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DESIGN AND SIMULATION OF HYBRID RENEWABLE ENERGY SYSTEM TO SUPPLY SINGLE PHASE INDUCTION MOTOR USING FUZZY LOGIC CONTROLLER

K. Saravanan
Associate Professor/Dept of EEE, Dr.MGR Educational and Research Institute, Tamilnadu, India

ABSTRACT:
The whole world is now Focusing on advancing their pool of renewable energy resources such as Solar power, wind energy and fuel cell battery. Immense growth has happened in the field of renewable energy and the energy harvesting methods in the past decade.This paper deals with the detailed of a hybrid model of a solar / wind and fuel cell in Simulink, a high efficient hybrid model is developed and compared with the hybrid model which is using boost converter as its rectifier system instead of buck converter. The simulation includes all realistic components of the system, in this thesis power delivered by the combine system component is compared with each other and various conclusions are drawn. A comparative study of hybrid model of solar /wind and fuel cells system has been made. This paper describe of solar-wind-fuel hybrid system for supplying electricity to induction motor. Working principle and specific working condition are presented in this paper.

INTRODUCTION

One of the most promising applications of renewable energy technology is the installation of hybrid energy systems in remote areas. The whole world is now concentrating on advancing their pool of renewable energy resources. Rapid depletion of fossil fuel resources on a worldwide basis has necessitated an urgent search for alternative energy sources to cater to the present days' demand. Another key reason to reduce our reliance on fossil fuels is the growing evidence of the global warming phenomena. Therefore, it is imperative to find alternative energy sources to cover the continuously increasing demand of energy while minimise the negative environmental impacts. Solar , wind energy and fuel energy systems are being considered as promising power generating sources due to their availability and topological advantages for local power generations in remote areas. Utilization of solar ,wind and fuel energy has become increasingly significant, attractive and cost-effective, since the oil crises of early 1970s. However, a drawback, common to solar and wind options, is their unpredictable nature and dependence on weather and climatic changes, and the variations of solar and wind energy may not match with the time distribution of load demand. This short- coming not only affects the system's energy performance, but also results in batteries being discarded too early. Generally, the independent use of both energy resources may result in considerable over-sizing, which in turn makes the design costly. It is prudent that neither a stand-alone solar energy system nor wind energy nor a fuel energy system can provide a continuous power supply due to seasonal and periodical variations for stand-alone systems.

Fortunately, the problems caused by the variable nature of these resources can be partially or wholly overcome by integrating these three energy resources in a proper combination, using the strengths of one source to overcome the weakness of the other. The use of different energy sources allows improving the system efficiency and reliability of the energy supply and reduces the energy storage requirements compared to systems comprising only one single renewable energy source. With the complementary characteristics between solar energy and wind energy for certain locations, the hybrid solar–wind power generation systems with storage banks offer a highly reliable source of power, which is suitable to electrical loads that need higher reliability. In the past, the hybrid systems have been considered as preferred for remote systems like radio telecommunication, satellite earth stations, or at sites far away from a conventional power system. Today, there is a trend to update the existing one source system (PV, wind or hydro) into hybrid system to run the induction motor.

In order to efficiently and economically utilize the renewable energy resources, one optimum sizing method is necessary. The optimum sizing method can help to guarantee the lowest investment with full use of the PV array, wind turbine and battery bank, so that the hybrid system can work at the optimum conditions in terms of investment and system power reliability. This type of optimization includes economical objectives, and it requires the assessment of the system's long-term performance in order to reach the best compromise for both reliability and cost.

The recent state of art hybrid energy system technological development is the result of activities in a number of research areas, such as

1) Advances in electrical power conversion through the availability of new power electronic semiconductor devices, have led to improved efficiency, system quality and reliability.
2) Development of versatile hybrid energy system simulation software; continuing advances in the manufacturing process and improve efficiency of photovoltaic modules.
3) The development of customized, automatic controllers, which improve the operation of hybrid energy systems and reduce maintenance requirements.
4) Development of improved, deep-cycle, lead-acid batteries for renewable energy systems.
5) Availability of more efficient and reliable AC and DC appliances, which can recover their additional cost over their extended operating lifetime.

Proper topology based implementation of power electronics and motor drives in the generation of various renewable energy sources such as solar power, wind power and fuel cells energy storage elements are discussed in details. Individual sources of renewable energy resources interfaced with multi stages of power electronic systems are elaborated in the paper.

GROWTH TRENDS OF RENEWABLE ENERGY RESOURCES

Renewable energy sources such as solar power, wind power and fuel cell are becoming an increasingly important part of every nation's electricity fuel mix. Renewable sources produce minimal environmental impact and generally have little or no fuel costs. There is a remarkable development of RERs, being projected across the globe as shown in Fig. 1 The rate of growth of RER from 2004 to 2008 has not been that significant. But starting 2009 there has been a global move towards more of green energy or clean coal technology which has resulted in considerable amount of growth in the past year as projected in Fig. 1.

