

A Survey on Hybrid Renewable Energy System for Standalone and Grid Connected Applications: Types, Storage Options, Trends for Research and Control Strategies

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Abstract—This article presents an critical review on various issue concerning to HRES like types, storage, trends for research and control strategies of HRES. Various interconnection techniques for HRES are presented. It has been made a short review of Mathematical model for renewable energy sources. Conclusion and result of control strategies work of HRES, Storage techniques of HRES for energy flow management is presented. Finally, it has been made a summary of the future analysis, challenges in techniques and improvements of HRES based power generation techniques for Isolated and grid connected applications.

Keywords—Renewable energy, hybrid power system, control strategies.

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1. Introduction

There is no reason to doubt that in the future our existence will be more and more dependent upon the energy. Specially in developing countries energy condition are improved by renewable energy sources from last many year. And for conventional source it becomes difficult to match increase demand of electricity. Renewable energy source generally does not require fuel and mostly eco-friendly but it is fluctuating in nature. Difficulty in availability and remoteness makes conveyance of sustainable energy sources costly. Grid extension is also not cost effective [1]. Sustainable source are the optimal outcome to provide power in remote zones. Also to meet the energy requirement locally available energy source is best.

Various researchers proposed renewable hybrid power system to supply the remote areas. there are various sources like PV, wind, biomass, fuel cell which can be utilized for power production [2]. HRES has been advised by different explorer to supply electricity in distant zones. To achieve reliability of supply combination with rechargeable batteries for energy supply system during peak load periods and operation with some other kind of generator is considered for isolated utilization. These arrangements are permanently provided along with storage option to rectify the unreliable manner of sustainable energy genesis like PV and Fuel [3].

Control strategies are the backbone of HRES that perform the communication and passes the information together with several elements of structure. Control strategies modifies the result of sustainable energy sources and in addition schedules the storage and load connected to grid. This limits the storage option and protect it [4]. Whenever extra energy is accessible, it is feeded to storage cells to stock the extra energy. When demand is more than supply then stored energy is utilized [5]. But some times it is required to connect conventional energy source with RES to bear the load [6].

This Paper imparts a survey on different issue related to HRES in isolated approach, types, storage, trends for research and control strategies of HRES.

2. Integration Scheme

There are following basic arrangement to integrate distinct sustainable energy provenance like, DC linked scheme, AC linked scheme, Hybrid linked scheme [7].

A. Stand-alone hybrid systems

There are two design of Stand-alone hybrid systems, dc link bus and centralized ac linked bus system. In this system all the power and storage device, and burden are linked to a dc link bus by means of suitable equipments as shown in Figure 1 [8], [9].

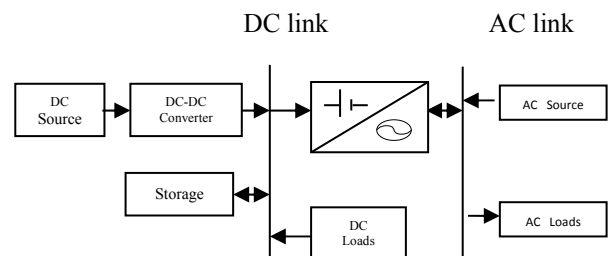


Fig. 1 DC Bus

Also in ac link scheme, the energy producer, storage cells, and loads are linked to an ac link bus by means of suitable power electronic equipments as depicted in Figure 2. It is advance structure, which provides the increasing energy needs [10].

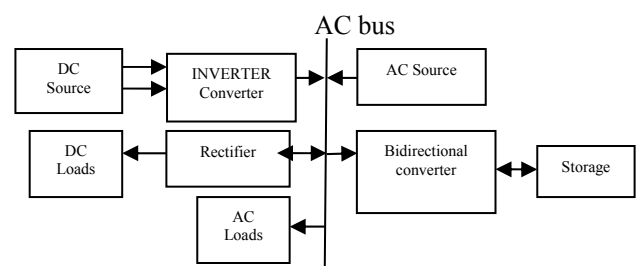


Fig.2 AC Series

In parallel scheme the ac genesis and different loads are right away coupled to ac linked bus as shown in Figure 3 [11], [12]. Such scheme makes system robust and insure reliability.

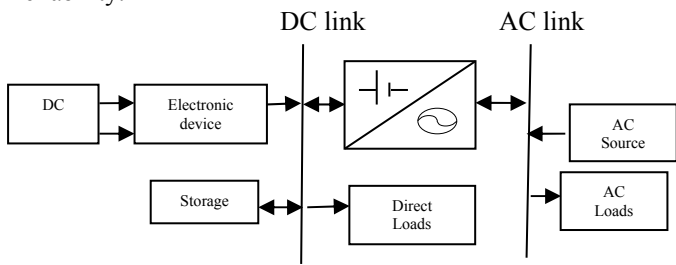


Fig.3 Parallel

In distributed configuration there is restriction for connection of single source to the load at a particular case as shown in Figure 4 [13].

