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Maximum Power Extraction by using Converters for Hybrid Renewable Energy Sources Fed Micro Grid

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***Abstract*: Due to the rapid growth of power electronics techniques, applications with photovoltaic (PV) energy and wind energy have been increased significantly. The use of solar and wind energies individually would not provide a saturated output voltage. So Solar energy and Wind energy are combined to form Solar-Wind Hybrid Power System (SWHPS), which will enhance the qualities of each other and another. To reduce the power demand on the conventional power generation sector, we propose this system. Various methodologies are in practice for generation of power using Solar-Wind Hybrid System with Maximum Power Point Tracking (MPPT).**

***Keywords*: DFIG, Vector control, Dual Active Bridge, critical loads**

1. Introduction

This is a well-known fact that the whole world is facing a major threat of fast depleting fossil fuel reserves, the awareness of environmental impact have led the researchers to think of alternate sources of energy for a safer life on this earth. Therefore, the whole world is looking for non- exhaustible energy sources for their future. Most of the present energy demand is met by fossil and nuclear power plants, but there will soon be a time when we will face a severe fuel shortage; therefore now a days researcher's attention is towards renewable energy sources, such as solar photovoltaic (PV), wind, fuel cell stack, biomass, tidal energy, etc. Out of these, solar PV and wind are most popular sources due to their cleanness and cost effectiveness. There are some places where connection to the utility network is either impossible or unduly expensive. Load demand is comparatively lower at these places due to limited end customer devices. This requires isolated power generation systems. Photovoltaic (PV) systems and wind-electric systems among renewable sources are viable alternatives for the designer of such remote supplies. Earlier independent Solar PV generation system and wind electric generation systems were installed, but these systems have following disadvantages:

Solar PV generation system: The solar radiation varies over time and is dependent on environmental conditions (temperature, irradiance, etc.). Thus it becomes tough to get an average generation throughout. Also, at night we cannot have the solar energy supply so we have to go for large size battery storage. If due to the rainy conditions or some other natural disaster we do not have solar for sufficient time we will not be able to store the battery.

Wind Power generation system: The irregular nature of wind in our country does not give us a consistent power generation, therefore requires battery storage and diesel generator integration etc. The average wind velocity is 3.5-4.5 m/s which is not sufficient for a standalone system.

Due to above-mentioned demerits, these independent systems are not very efficient and hence research has turned towards Solar-Wind hybrid systems as these two renewable sources are complementary in nature. Though solar-wind hybrid systems, are consistent with power generation, there is still some possibility of power interruption as both sources are environment dependent, and some critical loads like telecom towers, hospitals etc. cannot afford it, therefore a comparatively small battery back-up is also required for these critical loads.

A. *Existing hybrid topologies*

- *DFIG for wind generation, Solar PV generation system and battery-backup[2]:* This scheme uses Doubly fed induction generator for wind generation, which enables power generation at a constant frequency around + 30% of synchronous speed. Rotor power is being extracted, converted into DC and supplied to DC micro grid. When total power generated from solar and wind exceeds the power demand, it is stored in the battery, which is used later in case of solar and wind failure. Power converters are being used in rotor circuit, therefore are required to be rated at slip power. In this scheme, battery size is comparatively lesser but the main disadvantage is that the battery is directly connected to the DC link, there is no proper control for its charging and discharging.
- *SCIG for wind generation and solar PV system (without capacitor banks):* This scheme eliminates the use of large capacitor banks, and uses a DC link capacitor between two converters. Solar power is

being supplied at DC link. In this scheme also, the converters used are of full rating and slip power in the rotor of SCIG results in the copper loss. Wind generation system and solar PV system must have the same rating so as to supply the load alternately. There is no provision for critical loads in case of wind and solar failure.