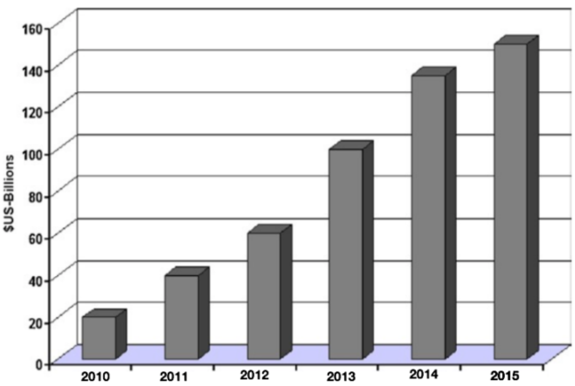


Fig.2.1. Approximate global annual grow thing (%) of renewable energy ressources

The growth in RER is no longer confined to the developed world. There are significant prospects of RER expansion happening in developing countries. Despite the continuing upward trend of renewable energy growth and the positive achievements, the world has extracted only a small portion of the RER. RER development policies and efforts are now continuously being investigated in order to strengthen the development to the next level. This continuous process of enhancements of energy policies leading to a great market penetration of RER in the energy sector will play a critical role in building a long-term, stable, low-carbon global green economy. There are significant investments happening in different areas of RERs around the globe as shown in Fig. 2. Based on the recent trend of fastest growth ever in the field of RER, it can be projected that the world wide investments in the field of renewable energy is going up by manifolds as projected.

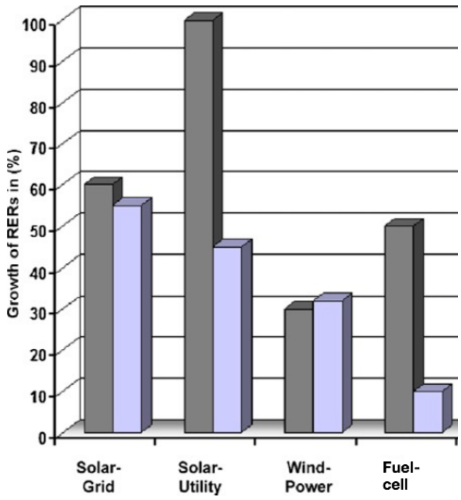


Fig. 2.2. World-wide annual growth in investments in renewable energy resource

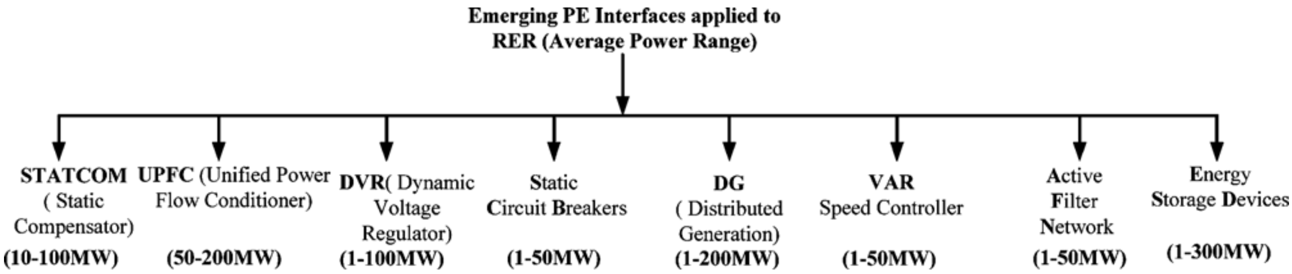


Fig. 2.3. Different applications of PE with respect to RER

MODELING OF HYBRID RENEWABLE ENERGY SYSTEM (HRES)

The proposed HRES consists three parts; (i) wind energy conversion system with Permanent magnet synchronous wind turbine generator, uncontrolled full bridge rectifier and PI-controlled boost converter, (ii) solar energy conversion system containing solar panels, MPPT and PI-controlled boost converter, and (iii) Fuel Cell Battery. Each output of the energy conversion systems are combined through IPT to fixed DC link voltage for required input voltage of full bridge inverter. The proposed HRES is illustrated in Fig. 1.

3.1. Modeling of photovoltaic system:

The input energy to PV system is solar radiation and total solar radiation on an inclined surface is estimated as

$$I_T=I_bR_B+I_dR_d+(I_b+I_d)R_r, \quad (1)$$

Where Ib and Id are direct normal and diffuse solar radiations,

Rd and Rr are the tilt factors for the diffuse and reflected part of the solar radiations [5].
The total solar radiation thus estimated depends on position of sun in the sky, which varies from month to month. Hourly power output from PV system with an area Apv (m2) on an average day of jth month, when total solar radiation of IT (kW h/m2) is incident on PV surface, is given by [6]

$$P_{sj}=I_{Tj}\eta A_{PV}, \text{.......................................}(2)$$

where system efficiency η is given by [7]

$$\eta=\eta_m\eta_{pc}P_f\text{.......................................}(3)$$

and, the module efficiency ηm is given by

$$\eta_m=\eta_r[1-\beta(T_c-T_r)], \text{.......................................}(4)$$

b is the array efficiency temperature coefficient, Tr is the reference temperature for the cell efficiency and Tc is the monthly average cell temperature [8] and can be calculated as follows:

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

where Ta is the instantaneous ambient temperature.

