Power Flow Management in Hybrid Renewable Sources

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Abstract. The aim of this paper is to manage the power flow in hybrid renewable energy sources in efficient manner. In this there will be two renewable energy sources, battery, load and grid. In this system the bidirectional buck boost converter is used for PV source and battery, dual half bridge converter with transformer coupling and inverter for load / grid. In a standalone system, PV and wind source are made to operate in Maximum Power Point mode where the load will take the required power. In case of systems which are connected to the grid, two sources will always be operating at its MPP. If both the sources are not present, the required power will be taken from the grid and is used for charging the battery when the situation arises. MATLAB/Simulink is used to obtain the simulation results and the performance for the management of power flow is determined for various modes of operation

Keywords: Bidirectional converter, maximum power-point tracking, power flow management, hybrid system

Introduction
The world had seen rapid growth in demand for oil, largely met by fossil fuels. This causes some climate change and it motivates energy production. Technology development is required to obtain power from the renewable resources. Owing to its environmentally friendly nature, the common energy sources which do not have any impact on nature like the Wind and Solar Photovoltaic are increasing used nowadays with limitless supply. Currently researchers and scientist are using efficient ways with less component usage to obtain energy from these efficient sources. [1]

One such option available in the generation of electricity is from solar radiations. Technology development to utilize the Solar Energy, Heat and Solar Radiation light obtained from Sun which is limitless in supply are consistently available for used for emerging innovations. Solar energy consuming techniques like Solar Photovoltaic from the solar radiation, solar thermal electricity and solar Architecture are the solution for the energy related issue currently that are faced in the commitment noteworthy world. But the solar energy is used very limited due to the intermittent availability of the source which makes PV source a unreliable one for the use in critical applications. Such shortcomings can be overcome by operating other energy sources in conjunction with the PV source when it is not available [2]. Other solution also includes the usage of energy storage system for the operation with such intermittent sources of power.
Due to less supply of renewable energy (e.g., solar, wind, wave, ocean etc) resources which are intermittent in nature, hybrid innovations like combination of two or three power generation technologies which are related to each other with good storage can increase the increased efficiency. The hybrid system will convert the energy from all these resources into the typical energy form electricity and stored in the energy form and the output is connected to various loads. On the other hand, the benefit of this kind of system is, the system autonomy is guaranteed with the combination of these renewable resources. Several researchers used wind generator, solar generator and other storage system to create Hybrid stand-alone system install at ions to base the work [3]. Hybrid system with multi source still has the means or technique for energy efficiency as the main asset for making effective use of available resources. To ensure the minimal usage of the energy generated and satisfy the load demand efficient energy management algorithm can be derived.

The generation of hybrid power is becoming more popular due to its reliability factor. Power Plants can produce electricity by using traditional fossil fuels like (hybrid or non-hybrid systems), but the transport difficulties and fuel prices have forced more energy sources to be explored [4]. Different climatic factors such as wind speed, solar irradiation level and temperature which will lead to reduction in the efficiency of the WT and PV for production of electric power. The idea of hybrid power generation is more appropriate from the reliability point of view.

For hybrid systems, an efficient power flow management and control theory has been suggested in light of the above viewpoints and issues. The AC connect interfacing power electronic converters transfer the real power from renewable energy resources along with enhanced features of power quality [5]. An integrated high addition DC-DC help converter is used as a tracker for full solar power level. Everywhere in the earth there is a wind and sun; hence there’s more intensive analysis of these sources. Power management is essential to ensure both effective and economical system operates in integrated use of renewable energy sources. It is made possible by unpredictable weather conditions, day-night conditions and frequent voltage shifts [6].

In the proposed system, the battery source is used as a backup in addition to the solar pv. When the solar power is available, the battery will be charged. But when the solar power is unavailable, battery will drive the load [7]. the power flow in both directions is controlled by the bidirectional converter. The proposed system eliminates part numbers, thereby reducing power conversion stages relative to current grid-connected hybrid systems. Integrating the various renewable energy sources for each and every source we required a single- input converter. The power conversion takes place in any stage because of multiple converters, thus reducing system performance. Some surveys recommend size minimization and improved performance. Wind and battery sources are interfaced in the proposed solar system with the help of a single multi-input converter [8]. This type of converters can be used in stand-alone systems and grid connected systems. There may be different types of modes of operation present in this article. For stand-alone systems, the power is initially generated from the solar photovoltaic cell, the power produced will be given to the load, and the excess power is used to charging the battery, and is given to the grid. Wind sources are present, the load is given the produced power and the grid is given the excess. When charging the battery, it charges before it exceeds the maximum limit and is deviated and given to the other loads after the status has been obtained [9].