- *SCIG for wind generation and solar PV system (with capacitor banks):* In this scheme, constant frequency power generation is possible, at or slightly less than synchronous speed. It does not use any converter while supplying from wind power but needs an DC/AC converter while supplying from solar energy. The main disadvantage of this scheme is the power loss in rotor circuit of SCIG and requirement of large 3-phase capacitor banks to supply reactive power demand. Also, in case of wind and solar failure, there is no alternative option for critical loads.
- *PMSG for wind generation and solar PV system:* This system uses permanent magnet synchronous generator for wind generation which is very efficient as compared to other wind generators. Loads are supplied at constant frequency using AC/DC and DC/AC converter in series. In case of low wind power, solar PV generates the required power and DC link capacitor supplies required reactive power, and in case of low PV generation (at nights or in bad weather condition), wind generation supplements. The main disadvantage of this scheme is full rating power converters are required, and in case of failure of both solar and wind, loads remain unsupplied.

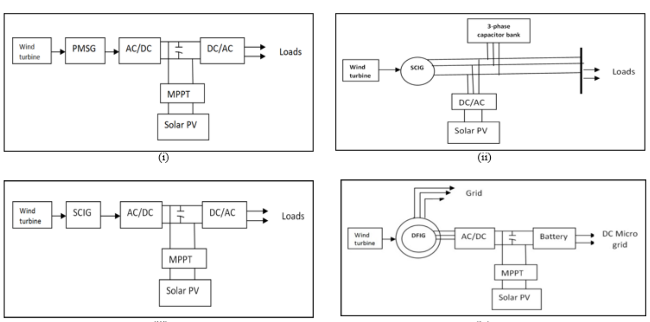

Fig. 1. Existing Configurations for Hybrid Wind-Solar Power Generation System

2. Proposed hybrid topology

The PMSG machine is the most efficient of all electric machines since it has a movable magnetic source inside itself. Use of permanent magnets for the excitation consumes no extra electrical power. Therefore, copper loss of the exciter does not exist and the absence of mechanical commutator and brushes or slip rings means low mechanical friction losses. Another advantage is its compactness. The recent introduction of high-energy density magnets (rare-earth magnets) has allowed the achievement of extremely high flux densities in the PMSG generator; therefore, rotor winding is not required. They have very long lasting winding insulation, bearing, and magnet life length. Since no noise is associated with the mechanical contacts and the driving converter switching frequency could be above 20 kHz producing only ultrasound inaudible for human beings.

A. Function of Proposed System

The proposed system consists of solar PV system and Wind power generation system forms the micro grid system is connected to the grid with the proposed interleaved boost converter and Incremental conductance MPPT algorithm.

The inverter circuit is used to convert the boost output DC voltage to AC voltage with the grid integration through PWM wave generation with 50 Hz frequency. This chapter discusses the control methodology proposed and their characteristics for non-linearity in solar PV system and wind power generation.

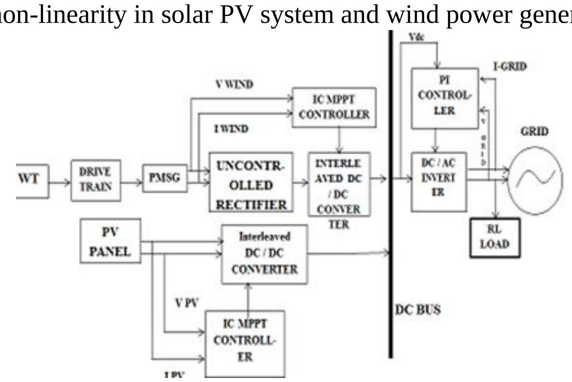

Fig. 2. The block diagram of the proposed System with micro grid

The MPPT algorithm has vast techniques which are used for maximum power extraction from solar system by varying with non-linearity of renewable energy system. In this project a most trained technique used for the tracking of Maximum power is advantageous over P & O algorithm. The proposed algorithm is briefly discussed in this paper.

3. Problem finding

A generating system with a single power source non-conventional energy does not supply electricity required.

Uniform and constant voltage with maximum power at output is not obtained.

The output of Solar-Wind system is not certain one might give more power and other might give less power or no power.

4. Need for hybrid energy system

As considering these two energy resources i.e wind energy and solar energy, the output is not certain due to environmental or day and night situations.

