Hybrid renewable energy: future of the world

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Abstract. Sustainable energy and energy security are becoming of increasing concern for modern world. In a vast country like India these are concerns too. Therefore, it is time to leap towards sustainable, renewable and environment friendly energy to curb the pollution, greenhouse gas and enhance the economic growth rate for socio-economic development. Solar, wind, hydro etc. are the common sources of clean renewable energy sources. Adding to this basket hydrogen seems to be potentially viable. In a very small area combining these energy sources together large amount of energy can be produced which can solve the problem of energy. This study aims to present the generation, storage and supply of hybrid energy.

1. Introduction
With growing population and industrialization, demand for energy is growing rapidly. The most common energy resources such as coal, petroleum, gas etc. are depleting very fast. These resources are carbon based and generating huge amount of CO2 besides other harmful gases. CO2 being the main greenhouse gas causing global warming and climate change which in the present time has come into an alarming level. To curb these polluting gases and save the earth scientists attempted for environment friendly renewable energy such as hydro, wind, solar etc. Hydrogen is a zero carbon fuel and having high energy content. So this is also a clean renewable energy. Still now fossil fuel based energy is widely used as they are comparatively cheap. Therefore to make the renewable energy cheaper their production efficiency should be increased. In a small area a combination of all renewable resources together can produce more energy which can be cheaper than the individual energy.

1.1. Renewable energy sources

Hydroelectric: Hydroelectric power is one of the oldest methods of producing power. It is a well developed renewable energy technology. It uses flowing water to spin a turbine connected to generator that produces electricity. The amount of electricity generated depends on the volume of water and the height of the water above the turbine. For large power plants dams are required to store the water. The electricity generated by hydroelectric plants can vary from year to year depending on the rainfall.

Solar: Solar energy is the most readily available source of energy. It is the most important source of energy for life forms. It comprises of radiant heat of light from the sun. It can be harnessed with some modern technology like photo-voltaic, solar heating, artificial photosynthesis, solar architecture and solar thermal electricity.
Wind: Wind energy is generated when wind turbines convert the kinetic energy in the wind into mechanical power. With the help of a generator this mechanical power can be converted into electricity to power homes, schools, mills etc.

Hydrogen: Most recent development is the use of hydrogen ($H_2$) as energy source. Hydrogen is the lightest, simplest elements in nature. It is a zero carbon fuel. It is high in energy content as it contains 120.7 MJ/Kg but its energy content on volume basis is very low [1]. It is found always combined with other elements. Therefore separation and storage is important for this. It can be produced from water by electrolysis, high temperature process, using solar, nuclear, coal, gas, bio-mass burning etc. Now, there is thrust on renewable energy to produce hydrogen from water. As it is very light and inflammable, its storing is very important. In gaseous form it can be stored in high pressure tanks, in liquefied form in cryogenic dewar, in solid form in metal hydrides, carbon nano structures and glass microspheres [2]. It can be used in onsite power generation using gas turbines or fuel cells as a fuel in the transport sector [2].

2. Methodology

2.1. Generation, storage and supply:

Here, we propose a model diagram as shown in figure 1, for combining the different types of renewable energy for the optimum utilization of renewable, pollution free energy as per demand of that time in that region. On the top left, there is a small scale hydroelectric power plant. Water from the upper reservoir is released downward and it is used to move the blades of the turbine which converts the kinetic energy of the falling water into mechanical energy. A generator can convert the mechanical energy into electricity. At lower reservoir the water is collected and stored and later pumped again to upper reservoir. A part of the water collected at lower reservoir is used to produce hydrogen by sending the water to the electrolyser which decompose water molecules and thereby produce $H_2$. Electricity from the power bank is used for decomposing the water molecules. The gas is then sent to gas treatment plant and then stored in storage. From storage, the $H_2$ gas is then used in the fuel cell where the $H_2$ gas reacts with the air and finally generates electricity. A part of the $H_2$ gas is sent to the $H_2$ pumps for supplying as a fuel to vehicles.

On the middle left of figure 1, there is solar power which is another promising source of clean and renewable energy, and abundantly available in nature. The solar panel convert the light from the sun into electric energy which is fed to the power bank. On the bottom left, wind energy is shown in the figure. Turbines are used to convert the kinetic energy of the wind into mechanical energy which runs a generator to produce electric energy. Electricity derived from wind power is then feed into the power bank. From the power bank, a part of the electricity can be directly fed to the load i.e. industry, household, etc. Another part is utilized by the electrolyser which converts the electric energy in the form of hydrogen gas energy which can be stored for longer time as well as can serve as fuel for vehicles and also can be converted into electricity by using hydrogen pump. If there is more production of solar or wind energy, or if there is less demand at the load at some point of time, in that case of excess electricity in the power bank, it can be used to produce and store energy in the form of hydrogen gas. Subject to the need and demand of that time, desired portion of electric energy can be diverted to produce hydrogen energy thereby getting the optimum benefit.
Figure 1. Model diagram for hybrid energy system.