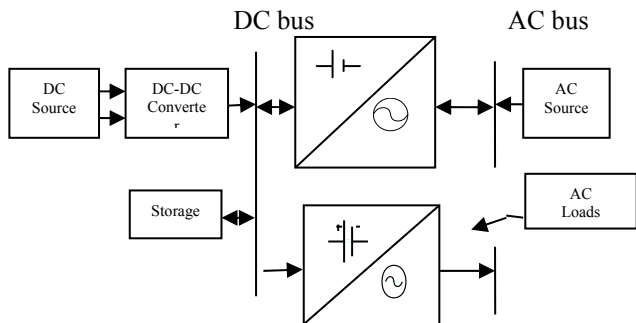


Fig.4 Distributed stand-alone hybrid system configuration

B. Grid tied systems

Various grid tied scheme are depicted in Figure 5 and Figure 6. The structure for specific site rely on geological, financial, and scientific factors [14], [15].

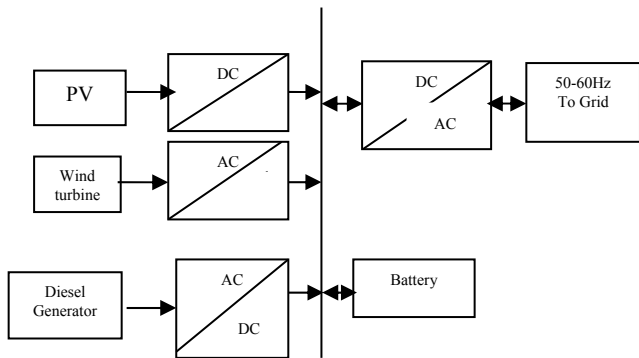


Fig.5 Centralized dc-bus

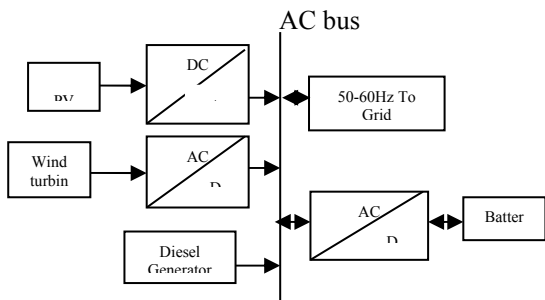


Fig.6 Centralized ac-bus

In this layout storage and source are connected at one site and is coupled to a prime ac link bus, by means of electronic devices [16]. A grid connection is also provided with filter.PLL technique is used to synchronize the two systems. In grid connected configuration it is not required to installed energy sources close to each other [17]. The energy generated by several source is needed to be equivalent for different condition according to grid as depicted in Figure 7 [18], [19].

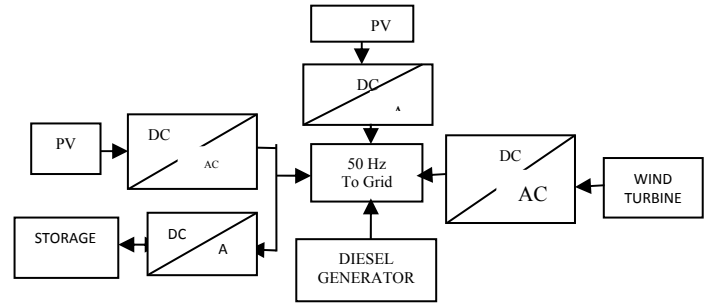


Fig.7 various standalone grid connected hybrid arrangement.

3. Modeling of sustainable energy genesis

A. Modelling of wind conversion system

Blades on the rotor convert wind kinetic energy into mechanical energy. This energy is transmitted by means of drive train to the alternator. The power of air flow at speed of v_w passing through area of A can be determined

$$P_w = \rho A v_w^3$$

Where ρ is the air density in kg/m^3 , A is the sweep area in m^2 and v_w is the wind speed in m/s . Normally near sea shore temperature of $15^{\circ}C$ and air has density of approximately $1.2kg/m^3$.

And wind power grabbed by the blades converted to mechanical power can be measured by

$$P_M = \rho A C_p v_w^3$$

Where C_p coefficient of power for wind blade. This coefficient of power for the modern age turbine lie between 0.19-0.49.

