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A review on hybrid renewable energy systems

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***Abstract*—Renewable energy sources are more suitable for off grid areas. It is very difficult to bring transmission lines to remote areas therefore a renewable energy system is preferred as a standalone system, so as to eradicate the need of fuel supply and transmission lines to remote areas. This paper focuses on different types of hybrid renewable energy systems available and their nature.**

I. INTRODUCTION

The current demand for electricity is increasing day by day and the electricity production mostly relies on fossil fuels and nuclear fuels, which are finite and pose a great threat to the environment. Therefore, energy models that involve clean and renewable energy sources are necessary to ease the concerns about the electricity generation needed to meet the projected demand. So the possible way is to switch to renewable energy sources like hydro power, geothermal energy, solar energy, wind energy, tidal energy, fuel cell, biomass, etc. The process of switching to the renewable energy sources is time consuming and costly but it offers a longer life span than the thermal and nuclear power plants. The real problem which delays switching to the renewable sources in full scale is its reliability in power production which is greatly influenced by the environmental factors. Hence in order to increase the reliability of renewable energy systems, combination of two or more renewable sources are integrated to form a hybrid system. The Hybrid Renewable Energy System (HRES) pose a great reliability due to its flexibility to adjust to the varying demand for the power. Further the reliability can be increased by implying effective control strategies.

II. RENEWABLE ENERGY SCENARIO IN INDIA

India is a developing country with a lot of power demand and much of its power demand is supplied by conventional sources. Though the country has a lot of renewable energy sources and area, the lack of infrastructure and money prevents the country from switching over to renewable energy sources. .Though the renewable energy sources are costlier to install they have a longer life span than conventional system. Indian power system has a total installed capacity of 303 GW out of which 52 GW are renewable energy sources like solar power, wind power and biomass. Currently India produces one fourteenth of the total renewable energy in the world. The following table depicts about the installed renewable energy capacity of India as of march 2017.

Grid Integrative Power

Sl. No	Source	Capacity in MW
1	Wind Power	28871.59
2	Solar Power	9235.24
3	Biomass	8182.00
4	Waste to Power	114.08
	Total	50744.76

Off Grid Power

Sl. No	Source	Capacity in MW
1	Wind Power	2.97
2	Solar Power	423.02
3	Biomass	186.88
4	Waste to Power	164.45
	Total	1448.04

III. FACTORS TO BE CONSIDERED BEFORE INSTALLING HRES

Before installing HRES a lot of factors has to be considered and some relative data has to be collected. The renewable energy systems are costlier than the conventional energy systems hence a well planned procedure has to be followed. The following are the factors to be considered:

- Total power demand and maximum peak load.
- Constant load and scheduled loads like street lighting .

- Load forecasting and load survey has to be taken.
- The geographical landscape and climatic conditions of the area where the system is to be installed.
- Wind flow pattern and solar radiation levels of the area.
- The total land area that is available to install the power plant.
- Which primary energy source and storage system is to be used .
- Total power production cost and tariff calculation.
- Domestic, commercial, industrial, municipal and irrigation loads has to be calculated.
- Resource assessment has to be done to calculate how much energy can be harvested from solar energy, wind energy and hydro energy. Accordingly capacity of secondary systems are installed.

Finally, all the data are put together to form a collective information guide in order to utilize the resources in maximum efficient way possible.

IV. Different Types of HRES Available

There are various Hybrid Renewable Energy Systems available. Based on the need of the power and availability of natural resources they can be chosen accordingly. The following are the commonly used HRES:

- PV – Wind System
- PV – Micro hydel System
- PV – Biomass System
- PV – Fuel cell system
- Wind – Biomass System
- Wind – Fuel cell system

These systems have solar energy and wind energy as their primary sources as they are abundantly available. Instead of two power sources a combination of two or more sources can also be used which includes conventional sources also. Some of the examples of different combination of renewable energy system is illustrated.

1) PV - Wind system.