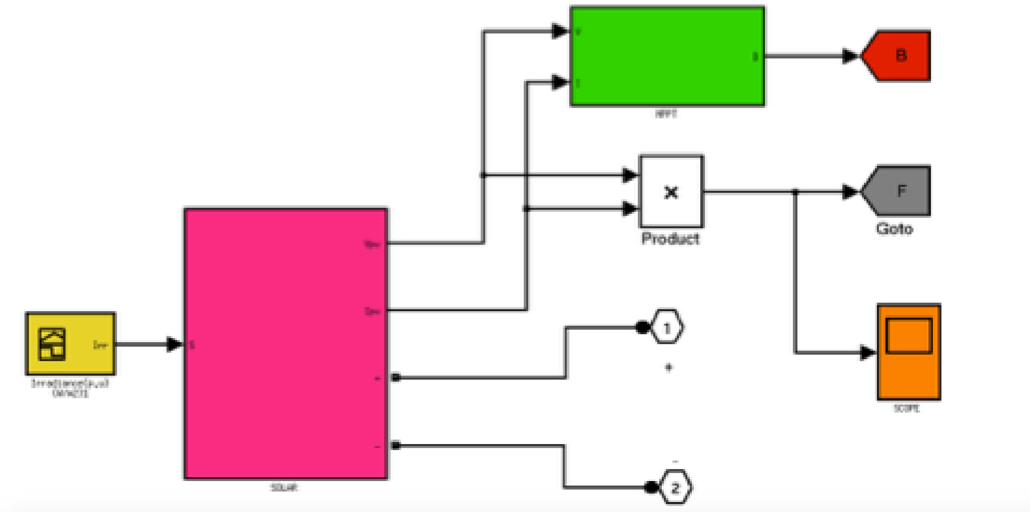


Fig 3.1.1 Simulation for subsystem of photovoltaic

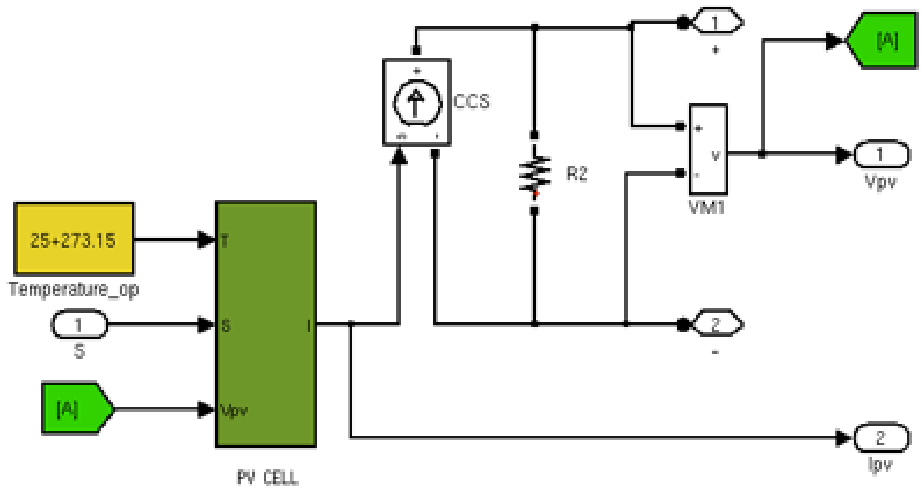


Fig 3.1.2 simulation for photovoltaic

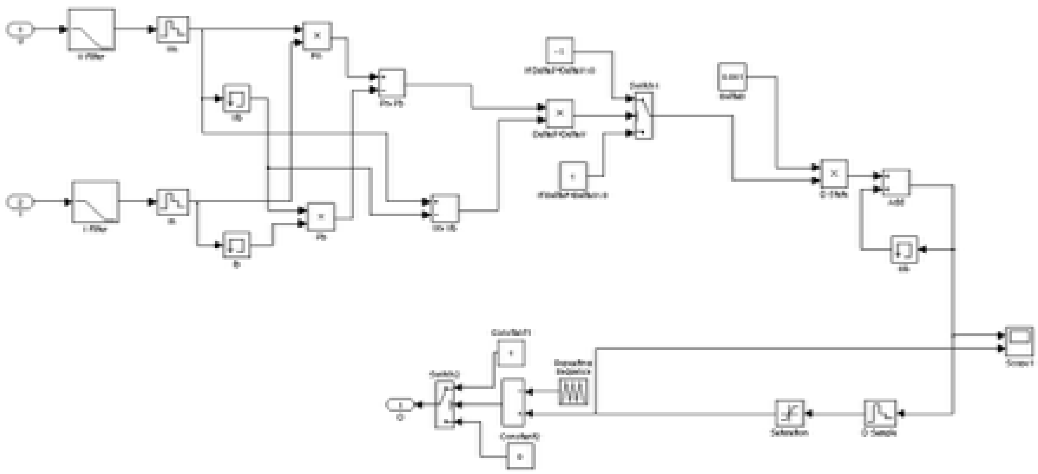


Fig 3.1.3 simulation for MPPT

3.2. Modeling of wind energy system:

Power output of wind turbine generator at a specific site depends on wind speed at hub height and speed characteristics of the turbine. Wind speed at hub height can be calculated by using power-law equation [9]:

☐ $$V_z = V_i \left[\frac{Z}{Z_i} \right]^x, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

whereVz and Vi are the wind speed at hub and reference height Z and Zi, and x is power- law exponent.