B. Modeling of Micro hydro Energy system

Energy captured from falling water which transfer its kinetic energy to the shaft in hydro power generation. This rotates the generator for the production of electricity. The power which can be generated in hydro plant in watts can be calculated by following formula

$$P_{MHPS} = 9.81 Q H_{net} \eta_0 \rho_w$$

where Q is the volume metre per second), H_{net} is the net height in metre available, ρ_w is the density of water, η_0 is the efficiency of hydro plant with turbine.

C. Modeling of solar photovoltaic system

Being more practical it is for the interest and analysis of performance that assessment should be done for maximum power. For the available radiation and suitable temperature calculation are done according to the manufacturing data available mentioned on the pv modules.

$$P_{PV} = \eta_g N A_m G_t$$

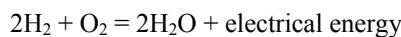
Where, η_g is efficiency of PV, A_m shows the area of a all cells perpendicular to irradiance (m^2).

D. Modeling of fuel cell system

This technique uses hydrogen-rich fuel to produce electron by use of two electrode. These electrode passes current to the load connected externally:



Electrons are produced by reaction which can give electricity is an electrochemical process, and that can be taken through load. Fuel cell gives dc voltage which can be utilized in different use by inverting in to AC as well. Equation based on hydrogen fuel cell is mainly combustion reaction given below as:



E. Mathematical model of Tidal system

The tidal energy modeling is identical to the wind model in various ways. Equation is used to model the turbine

$$P_{mt} = \frac{1}{2} \eta \rho_{water} A_T v_{water}^3$$

Where, P_{mt} is the mechanical power used by the tides, ρ_{water} is the density of water, A_T is the tidal blade area (m^2), v_{water} is the speed of tides and η is the efficiency. Cost of installation is much greater than life maintenance cost.

4. Storage

Storage option very essential for ensuring continuity of supply [20]. Various types of energy storage used in HRES [21]. Best solution for the storage used are batteries [22].

A. Battery storage system

Oldest electrical storage system is batteries which stores energy in form of chemical energy. It is environmental friendly and can be easily installed next to load [23], [24].

B. Superconducting energy conversion (SMES) system

This system stores magnetic energy initiated by the dc in coil associated with electronic device and cooled by it's below the superconducting critical temperature. It stores energy in the magnetic field, created by the flow of DC current in the superconducting coil [25]. Considerable issue for the development of magnetic storage are high system cost and environmental requirement [26].

C. Super capacitors energy storage

Density level of super capacitor are higher as compare to batteries so these capacitor are connected in series which further connected in parallel with adjacent modules the voltage range of 180–480 V for safety and reliability point of view [27].

D. Energy stored in flywheel

In case of flywheel Energy stored depend upon directly to the square of the rotational speed and it's weight. Normally Flywheel energy storage released its energy when torque is applied to load [28], [29]. Stored kinetic energy of flywheel is converted to electricity, when power is required. Flywheel efficiency varies from 75% to 90% [30], [31].

E. Pumped hydro storage (PHS)

This technique of storage is very old having high performance. It repository time is very large. Normally it has two vertically separated reservoirs [32]. Efficiency is in range of 55%-75% which depends upon the penstock size type of turbine and rating of generator for pumped storage. Pumped hydro system requires special geographical condition [33], [34].

F. Compressed air energy storage (CAES)

CAES is equivalent storage option having large capacity as pumped hydro storage of 60MW and above. The rating of CAES storage option lies between 05–350 MW [35], [36]. Its storage span is higher than other techniques which may be of one year and efficiency is in between 55-80% [37], [38].

G. Hydrogen storage

Hydrogen is originated by electrolysis process by usage of off-peak electrical power from renewable energy sources the hydrogen is generated by electrolysis process of water [39]. Fuel cells is key technology for portable and stationary power [40].

Various characteristics of each energy storage are given below (Table I):

Table I: Aspects of the energy repository development

ASPECT	PERFORMANCE	ADVANCEMENT	PRICE	ENERGY STORAGE	POWER STORAGE
BATTERY	80%	DEVELOPED	LESS	BIG	BIG
PH	80%	DEVELOPED	BIG	SIZE DEPENDENCE	DEPEND UPON HEIGHT
FUEL CELL	55%	DEVELOPING	LESS	HYDROZEN DEPENDENCE	DEPEND ON FUEL
FLYWHEEL	85%	DEVELOPED	BIG	LESS	BIG
SMES	92%	DEVELOPING	BIG	LESS	BIG
CAES	70%	DEVELOPED	BIG	BIG	BIG

5. Control Strategies

In recent years, tremendous amount of work came into notice in area of sustainable energy sources. It seen that most of the researchers worked on two broad categories, i.e., design of HRES and performance of hybrid power system. A number of research papers related to modeling and control strategies are available through out literature. In this article, hybrid renewable energy models and control strategy are considered. In addition, various issues related to hybrid modeling are also addressed. This article is formed according to the approaches and methods adopted by different researchers to achieve an optimal hybrid design. Various performance optimization strategies are discussed here [41], [42].

