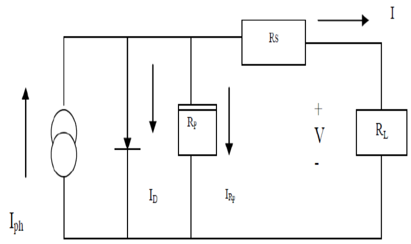

Figure 3.Equivalent circuit diagram

An electrical equivalent model of the PV cell is shown in figure 3 . It has current source in parallel with a diode. However no solar cell is ideal and thereby shunt and series resistances are added to the model as shown in the PV cell diagram above. RS is the intrinsic series resistance whose value is very small. RP is the equivalent shunt resistance which has a very high value.

Applying Kirchoff's law to the node where Iph, diode, Rp and Rs meet, we get

Iph=ID+IRp+I……………………………..(1)

We get the following equation for the photovoltaic current:

I=Iph-IRp-ID ……………………………….(2)

$$I = I_{ph} - I_{0}.\left[exp\left(\frac{V+I.R_S}{V_T}\right) - 1\right] - \left[\frac{V+I.R_S}{R_p}\right] \quad \text{…..(3)}$$

where, Iph is the Insolation current, I is the Cell current, I_0 is the Reverse saturation current, V is the Cell voltage, Rs is the Series resistance, Rp is the Parallel resistance, VT is the Thermalvoltage K is the Boltzman constant, T is the Temperature in Kelvin, q is the charge of an electron.

4. System Description

Implementing fuzzy control for using solar energy in a distribution system as a distributed generation (DG) unit. A nonlinear fuzzy controller tuned the modulation index of PWM inverter to feed the load in the grid via photovoltaic arrays. The controller also dispatched two dc sources to control the input of inverter. The proposed system controlled the voltage even during changing sunlight voltage condition or unbalanced load. Here, we investigate our method in a wind turbine to stabilize voltage through the inverter and connect the wind turbine to the grid. This paper utilizes the wind turbine driven doubly-fed induction generator using an AC/DC/AC converter as distributed generation to feed the load in the grid. The output voltage of DG will be remain stable and balanced via the controller even when the load or input is unbalanced and nonlinear, thus removing any unbalance and harmonic content of the load and hence increasing the power quality of the distribution system.

Wind energy and PV solar conversion systems have been widely used for electricity supply as Distributed Generation and it is favorable to combine energy storage into such hybrid power systems . Therefore, fluctuation of wind energy and PV energy can be smooth out and also the reliability of the system is enhanced. When the power produced by WGs and PVs are bigger than the load demand, the extra power will be stored in the storage batteries for future use. On the other hand, when load demand is greater than power generated by renewable energy sources, the stored power will be used to supply the load. Figure 4 shows the system with DC Bus and battery sources under control of fuzzy system. Two dc sources are used in battery storage unit, where one is employed as a major dc supply and another as a secondary bank. In a normal state when the generation power is greater than load demand, surplus energy stored in batteries. Under unbalanced state, for example when an abrupt variation in wind speed or a sag/swell in voltage or frequency occurs, fuzzy controller distributes the secondary source to obtain a desirable power, thus balancing the output voltage. When load is unbalanced or fault appears in system, the magnitude of secondary voltage automatically changes through fuzzy controller and regulates DC Bus voltage. For instance, when a sudden sag/swell in point of common coupling occurs, the fuzzy controller uses the secondary sources to provide a desirable power.

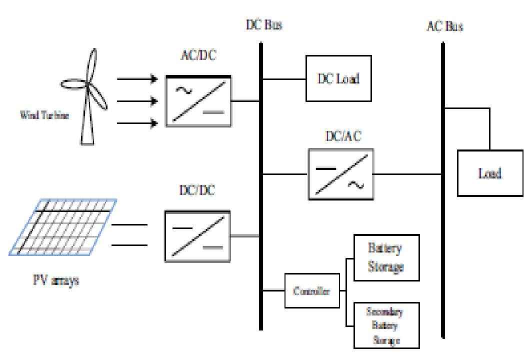

Figure 4.Hybrid system diagram

The figure 4 shows the wind/PV hybrid system in which the output from the wind and solar is feeded to DC link. The output of the wind system which is AC is converted to DC by rectifier , normally bridge rectifier. Also the output of the solar cells which is DC is boosted by an DC-DC Chopper. This both converted DC and boosted DC is feeded to a DC link which is stored at a Storage Battery controlled by a fuzzy logic controller. This controlled DC quantity at DC link is given to the inverter which convert it to the AC and feeded to the load.

5. Simulation model and result

Simulations of A Fuzzy Logic Controller for a PWM Inverter in a Hybrid PV/Wind system were carried out with the help of MATLAB/SIMULINK software shown in figure 5. Simulation was carried out to observe the working advantage of hybrid system of solar wind system. Fuzzy controller is preferred for the above as it has many advantage over other controller which is been stated below.

