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Hybrid Energy System Using Wind, Solar & Battery Storage System

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Abstract— Renewable energy sources, including wind and solar power, have progressively gained popularity as alternatives to traditional energy sources in recent years. Yearly consumption of the planet is less than the energy which can be produced by sunlight within 1 hour which is also carbon free (Barlev, Vidu, & Stroeve, 2011). Although these energy sources have shown potential, one of their key drawbacks is that they are not reliable sources of energy, like solar relies on sunlight and wind energy is based on the wind. A hybrid system of wind, solar, and battery backup can be used to offer a dependable and sustainable supply of electricity to resolve this problem. A complete hybrid system having solar, wind and battery system has been discussed in this paper. We also covered the advantages of using hybrid systems at residential level and for remote locations.

Keywords— Hybrid Renewable Energy resources (HRES), Renewable energy sources, Solar Energy, Wind Power, Battery Energy storage systems, Sustainable, Direct Current(DC)

I. INTRODUCTION

Solar and wind energy is not only freely abundant source of energy but also these are environment friendly. Because of their dependability on sunlight and wind have made scientist to deal with the challenges to enhance the reliability of these sources. Using both sources with the battery is getting more popular to use at remote locations. Battery system provides the backup for multiple days in case if any of the source or both are not available, which is decreasing the usage of fossil fuels, and these are very cost efficient and these more reliable energy resource (Nema, Nema, & Rangnekar, 2009). This system is referred as Hybrid Renewable Energy resources (HRES).

Mostly countries around the world have set the target to move towards the renewable energy, for instance United States of America has goal to achieve 80% of electricity from renewable energy with zero carbon emission (Energy experts share how the U.S. can reach Biden's renewable energy goals, 2023). There are different policies which have been made by many countries to achieve their goals. Developments have also been made towards this and there are some organizations like World Bank and Asian development bank which are updating policies and providing help to countries for shifting on the renewable energy by giving not only the financial help but also assisting in technical ways.

II. PHOTOVOLTAIC SYSTEMS

Electronic devices which are converting solar energy into electrical energy are called Photovoltaic cells. These systems have become more common because of the conversion of sunlight into electrical energy. This energy can be used either in the household or at industrial level because of its instant response to the load. It can easily meet the load requirement but in the daytime cause it's totally dependable on the sunlight (Lupangu & Bansal, 2017).

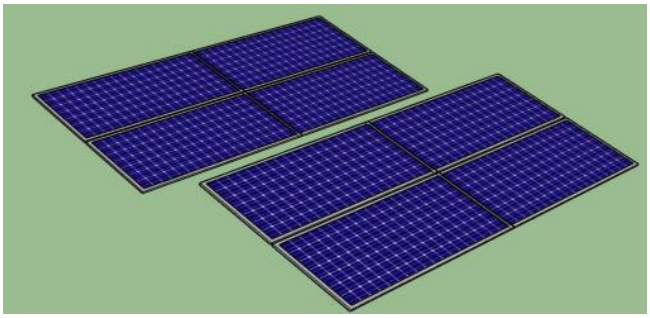

Fig.1 Solar panels (Farooq, Agili, & He, 2024)

As illustrated in the above figure, solar panels have been created by connecting multiple PV cells either in series or parallel.

A. Feasibility of the solar system

Production of solar systems varies from location to location. Basically, it depends on the sunlight irradiation which is different for the different locations. For checking the feasibility of the solar systems there are many software's which even gives the production of the energy per for a unit time by using some data base of climate like National Solar Radiation Database (NSRDB) (National Centers for Environmental Information, n.d.). By designing and making feasibility reports with different angles of PV panels, optimum solutions can be proposed for a particular site. There could be some other factors which can also be looked for feasibility of solar systems, like load of the consumer, technically and economically efficient solutions. Following is the normalized productions per installed KWp (450KW-Project) for Punjab, Pakistan area using PVsyst software.

