

Design and simulation of Hybrid Renewable Energy System (HRES) to supply three phase induction motor using fuzzy logic controller

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ABSTRACT

The entire world is now specializing in advancing their value of renewable energy assets equivalent as solar power, wind energy and fuel cell battery. Enormous growth has happened within the area of renewable energy and the energy harvesting approaches prior to now decade. This paper deals with the unique hybrid model of a solar / wind and fuel cell in Simulink, a high effective hybrid model is developed and when put next with the hybrid model which is making use of enhance converter as its rectifier system as an alternative of a buck converter. The simulation involves all logical components of the procedure, in this thesis power delivered by using the integrated process of more than a few add-on is when put next with each other and various conclusions are drawn. A comparative gain knowledge of the hybrid model with mixed approach of solar /wind and fuel cell system has been made. This paper describes the solar-wind-fuel hybrid system for presenting electricity to three phase induction motor with the aid of utilizing Fuzzy Controller and in addition maintaining frequency with MPPT in PV Cell. Working principle and detailed working condition are presented in this paper.

KEYWORDS: Photovoltaic cell(PV), Wind Energy, Fuel Cell, SEPIC Converter, MPPT (Maximum Power Point Tracking), Fuzzy Controller, Three Phase Induction Motor, Voltage Control, Energy Storage

1. INTRODUCTION

Nowadays the demand for hybrid system in power generation is growing in an incredible pace when compared to a standalone system. It is well known that the utilization of conventional energy sources like coal, crude oil and natural gas has several drawbacks including limited availability, increasing cost of these fuels, cost of generation of energy in addition to the higher level of pollution caused to the environment. Organizations and governments around the world have started showing increasing interest in the renewable sources like solar, wind and tidal energy after the oil crisis in the 1970s.

It is evident from literature on renewable energy that majority of the studies were focused on areas like cost reduction of generation, efficiency improvement and alternative sources of renewable energy. However, many studies also attempted on solving issues surrounding the enhancement of distribution of renewable energy to meet the increasing demand (Ersan Kabalci, 2013).

Despite the fact that the renewable energy show nonlinear characteristics in comparison with nuclear and thermal energy sources, they do not cause any environmental pollution. Solar energy, wind energy, fuel cell, hydel power and tidal sources are the most extensively used renewable energy resource for electricity generation. Research on renewable energy have been going for a long time in order to identify the energy alternatives and increase the efficiency of the current sources. Hybrid system in renewable energy generation is a new technique that combines the advantage of more than one form renewable energy source.

It described the distributed generation as the electric power source that directly connects to either the distribution network or to the consumer end (Ackermann T, Andersson G, Soder, 2000).

The distributed power system are depended on power sources like solar Photovoltaic (PV) cells, wind turbine systems, fuel cells, and micro-turbines. The distributed renewable systems are rapidly developing in order to meet the energy demand globally. The performance of the distributed energy generation systems can be improved by integrating various renewable energy sources to create a hybrid system. The advantage of such hybrid system is that if one of the energy source like wind energy fails to generate and supply to the load, the other source like solar, fuel cell etc can continue to supply. Thus, the sustainability of the power system can be ensured through continuous supply to the distribute load.

They have modeled three separate solar farms having rated power of 15kW's located in different places separated by large distances. The buck converter system based on Perturb & Observe (P&O) MPPT control algorithm was used for DC-DC conversion system. The advantage of the buck convertor system included stability in energy generation in all the individual solar forms (Çolak I, Kabalcı E, Bal, 2011).

They developed a Simulink model that included wind, solar and fuel cell energy sources. A novel topology was used to develop the dynamic model based on solar cell-wind turbine-fuel cell hybrid system. The model was simulated and the topology aids in complement the source when another source fails and eliminated the effects due to environmental changes. The study used fuel cell as ultra-capacitor model to store extra energy generated (Chen H, Qiu J, Liu C, 2008).

Noted that combining renewable energy systems in the so-called “hybrid renewable energy systems” may provide dependable electricity supply with positively reduced battery storage or diesel requirements. Generally, a fossil fuel-based generation is recommended to be included into the system preferably increasing when there is a demand for a wind turbine or PV sizes increasingly to survive with the worst month that is in case of seasonal changes (Celik, 2003).