Management of power is important to assure both efficient and economical work of the system in combined means of renewable energy sources usage. Variable factors like day-night conditions, weather conditions and rapid change in voltages make it necessary to control the power flow management in renewable energy sources. In hybrid renewable system there will be many sources available thus makes the power flow management slightly complicate. To provide the control scheme for the solar, wind, battery and grid connected system.

1. Proposed System
The proposed system mainly consists of two renewable energy sources: charging, network, battery etc. Therefore, an energy flow management system given in figure 1 is very much important to balance the energy flow between all these sources. Renewable power is connected to converter and supplied to the AC load via the grid and the inverter. The system uses a single converter instead of each converter for each source. A bidirectional buck- boost converter is used to use PV energy with a battery charge / discharge controller [10]. A transformer coupled heavy duty half-bridge converter is used for harness the wind and a single-phase bidirectional full-bridge converter is used to power the AC load and interact with its grid. The proposed converter had a low number of power conversion stages with a low component count. The circuit is mainly classified into three parts namely bidirectional buck boost converter, transformer coupled boost dual half bridge converter and inverter.
Bidirectional buck boost converter as given in figure 2 is used for PV source and battery for charging and discharging purposes [11]. Transformer coupled DC-DC converter interconnects with the various sources and the storage elements. Inverter is connected in the secondary side of the transformer that connects to the ac loads and the grid. PV and battery are connected in series for the boosting purpose.

A transformer-coupled backup half-bridge converter is used in the harness wind power, and a single-phase bidirectional full-bridge converter is used to supply an AC load and interact with its grid.

1.1. **Buck–Boost Converter**

Buck-boost converter can function as a step-down converter working in DC-DC or a step-up converter. Voltage source at the input is connected via a solid-state drive as given in figure 3. The second device used is diode [12]. The diode is connected to the capacitor, is charged backwards from the source, and the two are connected in parallel as shown.

The switch that is operated can be turned on and off by using any one of the pulse width modulation schemes. PWM was time or frequency dependent. Frequency based modulation technique also has drawbacks such as a wide frequency range is used to achieve the desired switching power that can provide the desired output voltage. Time-based modulation is often used for DC-DC converter [13] which is easy to install and use. The frequency for this type of PWM modulation scheme remains constant. In the buck boost converter, they are composed of two types of converters which are buck
converters and the other one is boost converters. Such converters can generate the output voltage spectrum as opposed to the input voltage. The buck boost converter features two operating modes.

**Mode I: Switch is ON, Diode is OFF**

In this mode as given in figure 4, the switch is turned ON and thus signifies a short circuit preferably giving zero resistance for the flow of current and when the switch is turned ON all the current flows will be flowing through the switch and the inductor and back to the source of the DC input [14]. When the switch is turned on, the inductor will stores the charge, and when the solid-state switch is turned off, the inductor has an opposite polarity, so current returns to its inductor through the load and the diode. The current path through the inductor remains the same.

![Figure 4. Circuit Diagram of Buck Boost Converter in ON condition](image)

Suppose if the switch will be turned ON for $T_{ON}$ hour and turned off for $T_{OFF}$ hours. The period $T$ can be defined as $T=T_{ON}+T_{OFF}$. When analyzing a buck-boost converter, the following should be taken in consideration:

- The inductor current will be constant and choosing the correct value for $L$ will solve this issue.
- The steady state inductance current can increase from the current value with a positive slope to the maximum value in the on-state, then decreases with a negative slope to its initial value. Therefore, the net change in inductor current is zero over each cycle [15].

**Mode I: Switch is OFF, Diode is ON**

In this case as given in figure 5, the inductor connections are reversed so that the energy stored is dissipated through the load resistance. This keeps the current flowing through the load in the same direction and allows its output voltage to act as an inductor. The inductor also functions as source in combination with that of input source. However, it also keeps the original rules for evaluating circuits using KVL for visualization. It has been found that the net inductor current change is already zero over the entire period.