PV - WIND hybrid system is most popular because of its ease of combining each other. The wind turbines are usually laid with a lot of gap between them, these areas are not utilized for any other purposes. Hence solar PV panels can be laid in between to effectively utilize the space and also to form a hybrid system. The PV - Wind system can supply load at day time without any interference if there is enough sunlight but in night time due to the absence of sunlight the power supply will not be optimal. Hence battery storage system is used when both the solar and wind source cannot supply the load due to climatic conditions. In additional to the solar and wind energy source a conventional energy source like a diesel generator is also present to be operated in case none of the solar energy, wind energy and battery energy was able to supply the load.

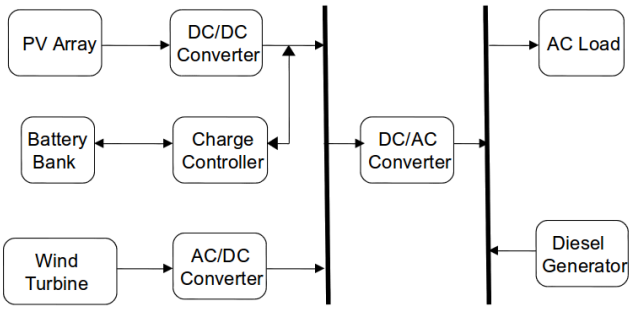

Fig. 1. PV - Wind system

2) PV - Micro hydel System

PV - Micro hydel systems are used in regions where rainfall and water sources are more. In this system PV array is made to operate at its maximum, to extract as much energy as possible from the solar radiations. The hydel system is used as a secondary source and as an additional storage system which is operated when the load cannot be supplied by PV array *i.e.* during night, low light conditions, during peak load and sudden load changes. In additional to that a battery storage unit is also provided to store the excess energy produced by PV array and utilize stored energy when needed. A diesel generator is also present as a backup system in case both the renewable source fails. In case of excess water flow occurs the Micro hydel plant is made to run and the energy produced is stored in the battery bank.

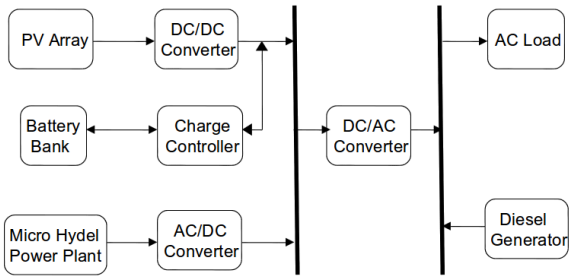

Fig. 2. PV – Micro Hydel system

3) Wind – Biomass system

Biomass is organic materials that comes from plants and animals, biomass actually gets its energy from sun. In plants by the process of photosynthesis plants traps the sunlight and stores it. This energy can be utilized to convert into electricity by burning the biomass in a combustion chamber. In Wind – Biomass system Wind

is the primary source and majority of load will be supplied through it. Though the Wind turbines are capable of producing large power it is not reliable as it completely dependent on environment. Hence a stable source like Biomass which can be controlled by human is used as a secondary system that will be operated when the power production in the wind turbines are not sufficient. In addition to that a battery storage unit is also provided to store the excess energy produced in wind turbines.