Proposed that using two or more RES is financially favorable especially for place/situations whereby seasonable changes notably over weather variations (Bhattacharjee, 2014) In (Gan, Shek, Mueller, 2014), the authors are suggesting the use of static programming technique to perform sizing of the hybrid system components (battery capacity and diesel fuel usage) within the 24 hours period or within peak demand.

It is presented an application based on island mode that is comprised of wind and solar energy. The proposed hybrid system included a battery bank and diesel generator which ensures continuous supply to the load. The authors suggesting the usage of dump load when the battery is charged fully and also when the power generated from solar and wind surpasses the demand. The dump load prevents the overcharge of battery bank. Thus, the lifetime of battery bank is increased and the continuous metering can also be avoided (Hirose T, Matsuo, 2011).

They have developed an effective hybrid grid-connected system based on fuel cell and wind turbine. The proposed system was controlled by fuzzy PI observer in Simulink and the total harmonic distortion (THD) rate produced by the system was lesser than 4%. The system very highly responsive to dynamic loads and reacts very rapidly to the load variations (Guo Z, Lee KY, 2011).

Ray et al. (2011) have developed a hybrid system based on renewable energy sources like wind, photovoltaic and fuel cell in addition to diesel engine generator energy storage elements using capacitor bank. The study suggests that variation in the wind speed and inconsistency in solar radiation pattern causes drastic variations in power output and frequency in offshore wind and PV system respectively. Thus, it recommends usage of Ultra-Capacitor (UC) as backup energy storage element and proportional-integral (PI) controller to bring about improvements in the frequency deviations. The authors compared the frequency deviations for various hybrid systems in the presence of HVDC link and HVAC line. It was observed that from the qualitative and quantitative analysis that inclusion of energy storage element using ultra capacitor (UC) has tremendously improved the frequency deviation profiles.

Vlad et al. (2010) have formulated the maximum power point tracking problem for the wind energy conversion systems characterized by low-power and fixed-pitch system. The study focused on computing maximum power that can be obtained using low-power wind energy systems operated using partial load. The system used multi-polar permanent-magnet synchronous generators, to analyze the variations in the efficiency over the wider operating range. Results shows that the steady-state performance of the conversion system depends on the generator behavior. The study reconfirms importance of generator efficiency for WECS.

In developed countries, most of the generated electrical energy is transformed into mechanical energy using electrical motors (Hussein Sarhan and Rateb Issa, 2006). The induction motor is the most widely used motor in the industries, they comprise about 91% of the motors. Induction motors have advantages in efficiency and robustness over other electrical motors. Normally most of the motors are uncontrolled, but the employment of electronically controlled drives is increasing.

The synthesis of literature in the preceding paragraphs points that the research focus as well as expectations from the distributed generation using renewable energy sources is increasing. In this paper, a distributed generation system is proposed to be designed by modelling a solar energy plant, wind turbine model and fuel cell as a hybrid input module and induction motor as output in Simulink. The designed model has four main subsections like solar energy plant, wind energy conversion system, fuel cell and DC-AC energy conversion part to run single induction motor. The renewable energy conversion systems are employed to convert the generated energy in DC bus-bar into AC supply using three phase full bridge inverter. The proposed distributed system using HRES produces loads with lower Total Harmonic Distortion (THD). The proposed HRES system was analyzed in the following in terms of design and analysis in the following sections.

- i.** Advancement in the conversion of electrical power using new power electronic semiconductor devices which has resulted in improved system quality, improvement in efficiency and reliability.
- ii.** Developments in the simulation software leads to flexibility in the design of hybrid energy system. The advancement in the manufacturing process and improvement in the efficiency of PV modules.
- iii.** The development in the area of customization of automatic controllers has improved the operation of hybrid energy systems and reduced the need for frequent maintenance requirements.
- iv.** Improvement in quality of lead-acid batteries. Which lengthened the renewable energy systems cycle of operation.
- v.** Growth in the reliability and efficiency of appliances (AC and DC) appliances which can recover their additional cost over their extended operating lifetime.

2. MODELLING OF HYBRID RENEWABLE ENERGY SYSTEM (HRES)

The proposed design of HRES includes parts:

- Wind energy conversion system consisting of full bridge rectifier, Permanent magnet synchronous wind turbine generator
- Solar energy conversion system comprising solar panels, MPPT and the PI-controlled boost converter, and
- Fuel Cell Battery.

The output of the individual energy conversion systems is combined using fixed DC link voltage to obtain the required input voltage from full bridge inverter.