Fig. 1 shows typical wind turbine characteristics. Power output Pw (kW/m2) from wind turbine generator can be calculated as follows [10]:

$$Pw=0, V<Vci;\ Pw=aV^3-bPr, Vci<V<Vr;\ Pw=Pr, Vr<V<Vco;\ Pw=0, V>Vco;$$

……………… (7)

Vci, Vco and Vr are the cut-in, cut-out and rated speed of the wind turbine.

Actual power available from wind turbine is given by [10]

P = PwAwZ, ………………… (8)

where Aw is the total swept area, Z is efficiency of wind turbine generator and corresponding converters.

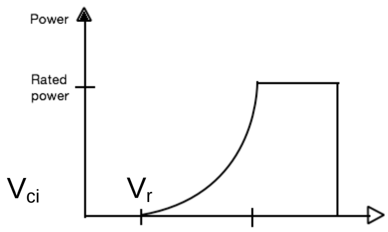


Fig. 3.2.1. Wind turbine characteristics.

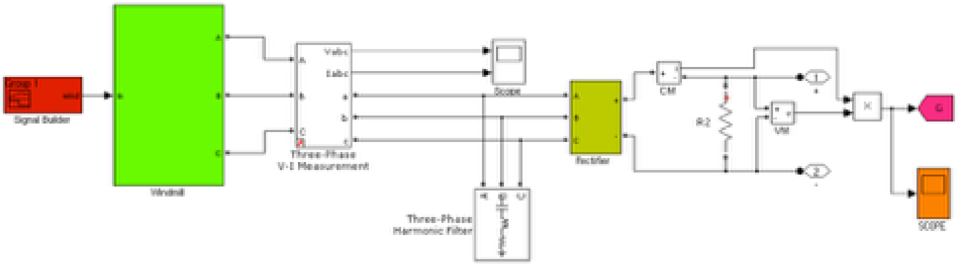


Fig 3.2.2 Overall simulation for wind energy

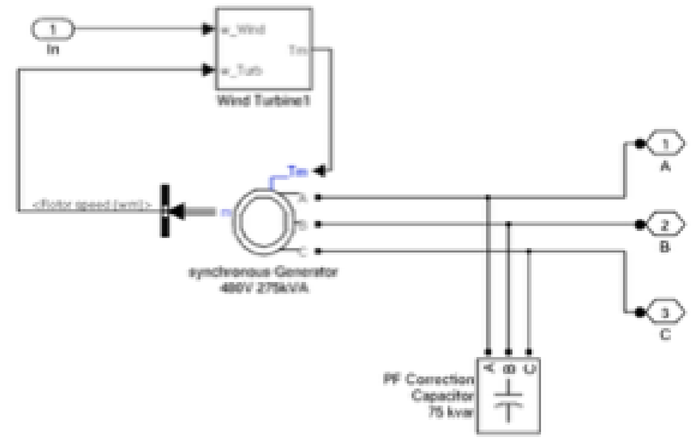


Fig 3.2.3 Simulation for wind mill

3.3. Modeling of battery system:

Battery storage is sized to meet the load demand during non-availability period of renewable energy source, commonly referred to as days of autonomy. Normally days of autonomy is taken to be 2 or 3 days. Battery sizing depends on factors such as maximum depth of discharge, temperature correction, rated battery capacity and battery life. Required battery capacity in ampere hour is given by [13]

$$B_{rc}=\frac{E_c(Ah)d_s}{(DOD)_{max}\eta_t}, \quad ....(9)$$

Where Ec (Ah) is the load in ampere hour, Ds is the battery autonomy or storage days, DODmax is the maximum battery depth of discharge, Zt is the temperature correction factor. Difference between power generated and load, decides
whether battery is in charging or discharging state. The charge quantity of battery bank at the time t can be calculated by [14]

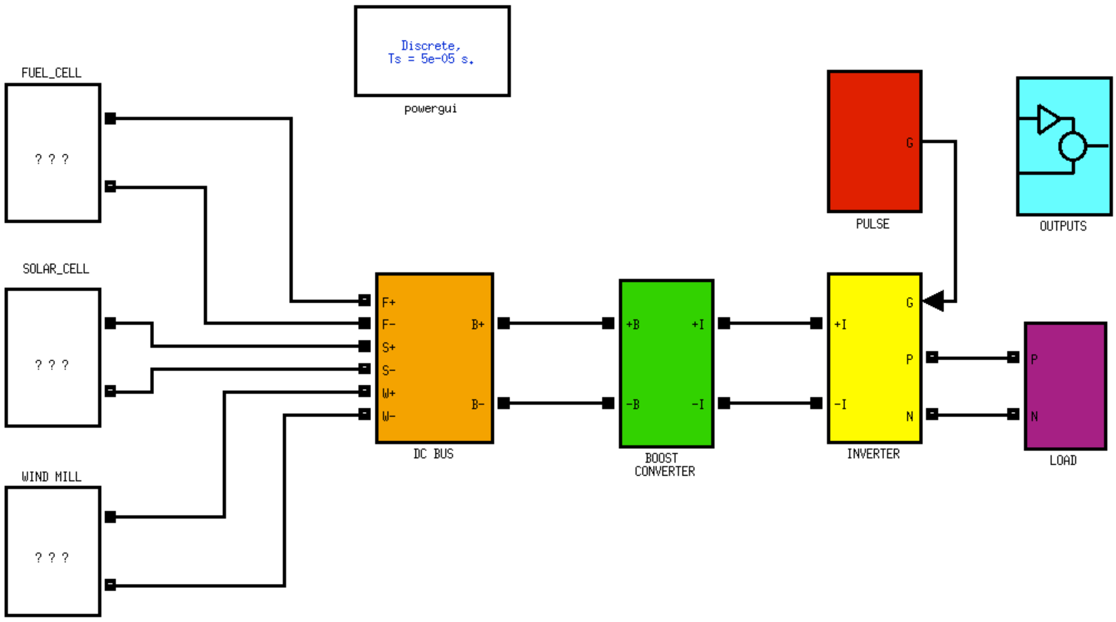
$$E_B(t)=E_B(t-1)(1-\sigma)+\left(E_{GA}(t)-\frac{E_L(t)}{\eta_{inv}}\right)\eta_{battery}, \quad ....(10)$$

