International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

Coordinated Supply of Solar and Wind Energy Using MPPT to Power Micro-Grids along with Battery

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Abstract: ***Wind and solar energy are two of the most feasible non-conventional energy sources due to their availability and environment friendly nature. Research has been done on operating both the energy sources alongside one another in order to take advantage of their complementary characters and leading to improve in efficiency and power dependency. Simulation analysis and experiments show that the hybrid system is able to capitalize the correlative nature of the two energy sources, and deliver energy reliably yearlong .A wind-PV hybrid power station is more beneficial than an individual wind or PV power station because when one system is faulted other can supply the power. Maximum Power Point Tracking (MPPT) system with Perturb And Observe (P&O) algorithm is used, which extracts maximum power from the PV system and wind system. Bi-directional converter is utilized to store DC power in battery bank and supply power to the micro-grid by converting the DC power into AC power. Hybrid generation systems are more conventional than making use of a single source to generate power that matches the requirements. Therefore by using both the power sources in parallel, power is extracted from the source which provides a higher output power at a given time. The process of battery getting charged and power supplied to the micro-grid is done simultaneously by any one of the sources. And the battery can be discharged to supply power directly when both PV and wind turbines aren't able to provide sufficient power to the grid. By using hybrid power stations higher generating capacities and uninterrupted power transfer to the micro-grid can be easily achieved. In this work, a coordinated supply of wind and solar energy would have been implemented to assure a continuous supply of power at the load end and the system is simulated using MATLAB.***

Keywords: MPPT, converter, micro-grid, wind, PV, battery

1. Introduction

Renewable energy sources such as solar, wind, hydro power, geothermal, biomass and ocean energy are considered as a technological option for generating clean energy. The overall output energy obtained from both solar and wind is much less compared to energy generated by fossil fuels, however, electricity generation by the use of PV cells and wind turbines has increased rapidly in recent years. The combination of non- conventional energy sources, solar and wind, are used for generating power called as solar-wind hybrid system. This hybrid system is designed using the solar panels and wind turbines for generating electricity. Solar power system can be defined as the system that uses solar energy for power generation with solar panels. The paper presents a hybrid system that harnesses the renewable energies available due to the wind and sun to generate electricity. Hybrid solar-wind power generating systems are suitable for industrial, household and agricultural applications.

With high economic growth rates and over 17% of the world's population, India is a significant consumer of energy resources. India's energy demand continues to rise despite the global financial crisis. India consumes its maximum energy in commercial, agricultural and residential purposes when compared to countries like China and Russia. Solar energy is the energy that is obtained from the sun. It is renewable, inexhaustible and does not emit any pollutants into the atmosphere. A solar charged battery system provides a power supply for complete twenty four hours a day irrespective of weather conditions due to the availability to store the charge when not in use. By adopting the right technology for the concerned geographical locations, one can extract a huge amount of power from the incident solar radiations. Moreover, solar energy is expected to be the promising alternate source of energy and almost every equipment is able to work with solar. The rise in the cost of conventional fossil fuel is making the supply demand of electricity product almost impossible especially in parts of the world where it is difficult to supply continuous energy. Wind energy is the energy associated with the movement of air across the surface of the earth. It has been used for many years for grinding grain, irrigation and most importantly, sailing. Wind energy systems convert this energy into other useful forms of power. Wind energy systems used in irrigation and milling have been used since ancient times and from the start of 20th century it is being used to generate electric power. Windmills for water pumping have been installed in different parts of the world, particularly in the rural areas. Wind turbines transform the energy obtained from wind into mechanical power, which can then be used directly for grinding and other applications or further converting to electrical energy to generate electricity. Wind turbines can be used singly or in clusters called wind farms.

There is a growing awareness that non conventional energy such as solar and wind power has an important role to play in order to save the present state. Hybrid power systems consists of a combination of renewable energy sources such as wind generators, solar etc used to charge batteries and generate power to meet the energy demand, considering the geography and other details of the place at which it is installed. These types of systems are not connected to the main utility grid. They are also used in stand-alone applications and operate independently and reliably. The best application for these types of systems is in remote places, such as rural villages, in telecommunications etc. The importance of solar-wind and other hybrid systems has grown as they seem to be the right solution for a distributed and clean energy production.