A fuzzy control system is a control system based on fuzzy logic—a mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0 (true or false, respectively).Fuzzy logic is widely used in machine control. The term "fuzzy" refers to the fact that the logic involved can deal with concepts that cannot be expressed as the "true" or "false" but rather as "partially true". Although alternative approaches such as genetic algorithms and neural networks can perform just as well as fuzzy logic in many cases, fuzzy logic has the advantage that the solution to the problem can be cast in terms that human operators can understand, so that their experience can be used in the design of the controller. This makes it easier to mechanize tasks that are already successfully performed by humans

Advantage of Fuzzy logic controller over PI controller

A PI controller is a controller that produces proportional plus integral control action. The PI controller has only one input and one output. The output value increases when the input value increases.A fuzzy controller is a generalization of the conventional PI controller that uses an error signal and its derivative as input signals. Fuzzy controllers have two inputs and one output. Multiple inputs allow for greater control diversity for a fuzzy controller over a conventional PI controller.

Fig shows the full simulation model of the proposed project work. As explained above it includes different blocks. Firstly the output of the hybrid system containing wind and solar cell is been is feeded to the common DC link which is stored at the battery. Depending upon the input variation the battery will store or supply the charge or energy to the DC link whose SOC is been adjusted by fuzzy. The DC at the DC link is feeded to the inverter which will convert it to the desired AC output

Also the DC supply at DC link is provided to the DC machine and the different output parameters are measured in output.

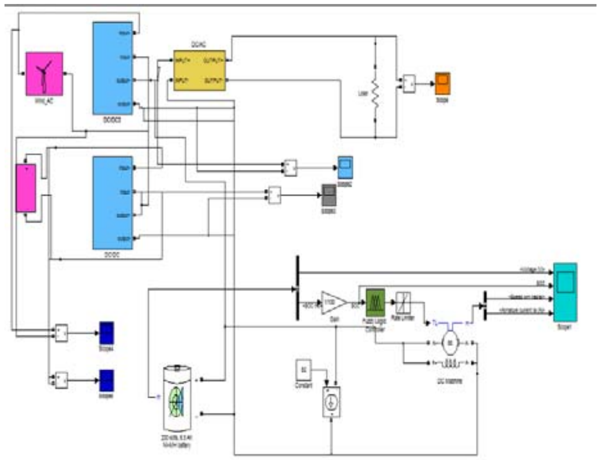

Figure 5.Simulation model of proposed work

The output of solar system and wind output is shown in the figure 6 and figure 7 .

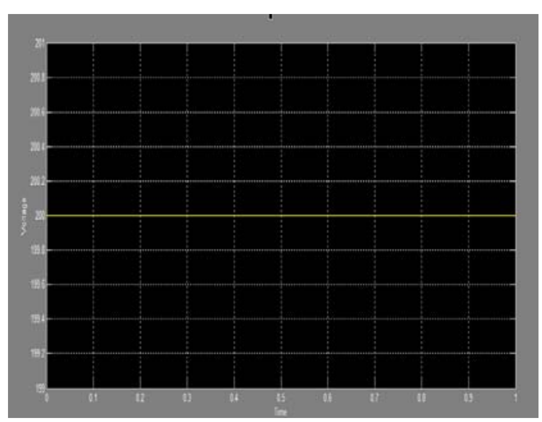

Figure 6.Waveform of Solar panel output

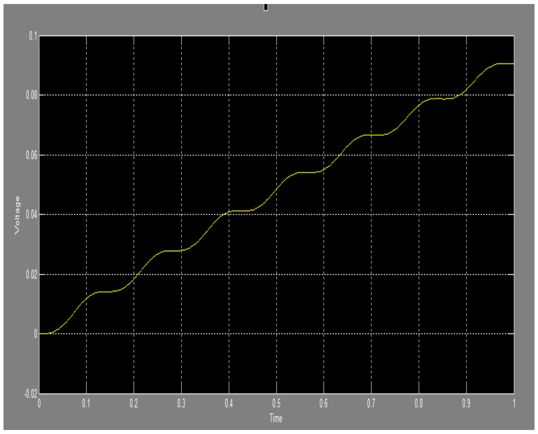

Figure 7. Waveform of wind turbine output

The inverter output waveform is shown in figure8. The output is with implementation of controller and battery.

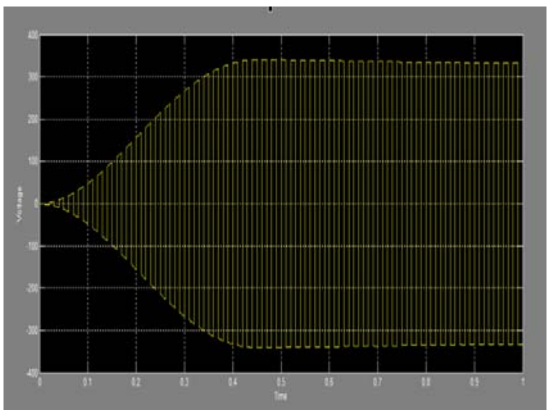

Figure 8.Waveform of output of PWM Inverter

6. Conclusion

The smart grid is a new idea for electricity grids around the world. The main objectives of smart system is to increase the efficiency ,reliability of the electricity networks by utilising full integration of RES. In this paper, wind energy has been used as Distributed Generation. A controllable battery bank is connected to DC link to save and control energy during any system operation work. A fuzzy controller regulates modulation index of PWM inverter and distributes the storage bank by controlling power.

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