where EB(t) and EB(t□-1) are the charge quantities of battery bank at the time t and t□-1, σ is the hourly self-discharge rate, EGA(t) is the total energy generated by renewable energy source after energy loss in controller, EL(t) is load demand at the time t. Charge quantity of battery bank is subject to the following constraints:

$$E_{B\max}\le E_B(t)\le E_{B\max}, \quad ....(11)$$

Where EB max and EB min are the maximum and minimum charge quantity of battery bank.

Here fuel cell is acting battery. Let us see the simulation of the proton exchange membrane fuel cell, it is basically advanced from the other fuel cell i.e, it acts also in low temperature.



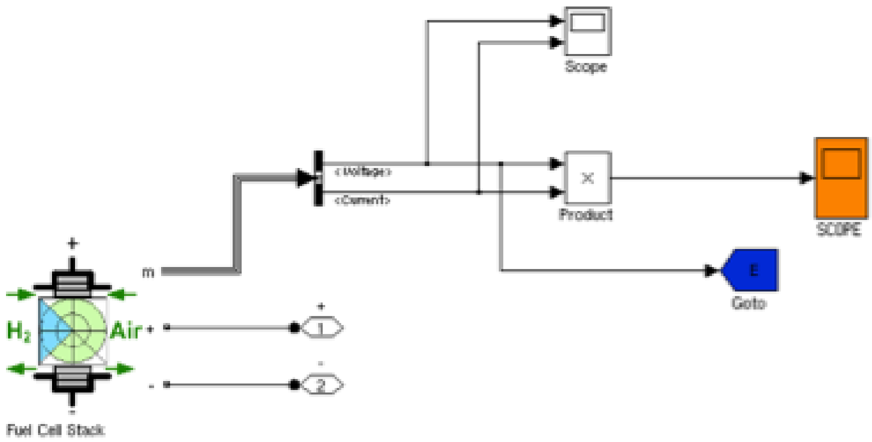


Fig 3.3.1 Simulation for fuel cell

3.4 Simulation of Boost Converter:

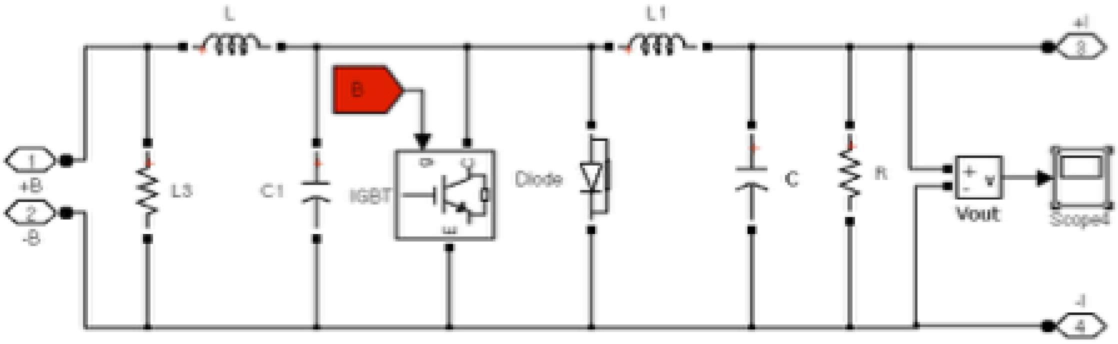


Fig 3.4.1 Simulation for boost converter

3.5 Simulation of overall hybrid RES system:
We have seen all separate system of hybrid RES in above system. The overall Hybrid system simulation is shown in the below fig.

Fig 3.5.1 The circuit diagram of the 1φ Hybrid System.

3.6 Simulation of Load:

Here we are using single phase induction motor for simple use and for checking purpose by limiting the input voltage of RES system.