![Figure 5. Circuit Diagram of Buck Boost Converter in OFF condition](image)

The above two are standard buck boost converter operating modes. We use bidirectional buck boost converter in the proposed system. When the switch $T_1$ is turned ON, the energy will be stored in inductor $L$ during battery charging mode. Energy that is stored in inductor $L$ will be transferred to battery when switch $T_1$ is switched OFF and $T_2$ is switched On. When the discharging current of the battery is greater than that of the PV current, the inductor current will be negative. Here, the energy that is stored in inductor increases when $T_2$ turns ON and decreases when $T_1$ turns Off.
2. Methodology

A hybrid grid connection system based on four energy sources (battery, wind, grid & PV) and three loads / sinks (load, battery and grid). In this paper, a control scheme is proposed for this hybrid system. By increasing the current flow, it can be regulated to flow between these sources. The theory of multi-source system control to control power flow is based on concept of power balance. For independent case, the solar and wind energy sources generate the required maximum power that will be absorbed by the load. Here, power balancing can be achieved by charging the battery before the maximum current value exceeds Ib max. After this limit is reached, one or both sources must deviate from MPP performance based upon load requirements to maintain a balanced performance. The two sources often work with MPPs on the network. If both power sources are unavailable, the current to charge the battery is drawn from the power sources as needed.

If the power available from the PV or wind source changes, you can control the battery current by controlling the current from the Ig network. Therefore, the operation of the single-phase bidirectional full-bridge converter is depended on the availability of the network, photovoltaic and wind energy sources and state of charge of the battery. Battery charging is prioritized to ensure the uninterruptible power supply for critical loads. The surplus power from renewable energy is supplied to the grid until the maximum charging current limit of the Ib max battery is exceeded. Battery charging from the network is done without these sources.

2.1. Maximum Power Point Tracking

Maximum Power Point Tracking (MPPT) is an algorithm used in a photovoltaic power generation inverter (photovoltaic power generation inverters) that continuously changes the impedance used by the photovoltaic power generation device to create various allows you to work under conditions. B. As the amount of solar radiation increases, irradiance, temperature, and load work at or near the MPP of the solar module. MPPT system is a type of electronic automated control system which allows a photovoltaic system will reach maximum power. It is not a single mechanical function that movement of module redirects and points directly at sun. The MPPT control used in this scheme is an electronic system that could generate the maximum power allowed by electrically changing the operating point of the module. The MPPT algorithm is often used in photovoltaic power plant controller control. The algorithm takes into account factors such as variable irradiance (sunlight) and temperature to ensure that the photovoltaic system always produces maximum power.

The maximum power point of a Photovoltaic module can be determined by various types of algorithms. Some of the commonly used ones are listed below,

i. Perturb and Observe algorithm
ii. Incremental Conductance algorithm
iii. Parasitic capacitance
iv. Voltage based peak power tracking
v. Current Based peak power tracking.

Perturb & Observe

Each MPPT algorithm will have its own strengths and weaknesses. P & O methods (Perturb and Observe) are widely used because of their simplicity. This algorithm introduces a disturbance in operating voltage of panel. If duty cycle of DC-DC converter is changed, it can cause voltage disturbances. Figure 6 indicate the PV characteristics of photo voltaic system. By studying the P-v properties shows that the power increases with decreasing the voltage on the one end of MPP, but increases with the rise of the voltage on the other end. P & O algorithms use this main principle to track MPPs.

![Figure 6. P-V Characteristics of the system](image-url)
Flowchart for Perturb and Observe MPPT Algorithm
Maximum power can be derived from the solar panel by using this algorithm. This algorithm as shown in figure 7 perturbs its operating voltage to ensure maximum power.

![Flowchart for Perturb and Observe MPPT Algorithm](image1)

**Figure 7.** Flow chart of MPPT algorithm.

3. **Results and Discussion**

3.1. *Proposed system connected to solar*

The Simulink model of solar power connected hybrid renewable system is given in figure 8.

![Simulink model of solar connected system](image2)

**Figure 8.** Simulink model of solar connected system.

The results for the power flow management in hybrid renewable sources are obtained from the MATLAB/Simulink. Results obtained for various modes of operation that includes only PV source, only
wind source, only from the grid and both PV and wind source. The figure 9 shows about form the solar power, voltage & current. When the input from the solar power is constant the current and power generated will also be constant.

![Figure 9. Solar input voltage, current and power](image)

Figure 9. Solar input voltage, current and power

Figure 10 shows in detail about the wind voltage and current when the wind supply is not there. Even though there is no wind supply there will be small amount of current and current .This is shown clearly in the below graph.

![Figure 10. Wind voltage and Wind current.](image)

Figure 10. Wind voltage and Wind current.

