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Hybrid Renewable Energy Systems & their Suitability in Rural Regions

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***Abstract*:** *With the technological and economical advancement India is observing an extraordinary growth in all aspects. However development of rural regions remains an area of concern. Almost 75% of population of the country lives in these regions and generally face the problem of electricity shortage. This greatly affects their development potential thereby promoting migration to cities . The paper discusses how hybrid renewable energy systems can be viewed as a promising solution to these problems*

I. Introduction

In present scenario India has been rapid growing economy with an average GDP growth rate projected around 6 percent over the past two decades [1], still the development aspect of rural areas is yet alarming. Though country have got a vast hydro electric potential but due to major river water distribution conflicts these cannot be harnessed. Thus, in order promote the development in remote areas there is a requirement to develop a sustainable and efficient energy system to deal with the persistent electricity problems in these areas. With cutting edge growth in renewable energy sector these can be viewed as a potential solution for current situation, infact hybrid systems could be look forth as a prior solution to such kind of issues. The present generation capacity and estimated potential has been estimated in the table1.

Table 1: Installed and Estimated Capacity of Renewable energy sources in India

Renewable Sources	Installed Capacity	Estimated Potential
Wind	2483 MW	45000MW
Biomass	613 MW	19500 MW
Micro hydro Projects	1603 MW	15000 MW
Waste to Energy	41 MW	1700 MW
Solar Photovoltaic cell	151 MW	20 MW/sq km

II. Scope of Work

Presently, scientists and engineers around the globe have been supporting the utilization of renewable energy resources. Science these are abundant, though dilute and variable, locally available, almost and don't contaminate the environment, simplicity in onsite generation. Since, it is dilute and variable in nature, many complexities exist in conversion, condition, control, coordination etc. They are utilized as a standalone system serves many applications i.e. lighting system, water pumping for irrigation, traffic control etc. But it is costly, unreliable, and requires individual conditioning and controlling units. In this challenging atmosphere, Hybrid Energy System (HES) is one of the feasible solutions to harvest energy from renewable energy resources.

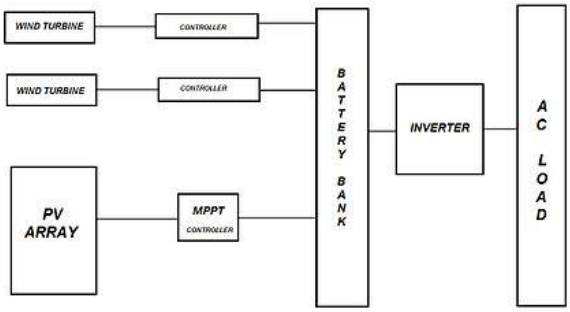
Overview of Hybrid Renewable Energy Systems

Hybrid energy system usually comprises of two or more renewable energy sources combined in such a way to provide an efficient system with uninterrupted power supply. In other words it can be said that hybrid energy system is a combination several (two or more) energy sources with appropriate energy conversion technology connected together to feed power to local load/grid. Since, it is categorized as a distributed generation system hence there is no unified standard or structure. It is beneficial in terms of reduced line and transformer losses, reduced environmental impacts, relived transmission and distribution congestion, increased system reliability, improved power quality, and increased overall efficiency.

Types of Hybrid Renewable Energy Systems

Biomass-wind-fuel cell: consider a load of 100% power supply and there is no renewable system to fulfill this need, so two or more renewable energy system can be combined. For example, 60% from a biomass system, 20% from a wind energy system and the remainder from fuel cells. Thus combining all these renewable energy systems may provide 100% of the power and energy requirements for the load, such as a home or business [3].

Photovoltaic-wind: Another example of a hybrid energy system is a photovoltaic array coupled with a wind turbine. This would create more output from the wind turbine during the winter, whereas during the summer, the solar panels would produce their peak output. Hybrid energy systems often yield greater economic and environmental returns than wind, solar, geothermal or trigeneration stand-alone systems by themselves [6].



Block diagram of a PV/wind hybrid energy system

Completely Renewable Hybrid Power Plant: Completely Renewable Hybrid Power Plant (solar, wind, biomass, hydrogen) a hybrid power plant consisting of these four renewable energy sources can be made into operation by proper utilization of these resources in a completely controlled manner.
Hydro-wind: A wind-hydro system generates electric energy combining wind turbines and pumped storage. The combination has been the subject of long-term discussion, and an experimental plant, which also tested wind turbines, was implemented by Nova Scotia Power at its Wreck Cove hydro electric power site in the late 1970s, but was decommissioned within ten years. Since, no other system has been implemented at a single location as of late 2010 [5].
Photovoltaic-Biomass: this is a combination of biomass gasifier and solar photovoltaic cells and the system is currently under research phase.