Solar and wind energy are complementary to each other, which makes sure that there is a continuous production of electricity throughout the year. The main components of the Wind Solar Hybrid System are wind aero generator and tower, solar photovoltaic panels, batteries, cables, charge controller and inverter. The given Hybrid System generates electricity that can be used for charging batteries and with the use of inverters power can be also supplied to AC loads. Wind aero-generator is installed on a tower having a minimum height of 18 meters from the ground level. Because of the height, the aero-generator gets wind at higher speed and thereby generates more power.

2. Description of Proposed System

Through this concept, the aim is design a system which provides coordinated control between wind and solar energy sources established by Maximum Power Point Tracking (MPPT). Apart from powering the micro-grid, which is the distribution system here, battery storage is also implemented as a backup power source. MPPT is used to extract maximum power from a given varying power source and to provide a constant output voltage to the micro-grid. The algorithm used in this concept is Perturb and Observe (P&O) algorithm. A relay module is used here for switching between wind and solar energy source based on power output. But for simulation, an Insulated Gate Bipolar Transistor (IGBT) is used for switching operation whereas a relay module is used in real life application.

There are two power sources used here, wind and solar. It is understood that both the solar and wind sources cannot give maximum power output at the same time, at all times. For example, one cannot expect power output from solar energy during the night and one cannot expect power output from wind turbines when the wind speed is too less. To overcome such issues, a hybrid model is designed where the solar panel and wind turbine are placed in parallel so that power can be extracted based on power output. Power is fed to the micro-grid based on the power obtained from both the sources. Most of the time, at least one of the sources will not have sufficient power that can be supplied to the micro-grid. But in a case when there is sufficient power from both wind and solar energy sources both can be used at the same time, provided the power at the end of both MPPTs is exactly the same.

At the same time, a battery is used in the given system so that it can be charged at the same time power is supplied to the micro-grid. The reason this has been used is because, if one is not able to extract enough power from either wind or solar power sources, battery will be able to supply power to the grid so that it ensures the grid receives continuous power. So basically, the battery is connected in parallel so that power is supplied to the micro-grid and that battery gets charged at the same time. The rate of charging depends on the amount of current available from each of the sources. Irrespective of the current, which obviously is an important parameter to be considered when running the loads, with any given current value, power can be transferred to the micro-grid.

2.1 Solar panel

Solar panels are used to convert solar radiation to electrical energy. The VI characteristics of PV cell are similar to that of a conventional PN junction semiconductor diode. When the junction absorbs photons, the energy of absorbed photon is transferred to the electron-proton system of the material, thereby forming charge carriers separated at the junction. Solar panel/array is a group of a several cells connected in parallel and/or series combination to generate the required voltage and current values. A solar cell is the unit that is used to convert solar energy into electrical energy.

2.2 Wind turbine

Wind turbine is that equipment that is used to extract energy from wind by rotation of the blades of the wind turbine. A wind turbine is of two types: vertical and horizontal. As the wind speed increases the power generated at the output is also increased. The power generated from wind is not continuous rather it is fluctuating power. For obtaining non-fluctuating power one can also use battery for storage and then supply power to the load

2.3 Charge controller

Charge controller has a basic function which is to control the source which is to be active/ inactive. It is used to simultaneously charge the battery and provide power to the load. The main functions of the charge controller are overcharge protection, short circuit protection and automatic dump-load and additionally have a function that it should vary the power based on the load demand. It adds both the power outputs so that the load demands can fulfilled. And when power is not generated at the source, power can be extracted from the battery and supplied to the load.