That is the output of Solar-Wind system is not certain one might give more power and other might give less power or no power.

So it required to stabilize output voltage from this system. These two systems are connected parallel to each other, that if

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one source is not available, then the other one can balance the system. Thus, these two systems can work individually and simultaneously too.

5. Solar PV power system

A PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array.

Typically, a solar cell can be modeled by a current source and an inverted diode connected in parallel to it. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n to p junction and parallel resistance is due to the leakage current.

6. PMSG based wind power system

In permanent magnet based WECS the output voltage and current is proportional to electromagnetic torque and rotor speed. A diode rectifier with a dc link capacitor followed by inverter circuit is most widely used converter with PMSG based WECS as shown in the figure below. It has the benefit of being simple and there is no need of controlling at rectifier side. But the most popular converter topology for PMSG based WECS is back to back frequency converter. Advantages of this technology are that, it provides active and reactive power control and also increases power factor because of Pulse Width Modulation techniques.

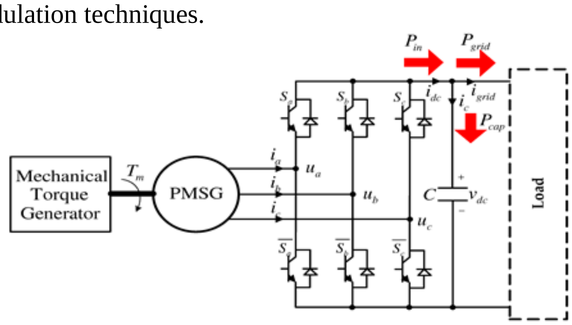

Fig. 3. PMSG wind turbine system

7. Incremental conductance MPPT

The disadvantage of the traditional method to track the peak power under fast varying atmospheric condition is overcome by IC method. The IC can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dl/dV and –I/V This relationship is derived from the fact that dP/dV is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm has advantages over P&O in that it can determine when the MPPT has reached the MPP, where P&O oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than P and O.

A. *Function of MPPT*

Global demand for electricity is increasing while production of energy from fossil fuels is declining and therefore the obvious choice of the clean energy source that is abundant and could provide security for development future is energy from the sun. In this paper, the characteristic of the supply voltage of the photovoltaic generator is nonlinear and exhibits multiple peaks, including many local peaks and a global peak in non-uniform irradiance. To keep global peak, MPPT is the important component of photovoltaic systems. Although many review articles discussed conventional techniques such as P & O, incremental conductance, the correlation ripple control and very few attempts have been made with intelligent MPPT techniques.

Maximum power point tracking (MPPT) is a technique used commonly with wind turbines and photovoltaic (PV) solar systems to maximize power extraction under all conditions. Although solar power is mainly covered, the principle applies generally to sources with variable power: for example, optical power transmission and thermos photovoltaics. PV solar systems exist in many different configurations with regard to their relationship to inverter systems, external grids, battery banks, or other electrical loads [5]. Regardless of the ultimate destination of the solar power, though, the central problem addressed by MPPT is that the efficiency of power transfer from the solar cell depends on both the amount of sunlight falling on the solar panels and the electrical characteristics of the load. As the amount of sunlight varies, the load characteristic that gives the highest power transfer efficiency changes, so that the efficiency of the system is optimized when the load characteristic changes to keep the power transfer at highest efficiency. This load characteristic is called the maximum power point (MPP) and MPPT is the process of finding this point and keeping the load characteristic there. Electrical circuits can be designed to present arbitrary loads to the photovoltaic cells and then convert the voltage, current, or frequency to suit other devices or systems, and MPPT solves the problem of choosing the best load to be presented to the cells in order to get the most usable power out.