In this mode the available source is only the solar Power. The output taken from the solar panel is shown in figure 11 is fed as input to the load through the rectifier. If there is any excess power available after supplying to the load, it is diverted to the grid.

![Fig .11. Rectifier output for solar input](image)

Figure 12 shows in detail about the power fed to the grid. It shows the Output current and voltage from the solar source that is to be fed to the grid.
3.2. Proposed system connected to wind

The Simulink model of wind connected hybrid renewable system is given in figure 13.

![Simulink model of wind connected system](image)

**Figure 13.** Simulink model of wind connected system.

The results for the power flow management in hybrid renewable sources are obtained from the MATLAB/Simulink. Results obtained for the system that includes only wind source, in this the solar source of power is not take into consideration. Generally in the second mode of operation the solar source will not be available, only source available will be the wind. Output of Voltage, current and power output when it is connected with wind source is shown in Figure 14. Figure 15 shows in detail the voltage and current when wind source is connected.

![Grid output voltage and current](image)

**Fig. 12.** Grid output voltage and current

**Figure 14.** Solar input voltage, current and power when wind is connected.
For the corresponding wind input with no solar input output of the rectifier is shown in the below graph. It gives the load sufficient power continuously for working and also charges the battery whenever required. Figures 16 and 17 shows the output of voltage and current given to grid.

3.3. Proposed system connected to Grid

The Matlab/Simulink model of hybrid grif connected renewable sources is given in figure 19.
The results for the power flow management in hybrid renewable sources are obtained from the MATLAB/Simulink. Results obtained for this modes of operation that includes both PV and wind source. In third mode of operation the solar input and wind input will not be present. The load runs from the grid supply and the battery is also gets charged whenever it is required as shown in figure 20. This helps for storing the energy when no other sources are available. The load works from the battery. This is the main features of the hybrid connected systems.

Figure 18. Simulink model of grid connected system.

Figure 19. Grid input voltage.

Figure 21 shows the charging status of the battery from the grid. The first graph shows in detail about the voltage fluctuations during the charging. The second graph shows the status of charging. Once the graph reaches the saturation point the charging will no longer happen.

Figure 20. Battery charging with voltage and percentage.
3.4. **Simulink Model For Solar, Wind & Grid Connected System**

The Simulink model for wind, solar and grid connected hybrid renewable sources is given in figure 22.

![Simulink model for the wind, grid and solar connected system](image)

**Figure 21.** Simulink model for the wind, grid and solar connected system

The results of the power flow management in hybrid renewable sources are obtained from the MATLAB/Simulink. Results obtained for this modes of operation that includes both PV and wind source connected in Grid. Sources like Solar, wind and grid are all connected in this mode of operation. Current, output power and voltage of solar PV source is represented in figure 23. Voltage and current output of the source connected with wind is shown in figure 24.

![Solar input voltage, current and power](image)

**Figure 22.** Solar input voltage, current and power.

![Wind input voltage and current](image)

**Figure 23.** Wind input voltage and current

The output of this mode of operation is given in the below two graphs as figures 25 and 26. First graph shows the output of the rectifier output and the next one indicates the output voltage and current of the grid when it is fed from solar, wind and grid connected system.
Figure 24. Rectifier output for the given system.

Figure 25. Grid output voltage and current

Figure 27 shows the battery charging status that charges from any one of the sources. The first graph shows the voltage of the battery and other shows the percentage of the battery.

Figure 26. Battery charging status when connected to solar, wind and grid.

The above Simulink model and the graph shows the different modes of operation in the solar, wind and grid connected systems. Thus, the power flow management plays the important role in satisfying about the load demand and provide the sufficient power to the load and excess is given to the grid.

4. Conclusion

A control scheme based on grid-connected hybrid photovoltaic wind-cell technology has been proposed. Thus, proposed hybrid system offers an elegant combination for solar and wind sources and gets total energy from both sources. This is achieved by a new bidirectional DC converter connected to a multi-input transformer, followed by its traditional full bridge inverter. Flexible control strategies are provided
in a grid-connected hybrid PV grid that powers AC loads and enables better use of PV, wind and battery capacity without sacrificing battery life. Detailed simulation experiments will be conducted to find out the feasibility of the given scheme. The results that are obtained from the experiment are clearly conforming with the simulations, supporting the testing of the system's ability to operate in mains mode or independent mode. The proposed design can provide uninterrupted power to the load and ensure that solar and wind power are delivered to the grid.

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