Modeling of photovoltaic system: The input energy to PV system through solar radiation and total solar radiation on an inclined surface is estimated as

$$I_T = I_b R_B + I_d R_d + (I_b + I_d) R_r \quad (1)$$

where I_b and I_d are direct normal and diffuse solar radiations, R_d and R_r are tilt factors for the diffuse and reflected part of the solar radiations.

The total solar radiation depends on the position of the sun and shows varying temperature from month to month. The power output from PV system calculated on hourly basis for an area (m^2) on any average day of j th month, when total solar radiation of I ($kW\ h/m^2$) is incident on PV surface, is given by equation 2

$$P_{sj} = I_T \eta A_{pv} \quad (2)$$

where system efficiency η is given by $\eta = \eta_m \eta_{pc} P_f$ (3)

and, the module efficiency η_m is computed using equation 4.

$$\eta_m = \eta_r [1 - \beta(T_c - T_r)] \quad (4)$$

β represents the array η temperature coefficient, T_r denotes the reference temperature for the cell efficiency and T_c is the monthly average cell temperature which can be calculated as follows:

$$T_c = T_a + \frac{\alpha \tau}{U_L} I_T \quad (5)$$

where T_a is the instantaneous ambient temperature.

Here the MPPT algorithm is mainly used to maintain the duty cycle and maintain it within the efficient frequency. It can also track the parameter by managing with temperature change. Let us see the simulation of Photovoltaic cell and MPPT in below figure 1

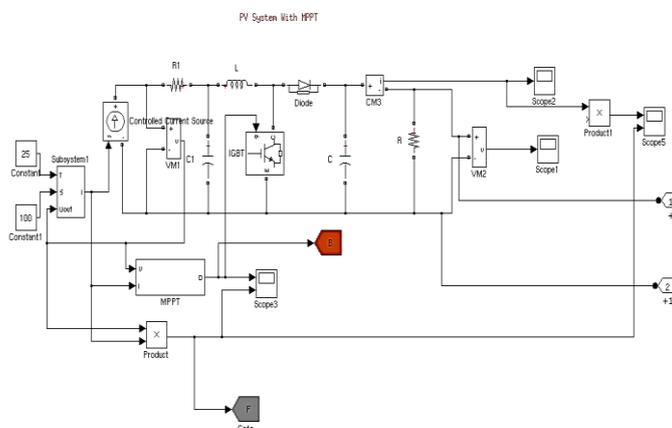


Figure.1.Simulation of PV system with MPPT

Modeling of wind energy system: In a specific site, the output power of wind turbine generator can be calculated based on the wind speed at hub height, speed characteristics of the turbine and temperature. Wind speed at hub height can be calculated by using power-law equation 6:

$$V_z = V_i \left[\frac{z}{z_i} \right]^x \quad (6)$$

where V_z and V_i represents the wind speed at the hub and reference height (Z and Z_i), and x is a power-law exponent. Fig. 1 shows the wind turbine characteristics. Power output P_w (kW/m^2) from wind turbine generator was computed as follows:

$$P_w = 0, V < V_{ci}; P_w = aV^3 - bPr, V_{ci} < V < V_r, P_w = Pr, V_r < V < V_{co}; P_w = 0, V > V_{co} \quad (7)$$

V_{ci} , V_{co} and V_r are the cut-in, cut-out and rated speed of the wind turbine. Exact power generated in wind turbine is given by equation 8.

$$P = P_w A_w Z \quad (8)$$

where A_w is the total swept area, Z is the efficiency of wind turbine system including converters