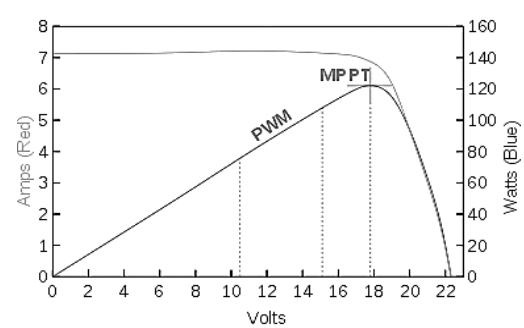

Fig. 4. MPPT V-I Curve for Maximum power tracking

Solar cells have a complex relationship between temperature and total resistance that produces a non-linear output efficiency which can be analyzed based on the I-V curve. It is the purpose of the MPPT system to sample the output of the PV cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions. MPPT devices are typically integrated into an electric power converter system that provides voltage or current conversion, filtering, and regulation for driving various loads, including power grids, batteries, or motors.

An MPPT tracker is analogous to a thumb placed over a garden hose. If you put your thumb over part of the opening of the hose (adding resistance to the circuit), the pressure (voltage) goes up and the stream flies faster, but less water (current) is getting through. If you completely cover the opening, nothing gets through. If you remove your thumb entirely, the maximum flow rate gets through, but the stream falls limply at your feet. That's the basic mechanism of the MPPT tracker: vary resistance in the circuit to modify current and voltage.

Now imagine that there are hundreds of pumps (solar panels) upstream of the hose and they are delivering water (energy) to you. Further complicating things, some of these pumps go offline at certain parts of the day (partial shading of the array). So the force behind the delivery of water will be constantly varying.

Your task is to wash your car, which is sitting still about 15 feet away. You need to keep moving your thumb as the upstream pump force varies in order to avoid undershooting or overshooting the car. The "car" in this case is the Maximum Power Point – for any array of solar panels, there is a configuration of current and voltage that aligns with maximum power generation.

8. MPPT basic configuration and components

Conventional MPPT systems have two independent control loops to control the MPPT. The first control loop contains the MPPT algorithm, and the second one is usually a proportional (P) or P–integral (PI) controller. The Incremental Conductance method makes use of instantaneous and Incremental Conductance to generate an error signal, which is zero at the MPP; however, it is not zero at most of the operating points.

The main purpose of the second control loop is to make the error from MPPs near to zero. Simplicity of operation, ease of design, inexpensive maintenance, and low cost made PI controllers very popular in most linear systems.

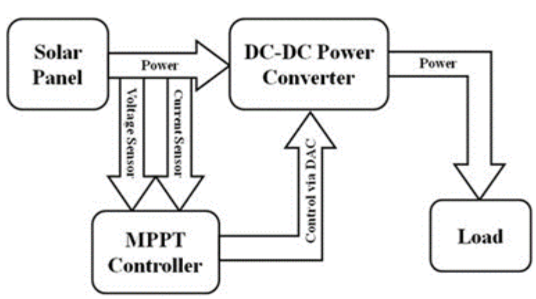

Fig. 5. MPPT functional Block Diagram

I-V output curve of a PV panel is previously presented. Associated with this curve is a MPP. This is the point where the solar cell is most efficient in converting the solar energy into electrical energy. The MPP is not a fixed point, it actually moves throughout the day depending upon the solar radiation. There are a large number of algorithms that are able to track MPPs. Some of them are simple, such as those based on voltage and current feedback, and some are more complicated. The most commonly employed MPPT Techniques [1] are: 1. Hill Climbing/P&O, 2. Incremental Conductance 3. Fractional Open-Circuit Voltage 4. Fractional Short-Circuit Current 5. Fuzzy Logic Control 6. Neural Network Having a curious look at the recommended methods, hill climbing and P&O are the algorithms that were in the center of consideration because of their simplicity and ease of implementation [6]. Hill climbing is perturbation in the duty ratio of the power converter, and the P&O method is perturbation in the operating voltage of the PV array. However, the P&O algorithm cannot compare the array terminal voltage with the actual MPP voltage, since the change in power is only considered to be a result of the array terminal voltage perturbation. As a result, they are not accurate enough because they perform steady-state oscillations, which consequently waste the energy. By minimizing the perturbation step size, oscillation can be reduced, but a smaller perturbation size slows down the speed of tracking MPPs. Thus, there are some disadvantages with these methods, where they fail under rapidly changing atmospheric conditions. On the other hand, some MPPTs are more rapid and accurate and, thus, more impressive, which need special design and familiarity with specific subjects such as fuzzy logic or neural network methods. MPPT fuzzy logic controllers have good performance under varying atmospheric conditions and exhibit better performance than the P&O control method [3]; however, the main disadvantage of this method is that its effectiveness is highly dependent on the technical knowledge of the engineer in computing the error and coming up with the rule-based table. It is greatly dependent on how a designer arranges the system that requires skill and experience.