Advantages and Limitations

Hybrid Energy Systems employs a wide range of primary energy sources, for frequent renewable sources generation as the stand alone system for rural electrification where grid extension is not possible or uneconomic. Design and development of various HES components has more flexibility for future extension and growth. Number of generation units can be increased with demand so as to assure consistent operation with existing system. If there is excess generation than demand, it can be feed in to grid which leads to revenue generation. Since many sources are involved in power generation, its stability, reliability and efficiency will be high. Running cost of thermal plant and atomic plant is high. Majority of the renewable source based electricity generation has minimum running cost also abundant in nature. While limitations of hybrid renewable energy systems can be explained as under.

Maximum power extraction: When different V-I characteristics voltages are connected together, one will be superior to other. In this circumstance, extracting maximum power is difficult for a constant load.
Stochastic Nature of sources: These distributed sources are site specific and diluted. So, the design of power converters and controllers has to be so designed to meet the requirement. Complexities in matching voltage and frequency level of both inverted DC sources like PV system, fuel cell, etc controlled AC sources like wind, hydro, etc. Because in case of these sources V-I characteristics depends on atmospheric condition, which is varying time to time. Forecasting of these sources is not accurate.
Coordination: In order to get reliable power, these systems can be connected to a utility grid. Often frequency mismatch arises between both systems. Hence it leads instability of the overall system.
Energy Conversion Technology: Sun is the primary sources of all energies. It is available in many ways like oil, coal, wind, hydel, sunlight. In modern era we are generating electrical energy from these sources directly or indirectly. So far, there is no unique viable method is used for conversion and utilization.
Power Quality: A wide range of power electronics converters are involved in power conditioning of hybrid energy system from source to user. These power converters generate many harmonic components in the transmission which causes large scale disturbances to the load/power distribution system.

Hybrid Energy Systems as a solution for overcoming drawbacks

If two or three types of renewable energy generation systems are combined into one hybrid power generating system their drawbacks can be avoided partially/completely, depending on the control units. As the

one or more drawbacks can be overcome by the other, as in northern hemisphere it is generally seen that in windy days the solar power is limited and vice versa and in summer and rainy season the biomass plant can operate in a full flagged so the power generation can be maintained in the above stated condition. The cost of solar panel can be subsided by using glass lenses, mirrors to heat up a fluid, that can rotate the common turbine used by wind and other sources. Now the question arises what about the winter nights or cloudy winter days with very low wind speeds. Here comes the activity of the Hydrogen. As we know the process of electrolysis can produce hydrogen by breaking water into hydrogen and oxygen, it can be stored; hydrogen is also a good fuel and burns with oxygen to give water. Hydrogen can be used to maintain the temperature of the biomass reservoir in winter so that it can produce biogas in optimum amount for the power generation. As stated above biogas is a good source in summer; in this period the solar energy available is also at its peak, so if the demand and supply is properly checked and calculated the excess energy can be used in the production of hydrogen and can be stored. In sunny, windy &hot day, the turbine operates with full speed as the supply is surplus and this excess power can be consumed for other constructive applications. In winter, the power consumption is also low so the supply limit is low, and obtained with lesser consumption.

Optimization Criterion for Hybrid Energy Systems

Presently, a wide-range of factors exist that affect the design and control of hybrid renewable power systems and the available design tools suggests that there is a need to improve the research conducted in this field. On the basis of prevalent studies and research three main groups of optimization criteria exist: economic, technical and environmental, where we have multiple potential criteria in each one to be analyzed:

- **Economic aspects:** Net Present Cost (NPC) is a summation of all costs: capital investment, non-fuel operation and maintenance costs, replacement costs, energy costs (fuel cost plus any associated costs), any other costs such as legal fees, etc. If a number of options are being considered then the option with the lowest Net Present Cost will be the most favorable financial option. Cost of Energy (COE) is a calculation of the cost of generating electricity at the point of connection to a load or electricity grid. It includes the initial capital, discount rate, as well as the costs of continuous operation, fuel, and maintenance. Internal Rate of return or economic rate of return (ERR) is a rate of return used in capital budgeting to measure and compare the profitability of investments.
- **Technical variables:**

Supply reliability: An energy source is considered reliable on this site if it can be used to generate a consistent electrical output and is available to meet predicted peaks in demand. Every energy source has strengths and weaknesses, such as its inherent limitations on reliability of supply, which could contribute to the likelihood of an energy gap, when supply falls short of demand, and might cause interruptions to the electricity supply.