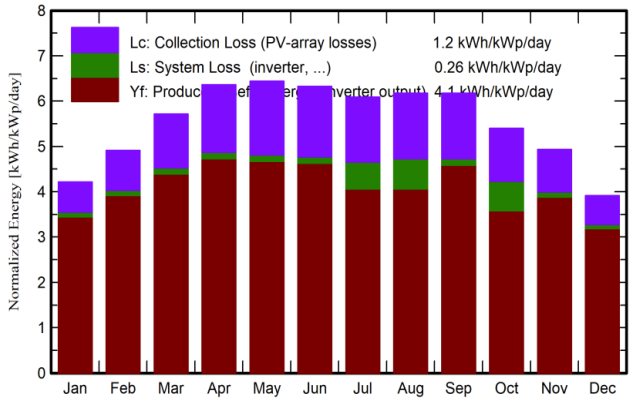

Fig. 2 Normalized productions (per installed kWp)

B. Solar Energy systems

Produced electrical energy from PV panels is DC (Direct current) which can be converted into alternating current by using solar inverter. There are different types of solar energy systems depending upon their operation for instance, Grid-Tied solar systems is also connected with the utility grid which is shown in the figure-3 which is prepared using Homerpro software and provide the energy to the load where extra energy can be transferred to the grid for making some money this is called net metering and Off-grid solar systems work independently from the grid.

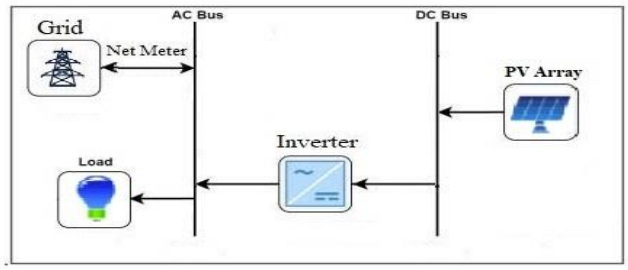

Fig. 3 Grid-tied solar energy systems

III. WIND ENERGY

Transformation of mechanical energy from the wind into electrical energy is called Wind Energy. Humans have been using wind turbines for over 7000 years for several purposes, like water pumping, sawing and windmill ship etc. There is around 10 million MW wind energy is available every time on the earth (Herbert, Iniyan, Sreevalsan, & Rajapandian, 2007). With the invention of dynamo, the first grid station was built in the New York in 1880, which made the way easy for building the wind turbines and then Wind was used to harvest an electrical energy for the first time in 1887 when first wind turbine was made in Scotland by Prof James Blyth shown in figure-4 (Shahan, 2014).

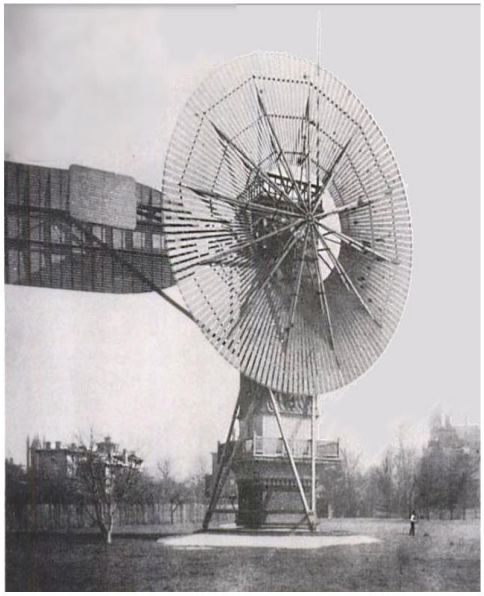

Fig. 4 First Wind turbine (Gipe & Möllerström, 2022)

Wind turbines are designed for multiple purposes, for example, land-based wind turbines are installed on the earth and these windmills are called onshore wind turbines, offshore wind turbines are used in water mostly in the Sea, and there are some turbines which can be installed at homes or at small level and this is named as distributed wind energy. Onshore wind power is economically efficient and easy to install as compared to offshore.

Fig 5. Onshore Windmill (Desrochers, 2019)

Fig 6. Offshore Windmill (W & Houlsby , 2003)

A. Operation of Wind

Wind turbines consists of several components which receive mechanical energy from wind and then convert it to the electrical energy, like, wind rotates the rotor blades which is connected to the generator and then generator starts generating the electrical energy which can be transfer to the grid with the help of transformer and transmission systems. Figure-7 shows some of the major components of the wind turbine.