A. MPPT algorithm IC technique

The disadvantage of perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by IC method. The IC can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dl/dV and –I/V This relationship is derived from the fact that dP/dV is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm has advantages over P&O in that it can determine when the MPPT has reached the MPP, where P&O oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than P and O.

B. Flow chart of IC MPPT algorithm

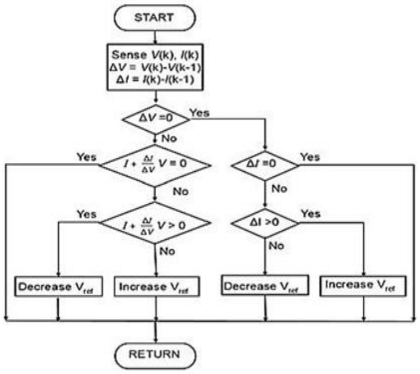

Fig. 6. Flowchart of MPPT

The shows that the slope of the P-V array power curve is zero at The MPP, increasing on the left of the MPP and decreasing on the Right hand side of the MPP. The basic equations of this method are as follows.

dI/dV- -I/V at MPP

dI/dV< -I/V left of MPP

dI/dV >I/V right of MPP

This method exploits the assumption of the ratio of change in output conductance is equal to the negative output Conductance Instantaneous conductance. We have,

P = V I

Applying the chain rule for the derivative of products yields to

$\partial P/\partial V = [\partial(VI)]/ \partial V$

At MPP, as $\partial P/\partial V=0$

The above equation could be written in terms of array voltage V and array current I as

$\partial I/\partial V = - I/V$

The MPPT regulates the PWM control signal of the dc – to – dc boost converter until the condition: $(\partial I/\partial V) + (I/V) = 0$ is satisfied. In this method the peak power of the module lies at above 98% of its incremental conductance.

C. Interleaved boost converter

The interleaved boost converter (IBC) works as normal boost converter but in this we connected two boost converter circuits in parallel shown in Figure. IBC converter has two switches S1 and S2, two inductors L1 and L2, two diodes D1 and D2, one capacitor C, and resistor R as a load. The IBC works in 4 modes described below.

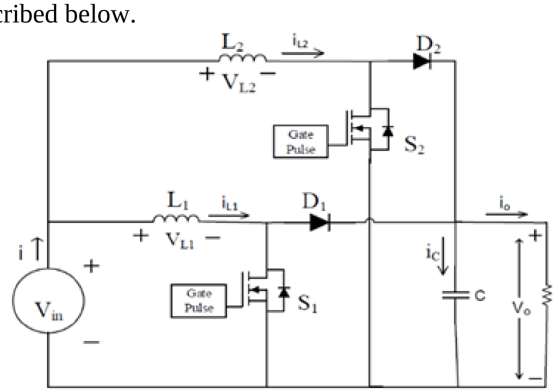

Fig. 7. Interleaved boost converter

9. Modes of operation for IBC

Mode 1: When Switch S1 is closed, switch S2 is opened In this mode D1 is reverse biased and D2 is forward biased. The current across inductor L1 increases by supplying the input voltage because of inductor L1 takes the energy from supply. Due to this input voltage, current across inductor L2 decreases because of inductor L2 supplies energy to the load.

Mode 2: Both Switches S1 and S2 are closed In this mode both D1 and D2 are reverse biased. The currents across inductor L1 and inductor L2 increases by supplying the input voltage because of both inductors L1 and L2 takes energy from the supply.