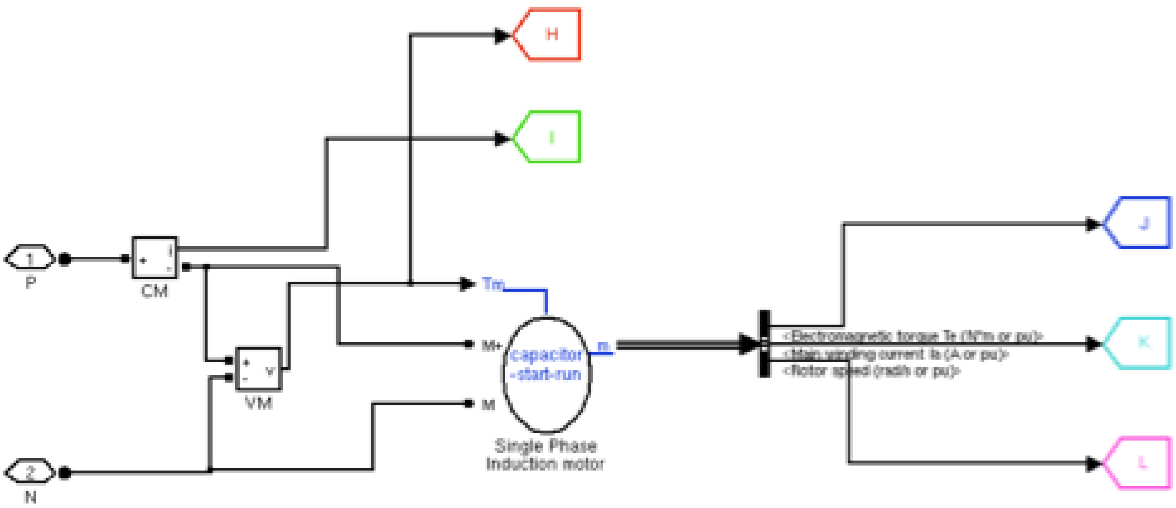
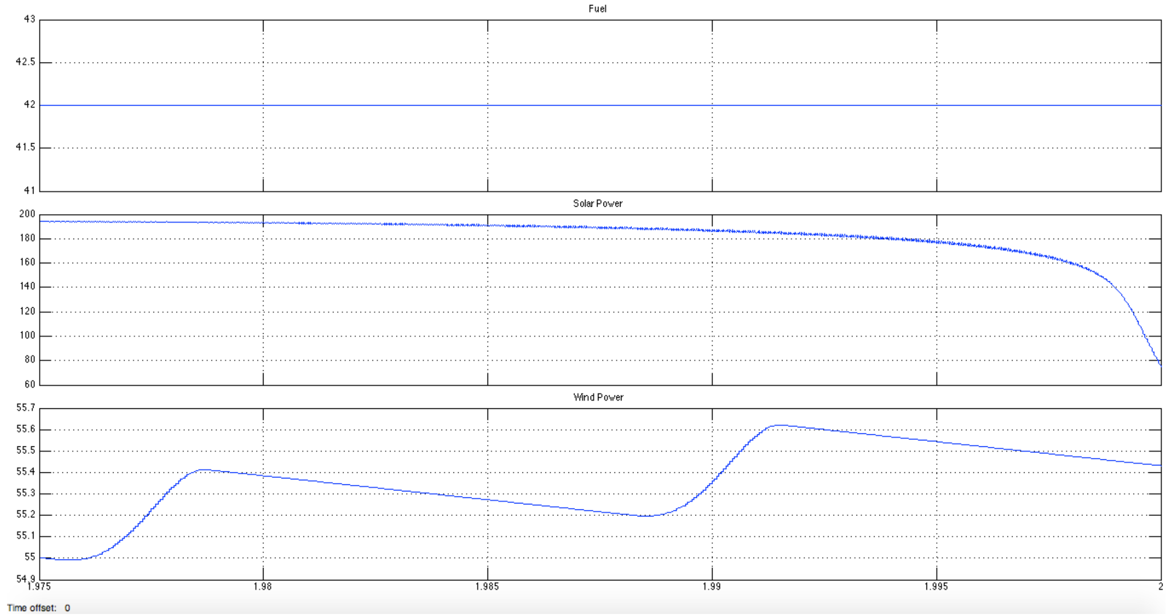


Fig: 3.6.1 Simulation for single phase induction motor

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

The input for hybrid renewable energy system of solar energy, Wind energy and Fuel Cell is shown in the following simulation with the limited values with dependent of Load 1phase Induction Motor.