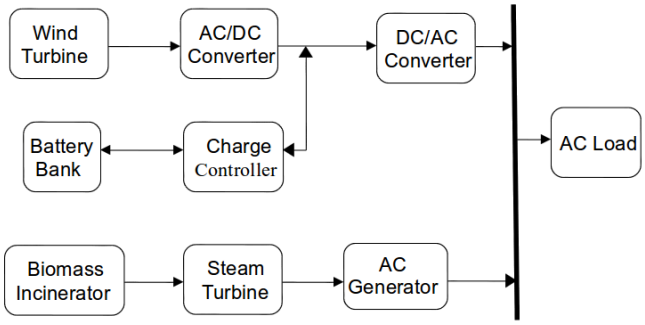

Fig. 3. Wind – Biomass system

4) Wind – Fuel cell system

Wind - fuel cell system is used as a replacement for Biomass because the biomass requires organic materials as well as it pollutes the environment even with the controlled combustion of the fuels. Fuel cell is now used as the new source for producing electricity. A fuel cell converts chemical energy into electrical energy through a proton exchange membrane. The most commonly used fuel cell is Hydrogen Oxygen fuel cell because of its abundant presence in the atmosphere. This Hydrogen Oxygen fuel cell produces direct current along with water as a by product. In this system Wind energy is used as a primary source and Fuel cell is used as a secondary source. A battery unit is also used for storing excess power and utilizing the stored energy when the need arises.

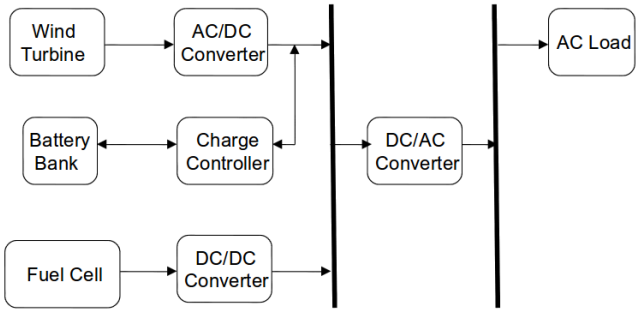

Fig. 4. Wind – Fuel Cell System

V. SIZING AND OPTIMIZATION

A) Sizing

Sizing is an important aspect in designing a Hybrid Renewable Energy System, a proper size of the system has to be determined based on the power requirement and total cost of the system. Over sizing of the system and its components will increase the total cost and will add additional cost to maintaining the system. Under sizing of the system will result in lower power production and dependency on the backup system will be increased.

Sizing of the system can be determined by using simulation softwares, mathematical calculations, probabilistic approach and data sheets.

B) Optimization

Optimization is an important process during the operation of the HRES, optimization helps in making the system more reliable and efficient. Optimization includes efficient integration of different energy sources in a bus, storage of excessive energy in battery, utilizing energy from battery when need arises, load sharing between the sources, priority for the energy sources, load forecasting and load side control. These parameters have to be optimized at the preferred values in order to ensure a smooth and economical power supply which reduces the overall operational cost.

Optimization can be brought into a system by using simulation softwares, iterative methods, mathematical algorithms, and artificial intelligence. In order to achieve maximum optimization various feedbacks are taken at different levels of the system and these data are processed by using any of the above mentioned technique. The optimization also includes the process of extracting maximum energy from the source, increasing the overall efficiency, minimizing both the operational and maintenance cost.

VI. CURRENT PROBLEMS OF HYBRID RENEABLE ENERGY SYSTEM

Though the HRES is cost effective in longer terms and Eco friendly, there are certain problems that are currently prevailing. They are.

- Stochastic nature of renewable sources.
- Energy conversion technology.
- Power quality.
- Storage system.
- Integration of different sources.

Hence modern technologies are used to overcome these limitations.

VII. FUTURE TRENDS

The renewable energy source showed a greater growth during the last decades with lots of innovations coming up. But there are still certain things that has to be improved to increase the efficiency and optimal use of the system. The following are those which might be the improved in future.

- The renewable energy sources like wind power and solar power are least efficient than the conventional systems, hence their efficiency can be increased.
- The manufacturing cost of the components of renewable energy systems are high which can be reduced.
- Power loss during conversion and storage can be reduced.
- Storage system technology can be improved to increase the life cycle of storage devices.
- Modern and more efficient control algorithms can be implemented.

VIII. CONCLUSION

This paper describes about the renewable energy sources and gives an overview about the Hybrid Renewable Energy System. Various types of HRES available, factors influencing the system, sizing and optimization are specified. The current difficulties faced and possible future trends are also discussed.

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