Mode 3: When Switch S1 is opened, switch S2 is closed In this mode D1 is forward biased and D2 is reverse biased. The current across inductor L1 decreases by supplying the input voltage. Due to this input voltage, current across inductor L2 increases because of inductor L2 takes energy from the supply.

Mode 4: Both Switches S1 and S2 are opened In this mode both D1 and D2 are forward biased. The currents across inductor L1 and inductor L2 decrease by supplying the input voltage because of both inductors L1 and L2 supplies the energy to the load.

10. PI Controller

A proportional–integral controller (PI controller) is a generic control loop feedback mechanism (controller) widely used in industrial control systems. A PI controller calculates an “error” value as the difference between a measured process variable and a desired set point.

The controller attempts to minimize the error by adjusting the process control inputs. PI control is needed for non-integrating processes, meaning any process that eventually returns to the same output given the same set of inputs and disturbances. A P-only controller is best suited to integrating processes. Integral action is used to remove offset and can be thought of as an adjustable bias.

11. Simulation diagram of Proposed system

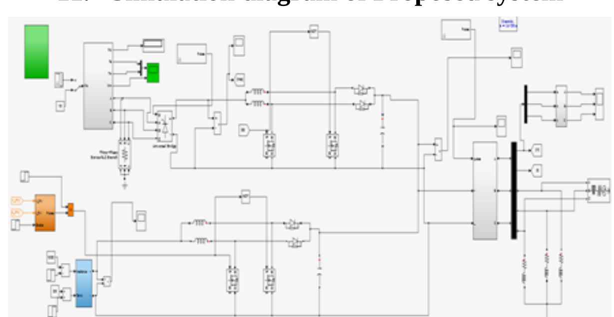

Fig. 8. Simulation model of solar power generation

This proposed maximum power extraction system consists of various elements to tune the system for better performance, those techniques which were explained above is implemented using MATLAB/Simulink simulation software which gives good platform for engineering projects to expand.

The total proposed system simulation model is shown in the figure 8. The power generated from solar and wind power is fed into interleaved boost converter and it is further sent to inverter circuit where the proposed PWM technique is used to give gate pulse to the semiconductor devices present in the circuit.

The method used for improving the dc voltage from solar is MPPT controller. The solar simulation model is simulated as shown in the figure. It represents the dependable current source exited with a digital signal which is generated by mathematical model of solar power generation in Simulink.

The wind power system consists of PMSG (permanent magnet synchronous generator) which is a synchronized steady output at variable input to get constant power output the simulation model of proposed PMSG based wind turbine is presented in the simulation model as shown in the figure 9.

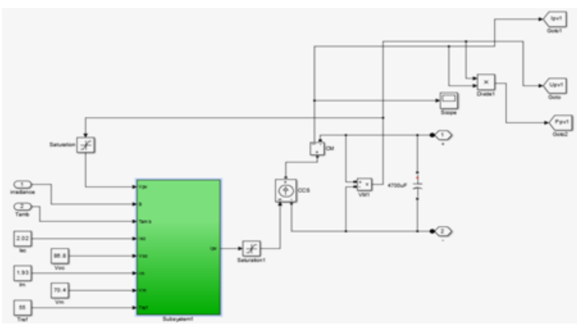

Fig. 9. PMSG based wind turbine Simulink model

12. PMSG base wind turbine simulation model

The power generated by solar and wind power system is coupled to the interleaved boost converter which is controlled using a centralized IC controller as shown in the figure 10. The simulation model is the MPPT with IC implementation for the generation of pulse for boost converter.

The voltage converter DC/DC will boost the voltage for the required level using the pulse from MPPT-IC combination technique which produces an efficient way of dc output voltage generation.