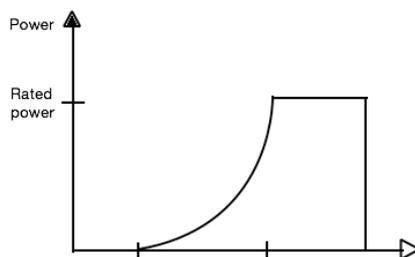


Figure.2. Wind turbine characteristics

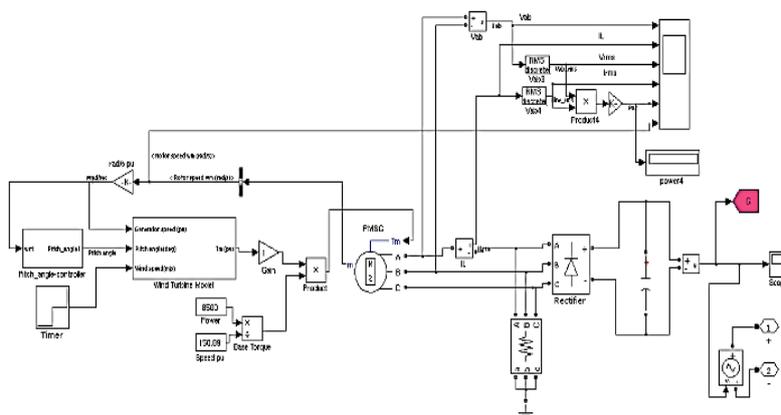


Figure.3. Simulation for wind energy

Modeling of battery system: In the HRES, battery storage has been employed for meeting load demand during the period when the renewable energy source are unavailable. It may extend for 2 - 3 days. Battery sizing depends on several factors like temperature correction, depth of discharge, battery rated capacity and effective battery life. The battery capacity in ampere-hr is given by equation 9

$$B_{yc} = \frac{E_c(Ah)d_s}{(DOD)_{max}\eta t} \quad (9)$$

here $E_c(Ah)$ is the load in ampere-hr, D_s is the storage days, Z_t is the temperature correction factor, $(DOD)_{max}$ represents the maximum battery depth of discharge. The difference between the load and the power generated indicates if the battery is in charging state or in discharging state. At time t , the charge quantity of battery bank can be computed by equation 10

$$E_B(t) = E_B(t-1)(1-\sigma) + \left(E_{GA}(t) - \frac{E_L(t)}{\eta_{inv}}\right)\eta_{battery} \quad (10)$$

where $E_g(t)$ and $E_g(t-1)$ represent the charge quantities of battery bank at time t and $t-1$, σ is used to calculate the hourly self-discharge rate, $E_L(t)$ is load demand at the time t , $E_{GA}(t)$ is the total energy generated by energy loss in controller by renewable energy source. Charge quantity of the required battery bank is subjected to the following constraints:

$$E_{Bmax} \leq E_B(t) \leq E_{Bmin} \quad (11)$$

where, E_{Bmax} and E_{Bmin} are the maximum and minimum charge quantity of battery bank. Here fuel cell is acting as the battery. The Matlab simulation of the proton exchange membrane fuel cell, which is an advanced form of fuel in comparison with fuel cell and it acts also at low temperature.

Simulation of Sepic Converter: The single-ended primary inductor converter (SEPIC) is a DC to DC converter that produces an output voltage greater than, less than, or equal to that of its input voltage. The output of the SEPIC can be controlled by the duty cycle of the control transistor.

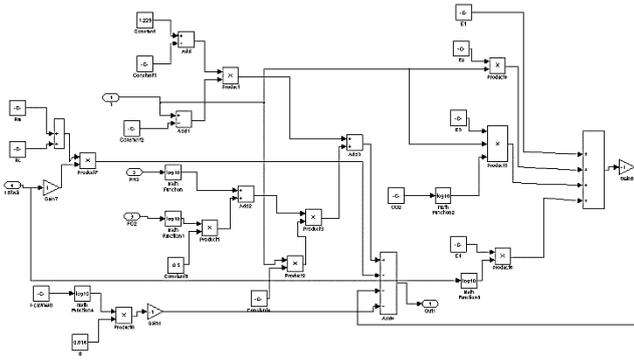


Figure.4.Simulation of fuel cell

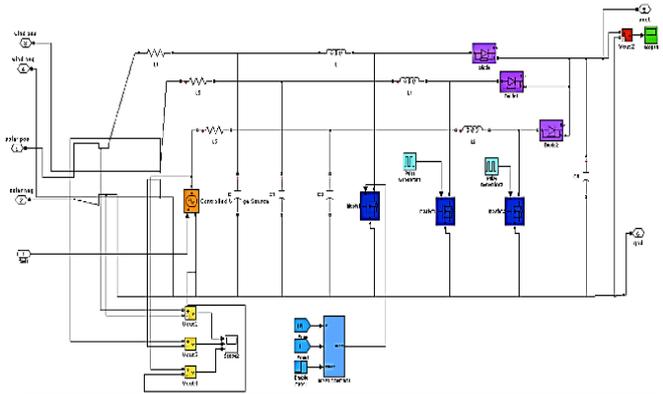


Figure.5.Simulation for SEPIC Converter

Simulation Result for input of Solar, Wind and Fuel System:

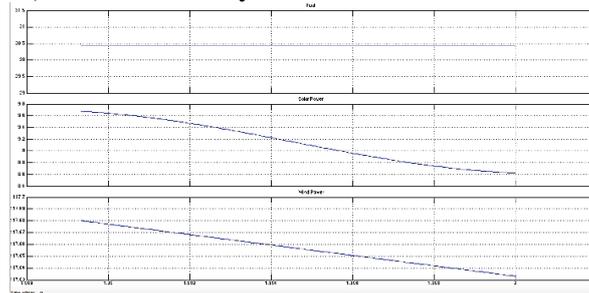


Fig.6.Simulation for RES Input

The input for hybrid renewable energy system of Solar energy, Wind energy, and Fuel Cell is shown in the Fig 3.6.1 simulation with the limited values wi dependent of Load three phase Induction Motor.

Simulation of overall hybrid RES system: The overall Hybrid system simulation is shown in the below figure 7.

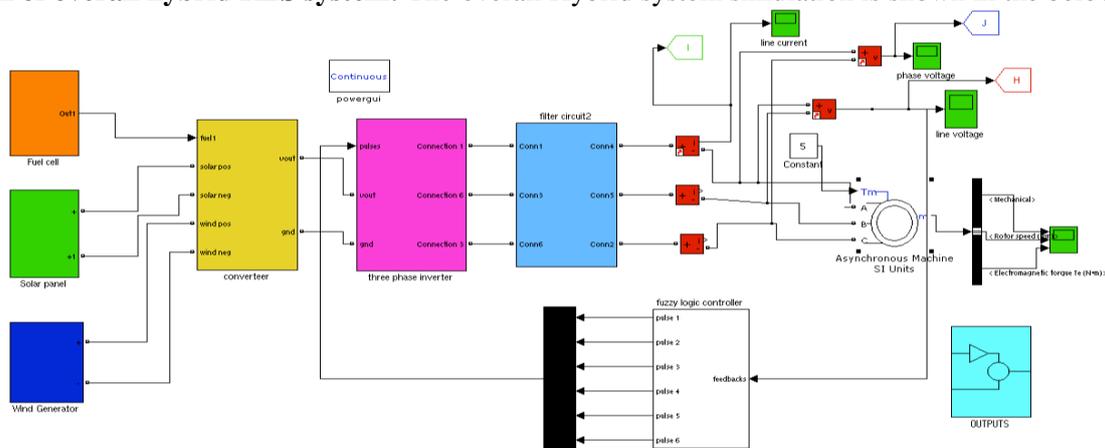


Figure.7.The overall subsystem diagram of the 3φ Hybrid System

Simulation result of three phase induction motor: The simulation result of Single phase induction motor which is connected with the hybrid RES system is shown below of the Figure.8.

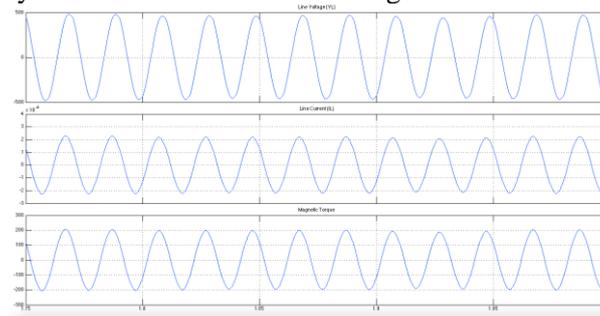


Figure.8.Overall Output

3. HRES FOR ENERGY FLOW AND MANAGEMENT

The major problems associated with the design of HRES is related to the control and management of the distribution system. The power quality and system stability are greatly affected because of dynamic interaction between the grid system with the power electronic interface of renewable source.

The main aim of the energy flow and management system is satisfying the demand. The efficient operation of the integrated power system can be achieved by satisfying the operating strategy for energy flow. The advantages of fuel cells include modularity, better efficiency and flexibility however the main disadvantage is slow dynamics of fuel cell.

The uninterrupted and quality power can be obtained by integrating fuel cells with PV power systems. The purpose of this paper is to design an effective power management system for a HRE system.