Fig: 3.7.1 Simulation for RES Input



3.8 Simulation result of single phase induction motor:

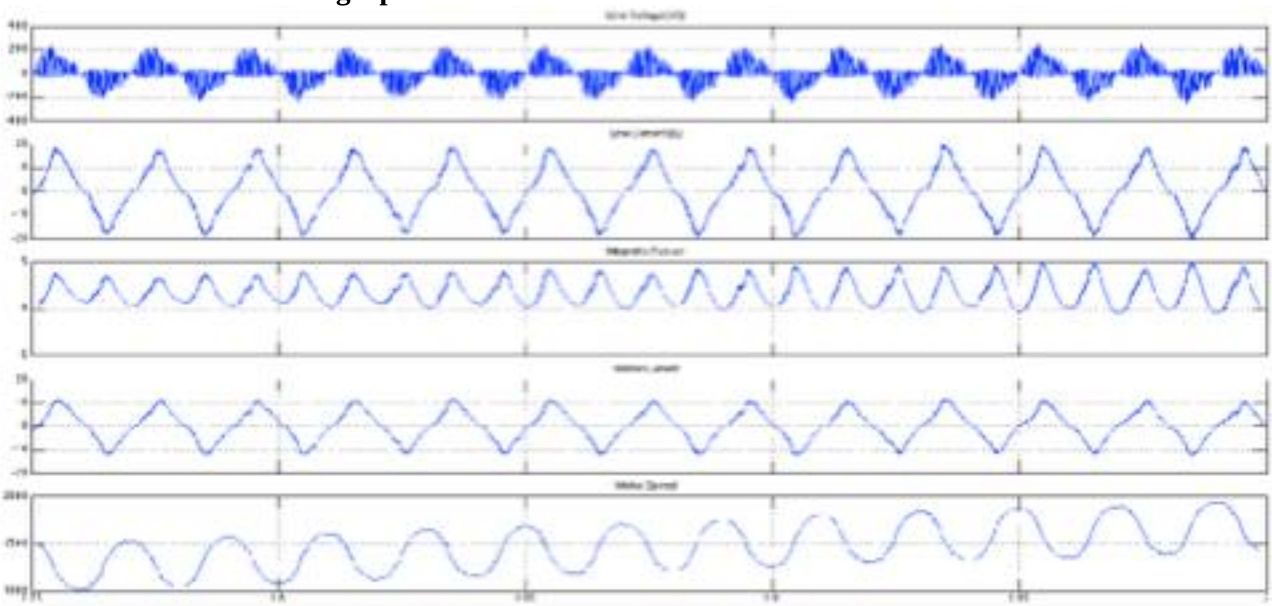


Fig 3.7.1 Overall Output

HYBRID CONTROLLER FOR ENERGY FLOW AND MANAGEMENT

One of the main problems of the HES is related to the control and supervision of the energy distribution system. The dynamic interaction between the grid and/or the loads and the power electronic interface of renewable source can lead to, critical problems of stability and power quality in new system, that are not very common in conventional power systems.

Managing the flow of energy throughout the proposed system to assure continuous supply of the load demand is to be done. The main objective of the energy flow and management system is to supply the load with its full demand. The operating strategy for energy flow in the system has been outlined before unit sizing and the same will be satisfied for efficient operation of integrated power system. To overcome the problem of intermittent power generation, PV power systems may be integrated with other power sources. Fuel cells are an attractive option because of high efficiency, modularity and fuel flexibility; however, one main week point is their slow dynamics. On the other hand, current technology batteries by themselves are usually insufficient to provide the long-term energy that the increasing loads require.

Hybrid systems composed of fuel cells and batteries can be integrated with PV power systems to provide uninterrupted high-quality power. The goal of this study is to design an effective power management system for a renewable based hybrid power system.

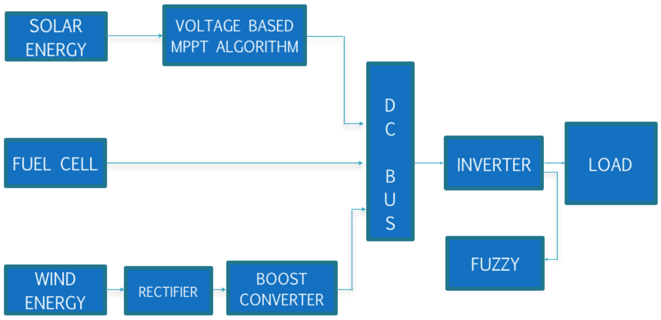


Fig 4.1 Block diagram of hybrid system

4.1. Using conventional approach:

Conventional approach of controlling the power supply to the load according to demand were used in various hybrid systems. In the conventional approach power electronics based DC–DC converter are used for maximum energy extract from solar and wind energy sources and control the complete hybrid system. Some researchers have used different controlling technique for different combination of hybrid energy systems. Here the reviews of different research paper are given as under.

Das et al proposes modeling of PV/wind/fuel cell hybrid energy system. In worst environmental conditions, when there is no output power from the wind or photovoltaic sources, the fuel cell will operate at its rated power of 10 kW. They proposed a simple and economic control method with DC–DC converter is used for maximum power point tracking and hence maximum power extraction from the wind turbine and photovoltaic array. The individual DC–DC converters are in turn connected to a single PWM voltage source inverter, which holds the output voltages of all the converters at a fixed value by balancing input and output power of the DC links. All the energy sources are modelled using PSIM software tool to analyse their dynamic behaviour. The complete hybrid system is simulated for different operating conditions of the energy sources. Abdin and Xu designed the control scheme for a wind energy conversion scheme using induction generators. The scheme consists of a three-phase induction generator driven by a horizontal axis wind turbine and interfaced to the utility through a double overhead transmission line. A static VAR compensator was connected at the induction generator terminals to regulate its voltage. The mechanical power input was controlled using the blade pitch-angle. Both state and output feedback controllers are designed using MATLAB software to regulate the generator output. From the simulation results the response of closed loop system exhibited a good damping and fast recovery under different type of large disturbances.

In this series Bansal et al discussed an automatic reactive-power control of an isolated wind–diesel hybrid power system having an induction generator (IG) for a wind-energy- conversion system and synchronous generator (SG) for a diesel- generator (DG) set. Park et al presented the power compensation system for controlling energy flow through hybrid energy system according to load demand. Valenciaga and Puleston andOnar et al developed the controller for hybrid power systems.

In the supervisor control developed three modes of operation and they used sliding mode control methods for controlling the hybrid system.

4.2. Using expert system:

The control system for HES configurations should minimize fuel consumption by maximizing power from the renewable sources. However, there are power fluctuations by the variability of the renewable energy, which cause disturbances that can affect the quality of the power delivered to the load. To manage the flow of energy efficiently with good quality power, it is needed to develop the advance controlling technique in near future.