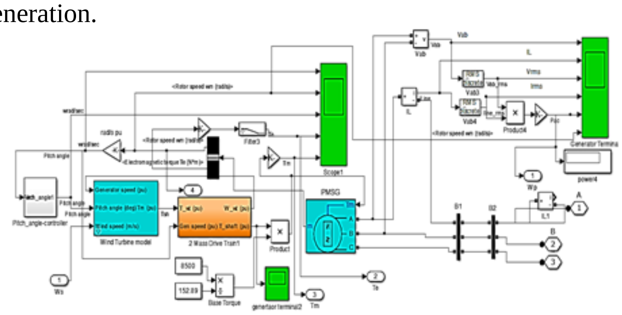

Fig. 10. Simulation model of Proposed IC MPPT

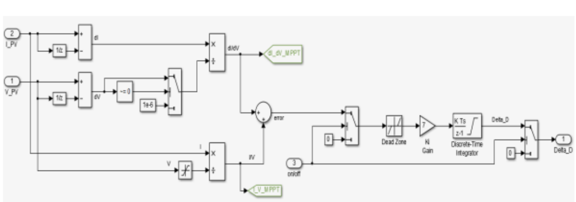

Fig. 11. Simulation model of proposed PWM technique

This dc voltage is converted in to ac with the help of inverter circuit which is supported with the proposed PWM technique as shown in the figure 11.

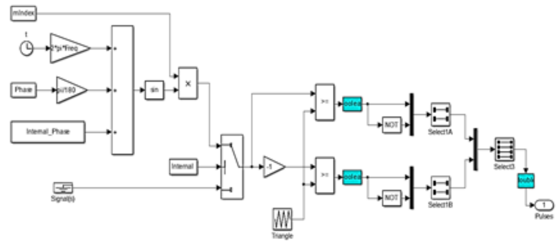

Fig. 12. Simulation model of Implemented Fuzzy Logic Controller

The implemented IC controller is shown in the simulation model of figure 13. It uses an Incremental Conductance (IC) to track the maximum power point there is Pulse generator generally to generate gate pulse with good speed of tracking the MPPT.

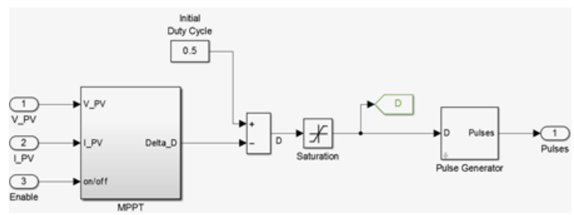

Fig. 13. Simulation model of IC controller

13. Simulation output and results

The simulation is done through MATLAB software simulation tool it gives good platform for engineering design in mathematical form. Here we use Simulink tools for developing this project with good efficiency in developing. The project is designed and simulation is compiles using MATLAB compiler and the output is made through scope.

The PV output voltage and wind output voltage is represented in the figure 14 and 15 respectively. It showed a constant output voltage due to the improved proposed MPPT technique. The solar power output is constant through MPPT controller at constant DC voltage of about 88 volt as shown in the figure.

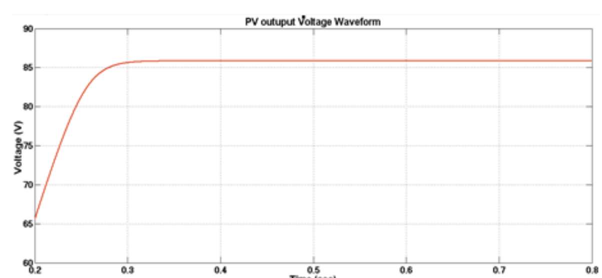

Fig. 14. PV Output Voltage waveform

The wind power produces voltage of distorted wave which is converted into dc voltage output. The mppt technique used which is triggered by IC controller using proposed technique.

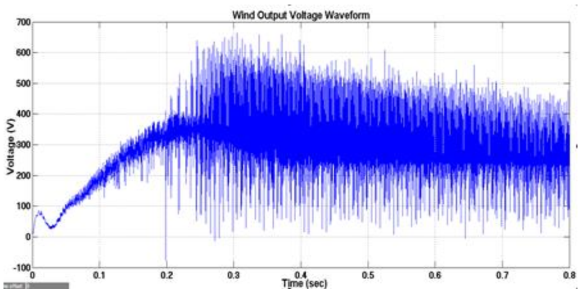

Fig. 15. Wind System voltage waveform output

Generated wind power is distorted due to its varying nature the output voltage is thus distorted the proposed IC conductance improve the voltage quality thus the DC output voltage waveform is as shown in the figure 16.