2.4 Battery Bank

A battery is used for the purpose of storing charge. If there is excess power produced which need not be utilized for a certain period, it can be stored in batteries in the form of DC. So when neither of the two main power sources is unavailable, the battery is used to supply power to the micro-grid. The rating of battery should be such that it matches the voltage rating at load end of the MPPTs at both power sources. And the rate of charging depends on the amount of current made to flow per hour. The battery bank size needs to be selected as per the load requirement so that it should fulfill the requirement of load for calculating the battery bank size we need to find following data:

a) Find total daily use in watt-hour (Wh).
b) Find total back up time of the battery

Benefits:

- In case of a power failure, the battery provides power within the shortest time possible.
- The batteries come in different sizing, some are capable of bridging power outages from 2-24 hours i.e. they can

provide power 2 hours per day twice a day, because the battery chargers are powerful enough to recharge the battery to cater for the second outage on the same day thereby providing enough time between the 2 outages at least 4-6 hours.

- Less maintenance is required.

2.5 Micro-grid

A micro-grid is a small-scale power grid that can operate with other small grids independently or otherwise. The practice of using micro-grids is known as distributed; dispersed, decentralized, district energy production. If the micro-grid can be integrated with the area's main power grid, it is often referred to as a hybrid micro-grid. Micro-grids are typically supported by generators or renewable wind and solar energy resources and are often used to provide backup power or supplement the main power grid during periods of heavy demand. A micro-grid strategy that integrates local solar and wind resources can provide redundancy for essential services and make the main grid less susceptible to a localized disaster.

Buildings equipped with electricity generation capabilities using solar panels and battery banks can also generate energy and revenue during downtime. By joining together with smart grid deployments, excess energy can be sold back to local micro-grids to create revenue in addition to providing resilience and capacity to local electrical grids. The final part of sizing a solar system is the solar panels. The power rating of a solar panel is given in Watts. To calculate the energy it can supply to the battery, multiply Watts by the hours exposed to sunshine. Using the above calculation takes into consideration any losses in the system from the regulator, cables and battery one may be using.

3. System Specifications

Table 3.1: Solar Panel

Parameter	Type/Rating
Cell Type	Polycrystalline
Cell Efficiency	14%
Solar Radiation	2000 kWh/ m^2
Total Power of Plant	200kW
Radiation on panels	3GWh
Power at Output	0.47GWh
Power at Output with losses	0.35GWh

Table 3.2: Wind Turbine

Parameter	Type/Rating
Turbine Type	Horizontal Wind Axis Turbine
Power Output	201.8 kWh
Average Output Power in a year	125.34MWh/year

Table 3.3: Battery

Parameter	Type/Rating
Battery Type	Lithium- Hybrid Battery
Voltage	240V
Current	100Ah
Power	24kWh

Table 3.4: Charge Controller

Parameter	Type/Rating
Controller Type	Maximum Power Point Tracking
Algorithm	Perturb and Observe
Voltage rating(max)	240V
Current rating(max)	110Ah

4. Design of System Components

4.1 Calculation of the Solar Energy

The final part to sizing a solar system is the solar panels. The power generation rating of a Solar panel is also given in Watts. In Theory, to calculate the energy it can supply to the battery, multiply Watts (of the solar panel) by the hours exposed to sunshine. Using the above calculation takes into consideration any losses in the system from the regulator, cables and battery one may be using.

$$E = A_T * H * P_r * r \qquad (1)$$

E = Energy (kWh)

A_T = Area of Solar Panel (m^2)

H = Annual solar irradiation on tilted panels (average value)

P_r = Performance ratio, loss coefficient (Value: 0.5-0.9)

r = solar panel yield or efficiency (%)

It is the yield acquired by the solar panel given by the ratio of electrical power of one solar panel to the area of each panel.