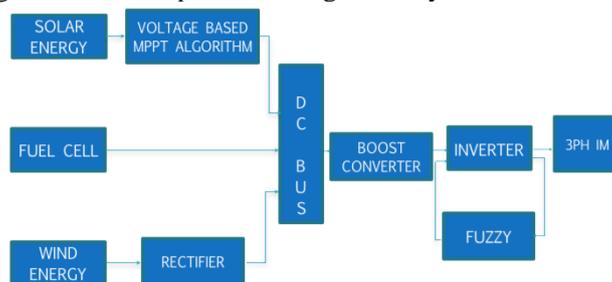


Figure.9. Block diagram of hybrid system

Using conventional approach: The various hybrid systems use the conventional approach for controlling the power supply according to demand. Advanced power electronics based DC–DC converter have better control over the integrated hybrid system by optimizing the maximum energy from solar, wind energy sources, and control the complete hybrid system. Some researchers have used different control techniques for the different combination of hybrid energy systems.

Das et al. (2005) have modeled the hybrid energy system consisting of PV/wind/fuel cell. In the case of worst environmental conditions, the fuel cell provides the rated power of 10 kW instead of the wind or photovoltaic cells. They introduced simple and cheaper control method using DC–DC converter that performed maximum power point tracking. As a result the model was able to obtain maximum power from solar array and wind turbines. The model included a single PWM voltage source inverter connected with the DC-DC converter holds its output voltages at a fixed value. PSIM software tool is used for modeling energy sources that analyze their dynamic behavior [27].

Abdin and Xu (1998) have designed and implemented a control scheme for a wind energy conversion using induction generators. The horizontal axis wind turbine drives a three-phase induction generator and a double overhead transmission line was used for interfacing to the utilities. The voltage at the output was regulated using a static VAR compensator. The mechanical power output was controlled using the blade pitch-angle. The generator output was regulated using MATLAB software through iterative design and feedback of output from controllers. The results showed that the closed loop system has produced fast recovery and good damping for large disturbances.

Using expert system: The design of the control system for HRES configurations should aim to reduce the fuel consumption by maximizing power output from the renewable sources. The variation of renewable causes power fluctuations, which in turn affects the power quality. The advancement in control technique of RES will improve the flow of energy in future.

The controller is developed by using the artificial intelligent or expert systems for energy flow in hybrid systems in some literature. Some review papers explain about these concepts as below. El-Shater et al proposed an energy system consisting of three energy sources, namely wind, fuel cells and PV that explains the Energy flow and management. These three sources are controlled in such a way that it provides maximum energy at optimum efficiency to DC voltage bus using Fuzzy logic control technique. Hancock et al propose a method of optimizing and controlling the operation of stand-alone hybrid power systems. It consists of the sources such as PV generation, auxiliary generator, and storage battery. This paper explains the method that optimizes the operation of hybrid systems.

On the basis of above literature review, researchers found that the individual components should be modeled first and then the combination of models should be evaluated to satisfy the demand.

4. FUTURE TRENDS IN HYBRID ENERGY SYSTEM

The above discussion on the hybrid energy system suggests that it is going to play a major role in solving the energy crisis as a sustainable energy system. Hybrid system can be designed and operated using two modes viz. a standalone mode and grid-assisted mode. A stand-alone mode of operation depends on wind–solar hybrid energy system. On the other hand, a grid-assisted system when the hybrid system goes to non-operational mode and fails to generate the power, it automatically draws the grid power. Thus, the design of the mode of operation of hybrid system

is very crucial in future. The decision has to be taken regarding how the system is operated either as a standalone system or grid assisted one. In a grid-connected system, the parameters in grid like variation in voltage, frequency pattern, waveform shape and power factor should be taken into consideration while connecting to the grid. The research interest in control of energy flow in hybrid system using power electronic converters is growing tremendously.

Future research efforts in solar and wind energy for electricity generation will result in reduced cost and increasing acceptability by wider section of society. The proposed HRES will facilitate production of economical and environmentally safe energy that is omnipresent.

In addition, energy management and optimization system of HRES can be further enhanced by adding the artificial intelligence. The paper suggest that research directions in HRES focus on areas like superior management strategies using centralized controller system and advanced control techniques, cost reduction using optimization of resource allocation, load demand analysis, resource forecasting etc.

5. CONCLUSION

This paper proposes a converter topology that interfaces three port power points connecting with three phase hybrid renewable energy sources (PV, Wind and Fuel Cell) to run a load (three phase induction motor) boosting up with SEPIC Converter to step up/down or balances the voltage technique requirements by which the efficiency has been improved with reduced components and less stress on switches as we neglect the boost converter. We can use this step up power system for even to conduct peak load.

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