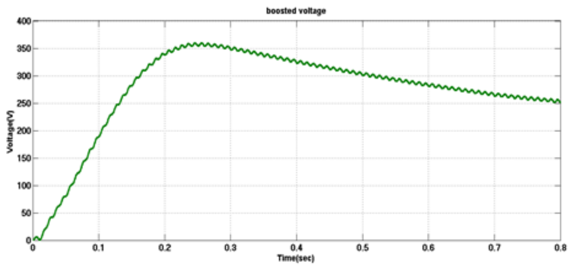

Fig. 16. Interleaved Boosted Output Voltage waveform

The boosted output voltage is with the proposed IC MPPT algorithm the IC algorithm generates signaling is as shown in the figure 17.

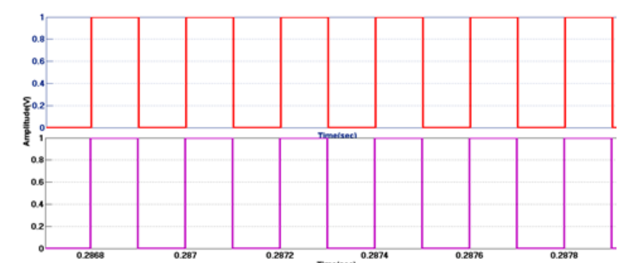

Fig. 18. IC MPPT Output Waveform for Interleaved boost converter output

The boosted voltage is DC and is converted into three phase AC voltage with the inverter fed PWM waveform for grid integration. The PWM pulse waveform is as shown in the figure 19.

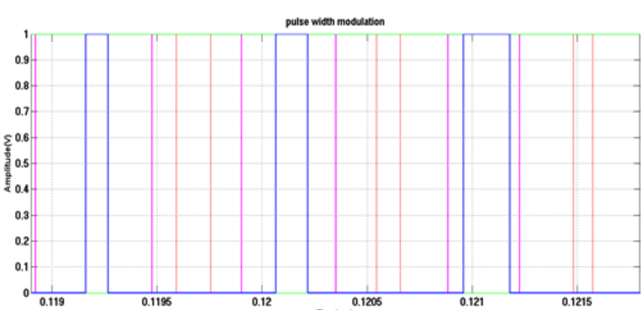

Fig. 19. PWM signal waveform for Inverter control

The three inverter output voltage waveform is as shown in the figure 20.

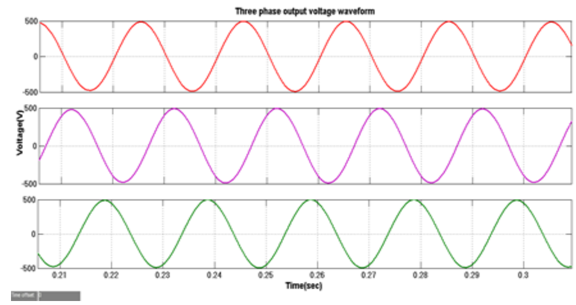

Fig. 20. Three phase output voltage waveform

14. Conclusion

From the above simulation results and output graphs we can come to a conclusion that out proposed method of hybrid wind and solar power generations output voltage is limited due to its nature. This condition is overwhelmed with the help of our proposed MPPT controller with IC implementation in interleaved boost converter this converted output dc voltage is capable of connecting with the grid with the help of PI controller.

This proposed technique has proved to be the best technique as compared to the traditional way of extracting maximum power from the hybrid wind solar generation system. The voltage gathered from wind and solar to be less as of 120 volt which is increased to about 400 volt as shown in the simulation diagram from the previous chapter.

This improvement in the voltage efficiency of a maximum power tracking due to the proposed technique IC MPPT and this proposed method provides less ripple and harmonics which is also verified using the simulated proposed system. The scope of this project can also expanded to very lengthy extent as the application of renewable energy poses good innovative technology in upcoming days.

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