=4,70,580 kWh/year x 75%(subtracting losses) = 3.53 GWh

4.2 Calculation of Wind Power

The formula to calculate power is:

$$Power = k\ Cp\ ½\ \rho\ A\ V^3 \qquad (2)$$

Where:

P = Power output, kilowatts

Cp = Maximum power coefficient. Dimensionless quantity (Range: 0.25 - 0.45). Maximum theoretical value = 0.59

ρ = Air density, kg/m^3 (Average air density in India is 1.225 g/m3)

A = Area swept by the rotor, m^2 or π D2/4 (D is the diameter of the rotor in m, π = 3.1416)

V = Wind speed, kmph (Ideal wind speed for obtaining maximum output is 64 kmph)

k = 0.000133. Constant, Yield power (kW)

P = 0.000133 x 0.59 x 27 x 1.225 x 0.35 x 643= 201.803kW

Power Output = 202 kW

To obtain a preliminary estimate of the performance of the given wind turbine, the formula given below is used:

$$AEO = 0.01328\ D2\ V3 \qquad (3)$$

AEO = Annual energy output, kWh/year

D = Rotor diameter, meter

V = Annual average wind speed, kmph

AEO= 0.01328 x 643 x 62= 125.34 MWh/year

4.3 Calculations for battery

Energy stored in battery:

Capacity of battery is measured in AH (e.g. 120AH). This is then converted to Wh by obtaining the product of the AH and the voltage rating of battery (e.g. 240V). Calculations are given below:

P (Capacity of battery in AH) x Q (Voltage of battery in V) = S (Power available in Wh) (4)

For a 120AH, 240V battery, the available power is 120(P)*240(Q) = 28.8kWH (S)

4.4 Power Consumption by Domestic Appliances

Energy consumed by a certain equipment in a given time period is equal to product of power consumption with the duration in hours it has been used for, add the output power of each appliance and obtain total consumption as given. The given calculations are based on power consumed by all appliances on a day.

Table 4.1: Power consumed by appliances per day

Appliance	Rating (W)	Usage(hr)	Consumed Power (W)
TV	30	2	60
Radio	8	5	40
Water pump	25	0.33	8.33
Main Light	20	3	60
Spot Lights	15	1	15
Total consumed power / day			183

4.5 Sizing of Solar Charge Controller

4.5.1 Solar Charge Controller Functions

The MPPT function is for regulating the charging of battery bank, for which the solar panel works as the source, and to check for overcharging. At night, it can additionally be used to avoid reverse current flow, for which a transistor is used here, that will help in shunting the PV charging circuit. This means that if battery is charged completely, it stops charging and if it reaches an unhealthy discharge point, it stops discharging. By using an MPPT, use of utility power is minimized and maximizes the efficiency and life cycle of the entire solar system which includes solar panels and batteries. More refined PV charge controllers ensure that batteries are charged by the utilization of PWM or MPPT techniques. Batteries can be made to work efficiently by giving pre-set low and high voltage cut-off settings.

4.5.2 Sizing Charge Controllers

It is really simple to size charge controllers. Solar charge controllers can be sized and rated depending on the PV array current (A) and the PV system's voltage (V).Therefore, sizing solar charge controllers is basically the process by which a charge controller that is substantial enough to handle the power generated by the solar system is obtained. The MPPT voltage is usually 12V/24V/48V. Amperage ratings of the system can range between 1A and 60 A and voltage ratings between 6V to 60 V. So if the PV system's voltage were 12 and the amperes were 14, the user would need a PV charge controller having at least 14 amperes. But considering factors like light reflection, there is an abrupt increase in current level, therefore a factor of 25% is added to bring the minimum current that the MPPT must have to a value of 17.5A. Hence, a 12 volts, 20 amperes charge controller is required. It won't affect anything if the derived MPPT current is higher; in fact it's a great idea with reference to practicality.

4.5.3 MPPT Charge Controllers

MPPT stands for Maximum Power Point Tracking and it is used in the very common case where the solar array voltage is higher than the battery bank voltage. MPPT solar charge controllers work great with systems that have panels with an odd voltage rating. When an MPPT solar charge controller observes a change in voltage, it will automatically and efficiently convert the higher value of voltage to a lower value, so the solar panels, battery and charge controller can all be at the same voltage. So with a 20 kW solar array with 250 volts, and the battery bank's voltage being 240 volts the user can determine the ampere the PV charge controller needs to have by dividing the power by the value lower of the two voltages. Watts / Volts = Amps. So, 20kW / 240V = 83.33 Amps Plus there should be an additional extra 25% for unexpected current increases due to factors such as light reflection and the final result is 104.16 amps. So the designed system is a 240 volt, 110 Amp MPPT charge controller.