PV cells capture the radiant solar energy (sunlight) and convert it into electric energy. Most commonly used solar cells are semiconductor devices but they have limited efficiency and high price. Recently scientists have developed photo-electrochemical dye-sensitized cells [3], plastic cells [4], thin film based cells [5], porphyrin sensitized cells [6] etc. to produce low cost cell with commercially realistic efficiency. These cells are used to produce low cost energy.

Wind energy depends mainly on the wind speed and turbine efficiency. The mean global wind speed at 80 m is around 4.54-8.80 m/s [7] which is in the range of limited suitable to highly suitable for wind power generation [8]. That means most of the parts of the world have more or less potential for wind energy. To generate electricity from wind, turbines are required. It is an energy converting machine to convert kinetic energy of wind into mechanical energy and ultimately electrical energy [9]. Horizontal axis, vertical axis, upwind, downwind turbines are there [9]. In terms of capacity wind turbines can be classified into micro, small, medium, large and ultra-large. They are also classified into direct drive, geared drive, on shore, off shore, on grid, off grid etc.[9] for different situations. Modern high capacity turbines which are used in the electricity grid, have blades with a cross section
similar to the aero-foils used to provide the lift in aircrafts wings. The number of blades in the turbine rotor and its rotational speed must be optimized to extract maximum energy from the available wind. Depending on the wind condition and design there is an operating limit for safety and efficiency. Design limits for turbines at 80 meter of height above the ground [10] are given in table1.

| Parameter             | Definition                                                                       | Limits (m/s) |
|-----------------------|----------------------------------------------------------------------------------|--------------|
| Cut-in wind speed     | Minimum wind speed below which no useful power can be produced                   | 3-4          |
| Rated wind speed      | The lowest wind speed at which turbine develops its full power                    | 15           |
| Cut-out wind speed    | The maximum safe working wind speed beyond which turbine needs to be shut down   | 25           |
| Survival wind speed   | The maximum wind speed that a wind turbine designed to withstand                 | 60           |

Since, the energy generated by different kind of sources are different in nature, their storage at a single place is difficult. It is required to have such energy storage which has high energy density, high power delivery capacity, low cost per unit of storage, long life cycle, low leakage etc. There are many energy storage technologies such as super capacitors, SMES, fly wheel, lead acid, lithium ion, NaS, redox flow, hydrogen CAES etc. Lithium ion batteries are suitable for “high energy” or “high power” storage, super capacitors and fly wheels are characterised by higher power densities, efficiencies and cycle life times compared to batteries. Renewable H2 is suitable for long-term energy storage; redox flow batteries are suitable for good cycle lifetime and recycling capacity [11]. To store hybrid energy a hybrid energy storage system as specified [12] can be used. This type of energy storage can be the “power bank”.

The energy generated by hybrid system should be transmitted for its utilisation at the places far from the source. But long distance transmission is problematic because electrical power is proportional to the product of current and voltage, while losses are proportional to the square of current. So raising voltage and lowering the current reduces losses when transmitting high power over long distances. But for very high voltage transmission the voltage strain the capability of semiconductor power-electronics to interconvert between AC and DC which raise the cost and limit the penetration of DC technology. Despite drawbacks high voltage DC transmission is preferred for renewable electricity transmission. It requires a single point of origin and termination, precluding wide area DC collection and end user distribution schemes. But conventional high voltage DC transmission is a mature technology to meet the renewable electricity transmission over moderate distances. Additional high voltage DC transmission within one or two state regions is needed to link regional renewable electricity sources to population centres.

Super conducting DC cables have no electrical resistance therefore zero loss. It can be used for transmission of renewable energy far distances but they require refrigeration to maintain them at superconducting temperature. For this development room temperature superconductor is necessary.

3. Vision for future hybrid energy
Global climate demands for clean and environment friendly and sustainable energy sources. The creation of hybrid energy will require the implementation of the model described above which will be efficient and cost effective. Once all the conventional energy sources are replaced by the hybrid
energy sources pollution will be very less, global warming will slow down and the economy will prosper etc. Therefore hybrid energy in future will be the key player of development and prosperity to the human being.

4. Conclusion

Renewable energy technologies have developed a lot due to research and development but there are still obstacles in terms of their efficiency and optimal use. The present study discusses about the efficient and low cost production, storage and distribution of the hybrid renewable energy. When there is excess electricity generation or high demand of energy for vehicles, desired portion of the electricity could be used for the purpose of hydrogen energy which serves for medium of long storage as well. It may help to utilise the renewable energy for obtaining optimal benefit depending upon the need of the time. There should be more research and development in this direction.

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