A. Design Optimization

The researchers worked under two broad optimization objectives [43]. One such category is the design of an optimal sizing of hybrid energy sources. This shows the selection of proper renewable energy sources with proper sizing, so that an optimized hybrid energy system could be developed, relying on the scope and feasibility of renewable power required of each source. By this technique one can design the capacity of sustainable system factors through optimizing the value of plant [44].

B. Artificial intelligence (AI) approach

There is no requirement of statistics for designing of combined power source in remote location when we use Artificial intelligence techniques [45]. Various techniques are available in research articles like PSO, artificial intelligence (ANN) [46], Genetic Algorithm (GA) [47], Grey wolf optimization (GWO) [48], honey algorithm, Blue whale optimization [49], fuzzy approach (FL), or a combination of any of above techniques. Genetic algorithm have also been widely used to optimize a hybrid system [50]. In such cases, Robust control has been widely used as compared to other artificial intelligence techniques.

C. Iterative approach

Sometimes iterative program approach is used to regulate the integrated energy system. And it ends up to optimal design is achieved. Many authors follow the storage option, PV panel ratings and wind rated power [51].

D. Probabilistic approach

This approach is used to design the size of HRES because it may change the parameter of renewable source. Probabilistic approach deals with radiation available and change in wind speed for the calculation of integrated system design. Dynamic variation of HRES cannot be identify by this techniques which is one of the disadvantage [52].

E. Graphical construction method

Various graphical optimization techniques have been reported in the literature. Only two variable were under consideration in this technique whether it is PV or Wind [53].

F. Globally standard computer tools for designing

HOMER is popular tool available for the sizing of HRES. This is done by decreasing the investment and increasing the use factor. Such software tools are for calculation of optimal performance on the basis of present cost [54].

G. Performance optimization

Only system sizing is not the matter of concern for the researchers. Thus, hybrid renewable energy systems need to be designed and controlled for the proper functioning of the system. Such controllers are responsible for the functioning of HRES at maximum power point, increasing the power quality, robust uninterrupted power supply, reduced internal losses and efficient cost effective power sharing among renewable energy sources in a hybrid system [55].

H. Online control

Real time simulators are also used for the analysis of power system now a day. In HIL simulation a prototype controller use only low power signals between a prototype controller and a plant [56].

I. Operating point control

Effort has also been done in controlling the operating point of the system keeping the system to work at MPP. Various operating point control algorithm is used for PV-Wind HRES to generate optimum energy to compensate the load demand [57].

J. Converter control

The characteristics of the renewable energy based system could be adjusted by controlling the converter parameters [58]. In case of single line to ground faults on the utility feeder without any storage device voltage source inverter (VSC) CAN control smooth operation in the system [59].

K. HRES Control

Power quality can be increased by the proper selection and management of HRES. Energy capturing option for the purpose of energy storage with a pair of hybrid magnetic bearings (HMBs); consisting of both superconducting magnetic bearings and active magnetic bearings applied with robust control method and zero bias method has also been developed [60].

6. Conclusion

An extensive review covering all the concerned aspects of HRES covering type's, storage, trends for research and control strategies of HRES has been presented. Sizing techniques algorithms implemented by various investigator for type of storage options are discussed. It has been observed that ANN techniques give relatively better result in order to find the reduced cost. Still It has been found much more work is required in this area of HRES; any how further exploration and attempts are mandatory to enhance power quality issues and storage option for their lower cost. In case of standalone

condition load can result in transient condition which may collapse whole HRES. For such scenarios various optimization algorithm for controller of the HRES is to be carried out. It is also found that researchers have taken various control techniques for the development of hybrid energy system. Power quality, stability and power stability control have also been taken as the control objectives by various researchers. It is seen that large amount of work is done using conventional control techniques or power convertor control methods. The consequences of computational intelligence in different issue of HRES especially in the field of optimization and control has acquired enormous focus.

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Conflicts of Interest

The author(s) declare no potential conflicts of interest concerning the research, authorship, or publication of this article.

Contribution of individual authors to the creation of a scientific article (ghostwriting policy)

The author(s) contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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