In few published literature artificial intelligent or expert systems are used to develop the controller for energy flow through hybrid systems. Here some papers are taken for review purpose of hybrid energy controlling process. El-Shater et al discussed the Energy flow and management of a hybrid wind/PV/fuel.In this paper, an energy system comprising three energy sources, namely PV, wind and fuel cells, is proposed. Each of the three energy sources is controlled so as to deliver energy at optimum efficiency. Fuzzy logic control technique is employed to achieve maximum power tracking for both PV and wind energies and to deliver this maximum power to a fixed DC voltage bus. In 1993, Fung et al presented, a solution to the short term generation scheduling problem in a hybrid energy system, used in remote area power supply (RAPS). Instead of extending the main electricity grid, RAPS systems are economical alternatives for the supply of electrical energy to consumers in remote areas. They proposed a new approach based on fuzzy-logic (FL) and genetic algorithm (GA) techniques for the scheduling of the battery and the diesel generator of a RAPS system. They also have developed two methods. One was based on a pure genetic algorithm (PGA) approach, and the other was based on a combined fuzzy-logic and genetic algorithm (FGA). Hancock et al describes a method for optimizing and controlling the operation of stand-alone hybrid power systems containing some combination of auxiliary generator, PV generation and storage battery. They have developed and analysed a method for optimizing the operation of hybrid RAP (remote area power supply) systems.

On the basis of above literature review, researchers focused on the design, operation, and performance analysis of individual system for HRES find that, In order to predict performance, individual components should be modelled first and then their mix can be evaluated, to meet the demand reliably.

FUTURE TRENDS FOR DESIGN AND OPERATION OF HYBRID ENERGY SYSTEM

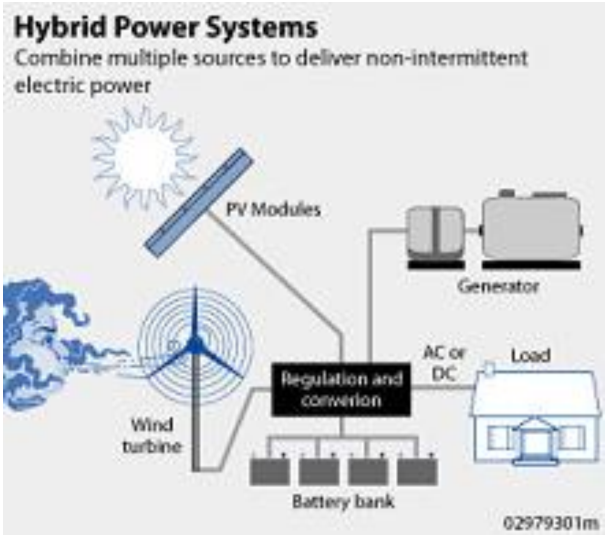
This system can be considered for a sustainable hybrid energy system, designed on two modes. One is standalone and other is grid-assisted mode. In stand-alone mode, it draws power from the wind–solar-fuel hybrid energy system. In the grid-assisted mode, when the hybrid system is unable to feed the power, it automatically takes the grid power. Here we use stand alonesystem.If the site-specific data is not available, one may use nearest meteorological station data in designing the system. In the grid system voltage,frequency, waveform and the power factor at time constant should maintain in limits. One can improve the power quality depending upon the local conditions. Hybrid energy flow is controlled using power electronic converters. This energy would be useful in many applications such as power systems, electric hybrid vehicles, telecommunication industries, rural electrification etc.

Further R&D improvements in solar PV and wind and also fuel cell battery technologies will reduce the cost of renewable energy sources. The cost of conventional energy resources is increasing every year. This system is going to be effective in future. Besides the cost, the environmental benefits are likely to facilitate the omnipresent use and acceptance of these systems.

As discussed in the previous section, the inclusion of artificial intelligence as part of the energy management system in near future, promises to optimise the operation of hybrid energy. The performance of modular hybrid energy systems can be improved through the implementation of advanced control methods in a centralised system controller. Optimum resource allocation, based on load demand and renewable resource forecast, promises to significantly reduce the total operating cost of the system. The application of modern control technique to supervise the operation of modular hybrid energy systems allows the utilization of the renewable resource to be optimised. Advanced control techniques will also improve the performance of such systems by improving energy management.

Hybrid Power Systems Offer Advantages:

Hybrid power generation systems can combine solar, wind, battery and generator power to keep your island hide away running around the clock and around the year. In many parts of the world, the peak operating conditions for solar and wind power occur at different times of the day or even during different seasons, so a hybrid system is more likely to deliver electricity when you need it. Reserve power (up to three days worth) can be stored in battery banks and a diesel or gasoline generator can be added to the system for those rare island days when there is neither wind nor sunshine. The diagram to the right, from the U.S. Department of Energy's Energy Efficiency and Renewable Energy (EERE) site shows a simplified Hybrid design.



CONCLUSION

This project proposed a converter topology that interfaces three power points are connecting three renewable energy sources(PV, Wind and Fuel Cell) to run a load boosting up with Boost Converter voltage step up techniques, by which the efficiency has been improved with reduced components and less stress on switches as we neglect the buck converter. We can use this step up power system for even peak load.

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