Battery throughput: it is the measure of the performance and storage capacity of a battery that is used for a specific purpose.

State of Charge of the batteries (SOC): is the equivalent of a fuel gauge for the battery pack in a battery electric vehicle (BEV), hybrid vehicle (HEV), or plug-in hybrid electric vehicle (PHEV). The units of SOC are percentage points (0% = empty; 100% = full). An alternate form of the same measure is the depth of discharge, the inverse of SOC (100% = empty; 0% = full). SOC is normally used when discussing the current state of a battery in use.

Rate of charge of the equipment, Excess of Electricity (EoE) and Grid connection requirements if available.

- **Environmental factors:** Renewable Fraction (RF), CO_2 emissions and site conditions. Others less studied are related to the legal framework and the subsidies/penalties associated with the generation technologies or differences among countries.

After defining the criteria to be considered, the main optimization principle in the objective function might be as diverse as: minimum cost, maximum financial viability, minimum CO_2 emission, minimum investment and/or maintenance cost (through life cycle analysis), minimum annual fuel cost, maximum continuity of supply, unmet load, etc [8]

Methodology for the design of hybrid renewable power systems depending on availability of energy sources and load characteristics is a primary point of concern. Further exhaustive research is also required for multi-objective optimum designs of hybrid systems. The importance of considering other criteria besides the cost is clear. From the analysis of case studies conducted earlier, an increase of only 1% in the optimum cost of the system almost doubles the fraction of renewable resources up to 47% [7].

Suitability of System

Rural areas in India amounts to about total land area of country and about 75% of population of country reside in these areas. The living condition here are very unhealthy and people lack here basic facilities like electricity, water supply, education, roads etc. Inorder to bring people living in these areas in mainstream and to prevent

large scale migration from these areas to metropolitan cities we need to develop some sources that can fulfill their basic needs amongst them vital classification to be electricity. And in this case hybrid renewable energy systems can prove to be a major cutting edge solution for these problems. Below we have classified the suitability of various techniques in hybrid renewable energy sources could prove to a solution and in what type of region on the basis of geographical pattern and location of that particular region. The suitability of different systems on basis of the geographical features is mentioned in table 2.

Table 2: Suitability of different HRE system on basis of geographical terrain

Geographical feature	Type of HRES applicable	Recommendations
High Altitude	Biomass-wind-fuel cell, photovoltaic-wind, photovoltaic-biomass	Photovoltaic-biomass
Mountain	Biomass-wind-fuel cell, photovoltaic-wind, photovoltaic-biomass	Photovoltaic-biomass
Plain	Photovoltaic-biomass, hydro wind, solarflower, combined HRES plant, biomass-wind, photovoltaic-wind	Combined HRES plant,
Semi Desert	Wind-fuel cell, wind-photovoltaic, wind-biomass, photovoltaic-biomass, photovoltaic-wind-biomass,	Photovoltaic-Wind-Biomass
Desert	Wind-fuel cell, wind-photovoltaic, wind-biomass, photovoltaic-biomass, photovoltaic-wind-biomass,	Photovoltaic-Wind-Biomass

Future Trends and challenges for research

The renewable technologies have come a long way in terms of research and development. However there are still certain obstacles in terms of their efficiency and optimal use. Following are the challenges faced by practitioners.

- The renewable energy sources, such as solar PV and FCs, need innovative technology to harness more amount of useful power from them. The poor efficiency of solar is major obstruction in encouraging its use.
- The manufacturing cost of renewable energy sources needs a significant reduction because the high capital cost leads to an increased payback time.
- It should be ensured that there should be minimal amount of power loss in the power electronic devices.
- The storage technologies need to increase their life-cycle through inventive technologies.
- These stand alone systems are less adaptable to load fluctuations. Large variation in load might even lead to entire system collapse.

III. Conclusions

Though hybrid energy systems could be potential solutions for the electricity problems in the rural region yet vast research is needed in this aspect to make it technically feasible to be employed at these areas. The prime focus of study should be the cost of the system and its output.

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