4.5.4 PV Charge Controller - Upper Voltage Limit

Charge controllers of all types have an upper voltage limit. It refers to the maximum voltage the charge controllers can operate on from the PV array. The user must know the upper voltage limit and make sure that it hasn't exceeded or it may end up burning out the solar charge controller.

5. Block Diagram

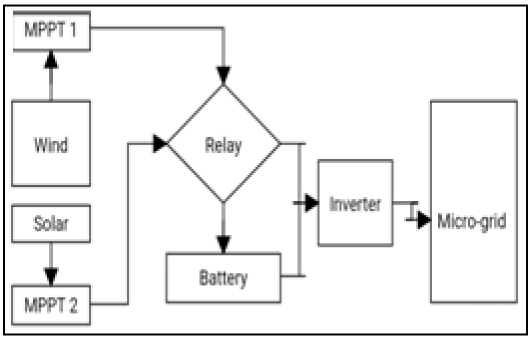

Figure 1: Block diagram of proposed system

6. Simulated Output Graphs

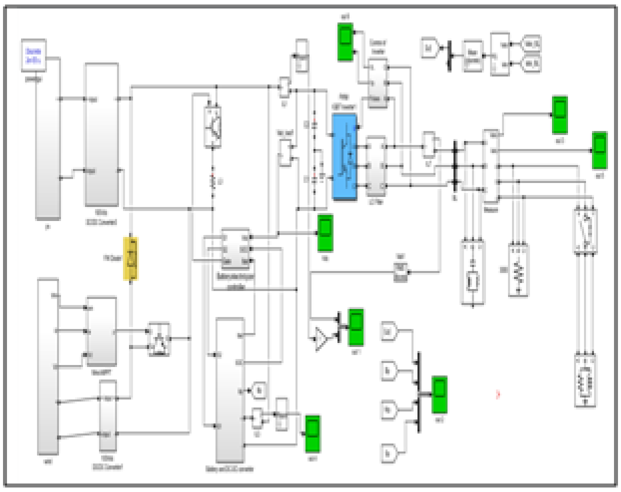

Figure 2: MATLAB Simulation of Proposed System

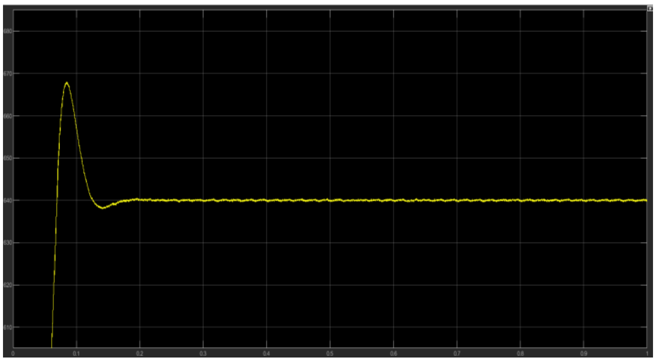

Figure 3: Input Power Waveform

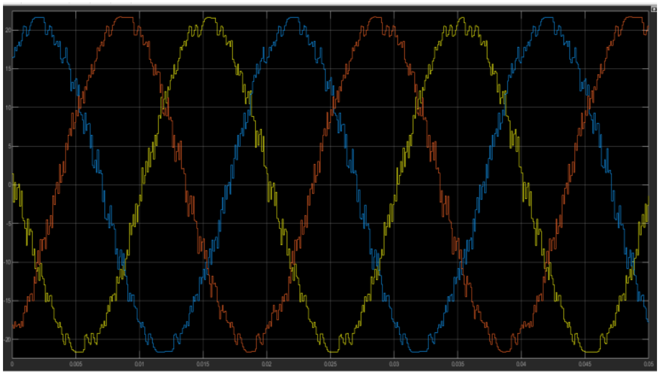

Figure 4: Output Current Waveform

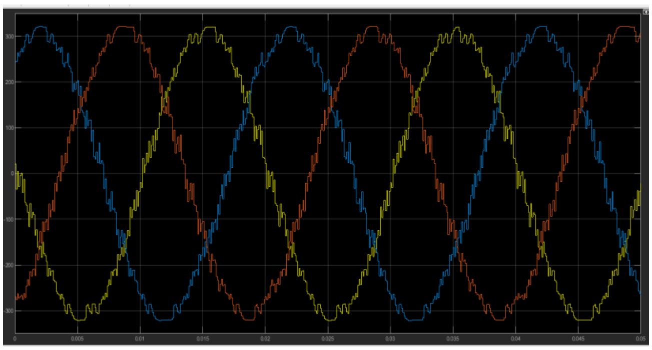

Figure 5: Output Voltage Waveform

Advantages of the System

A hybrid power generating system with two power sources namely wind and solar with an output that varies depending upon the weather conditions like irradiation falling on the surface of the earth and wind speed, but they can achieve synergy if used in parallel:

- The average output is more stable, on a daily basis
- Seasonal variations are offset.
- If it is an off grid installation, small battery packs would be sufficient.
- Making use of renewable energy sources in the most efficient way.
- Low maintenance cost
- High efficiency
- Load management

Comparison between Existing and Proposed Work

In the existing work, an uninterrupted power is supplied by using hybrid PV-wind energy system. When the given system was studied, it was understood that it involves the integration of two different energy sources that will provide uninterrupted power. Solar power is transformed into electrical energy using solar panels and wind energy is converted to electricity using wind turbines. Solar power is transformed into electrical energy with the help of solar panels and wind energy is converted to electricity with the help of wind turbines. The obtained electrical output can be used for various applications. Electricity is generated at a more environment friendly method.