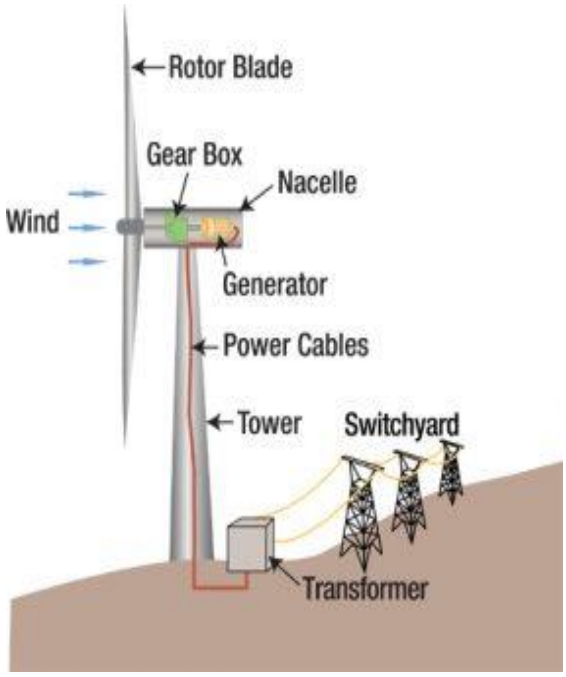

Fig.7 Operation of wind turbine (Kaylani, Alkhalidi, Al-Oran, & Alhababsah, 2021)

IV. Battery Energy Storage Systems

Battery Energy storage systems (BESS) are the systems which can store the electrical energy and then provide back when it's needed. From some decades, there has been a challenge for storing the energy for critical loads like in industrial or commercial level. As the world is moving towards the renewable energy rapidly but the major problems are efficiency and reliability, for instance in the daytime when there are solar generation peak hours which is generating more power than the load requirement, so energy storage systems play a significant part to store the extra energy and then it can easily manage the loads during of-peak hours. This system has the capability to balance the fluctuation in the load because of its controlling systems, this can be easily adjusted as per the required load or sometime some critical loads are on preference, so it only provide the energy to them (Joseph & Shahidehpour, 2006).

Fig. 8 Battery Energy storage system (Florence & Hopper, 2020)

V. Hybrid Energy System using Wind, Solar & Battery Storage System

Integration of multiple electricity generators by using the controlling circuitry is called hybrid energy systems, like solar energy and wind energy are connected in this project to produce electrical energy. These are also connected with battery storage systems, which will increase the efficiency and reliability of the systems.

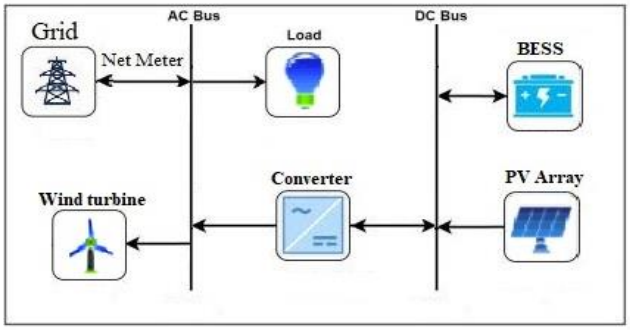

Fig. 9 Hybrid Energy systems

Hybrid systems are being used as an alternating solution for conventional energy systems limitations. This is the best solution for remote locations where there is no electricity but either wind or solar can be everywhere. This is not only limited to remote locations but also, it's operating with the grid as mentioned in figure 9, where solar and wind energy integrated with the grid.

VI. Conclusion

Hybrid energy systems using wind, solar and battery storage systems have been gaining more and more popularity for previous some decades because of their reliability and cost effectiveness. It has many advantages e.g. it has the ability to minimize the dependability on the fossil fuels, clean energy can be produced by these systems which is carbon free which

makes it environmentally friendly solution and also it provides the stable electrical energy to the systems which is beneficial for critical loads.

Using the energy storage system makes it an expensive solution and the operating cost is also high, but researchers are working to come up with a cost-efficient solution which will increase its popularity. Although, the installation cost of the system is high, but it can be payback in some years because it will reduce the electricity bills (Farooq, Agili, & He, 2024). So, overall, it is a cost-effective and environment friendly solution.

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