At 200 Lumen/m^2 irradiation and 50% of peak speed of wind turbine, the output voltage obtained using the system is 70V. The proposed design at 200 W/m^2 irradiation and 50% of peak speed of wind turbine, the output voltage obtained using the system is 320V. By using MPPT at both PV and wind turbine ends, the power given to the micro-grid is controlled. The process of battery getting charged and power supplied to the micro-grid is done simultaneously power is supplied by any one of the sources. And the battery can be discharged to provide power to the micro-grid directly when both PV and wind turbines aren't able to provide sufficient power to the micro-grid. By using hybrid power plants higher generating capacities and continuous supply of power to the micro-grid can be achieved.

Some of the other important details include the use of battery charging system in our system compared to other papers. Another important point is the usage of hybrid system in our paper to power a grid unlike the other papers where PV system is in use. This system is made specifically for a micro-grid because of a better efficiency in power output. If focused on a certain area, with limited number of loads, this can be used and a large number of solar panels and wind turbine won't be required for the same. The objective is to power a small region, here in the form of micro-grid, rather than focusing on powering a very large area where there are chances of power deficiency since both wind and solar are unreliable sources of energy to an extent.

7. Conclusion

By the end of this project, coordinated supply control of solar and wind power sources has been achieved using MPPT to provide power to micro-grids; along with battery storage provisions rendering high efficiency and reliability through added power backup facility. The objective of using an MPPT is to obtain a constant output voltage. In a given solar system where irradiation has some value, which gives a constant voltage of 240V. If the irradiation is more the value then the voltage remains the same. Since wind-solar hybrid power plant are more beneficial than an individual wind or solar power plant because when one system is faulted other can supply the power. The MPPT used in this system works with Perturb and Observe algorithm, which extracts maximum power from the wind and solar system. Bi-directional converter is used to store the DC power in battery bank and supply power to the micro-grid by converting the DC power into AC power, the desired objective is achieved in the proposed paper.

8. Future Scope

Solar panels can be placed in water bodies to avoid it heating up which will result in a higher efficiency. Work is undergoing to develop this project and research on the same.

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