RESEARCH ARTICLE OPEN ACCESS

Integration and Optimization of Hybrid Solar-Wind Energy Systems: A Technological Perspective

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Abstract:

In this Research, the universal issues about energy management for renewable resources, Solar wind hybrid power system is discussed. This system will improve energy efficiency with LEDs as the light source and additionally the wind turbine is placed with solar. The LEDs will save energy as well as will provide high lamination efficiency and high useful life to the proposed system. Also, the position of the turbine plays as major role for effective power production. By placing turbine in the vertical plane, due to the motion of vehicle air pressure is developed on the blades of the turbine. The pressure is developed from the both directions keeps turbine in continuous motion of all the vehicles such as Trucks, Buses etc., Due to this, an uninterrupted power generation by solar at day time and whenever vehicles cross the path both at day and night time the turbine rotates and energy is generated. This will reduce the electricity bill and the rate of pollution to certain level.

Keywords — **Hybrid Solar-Wind Energy, keywords are separated by comma**

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I. INTRODUCTION

Solar and wind energy is more effective and conventional form of renewable energy available at most it does not depends on any factor, solar energy begins when the day begin and wind is available with a motion of the vehicle at streets. Much researches are ongoing to overcome power crisis. The demand in country is hiking each and every day. But the available power does not meet the requirement.

Renewable energy resources must be utilized as much as possible to cut down the demand rate and it's non-polluting. At present, the issue is how to utilize and manage these resources. This report is proposed to overcome and enhance the power management as said, at highways, by acquiring the available energy sources at highways. The proposed system has some advantages such as the energy generated can be utilized not only by street lights but also in traffic signal, and direction and distance indicators.

Hybrid solo wind energy street light is an eco-friendly alternative energy product that saves electrical energy from wind & solar through its own power-control system. The energy will be used for lighting after sunset in the most efficient way, regardless of season or weather conditions. (The light will be turned on and off automatically). It provides affordable and stable clean energy in any weather condition without connecting to the grid.

II. LITERATURE REVIEW

A. *Solar–wind hybrid renewable energy system: Review [1]*

The demand for electricity is increasing day by day, which cannot be fulfilled by non-renewable energy sources alone. Renewable energy sources such as solar and wind are omnipresent and environmentally friendly. The renewable energy sources are emerging options to fulfill the energy demand, but unreliable due to the stochastic nature of their occurrence. Hybrid renewable energy system (HRES) combines two or more renewable energy sources like wind turbine and solar system. The objective of this paper is to present a comprehensive review of various aspects of HRES. This paper discusses pre-feasibility analysis, optimum sizing, modelling, control aspects and reliability issues. The application of evolutionary technique and game theory in hybrid renewable energy is also presented in this paper [1].

B. *A review of hybrid renewable energy systems: Solar and wind-powered solutions: Challenges, opportunities, and policy implications [2]*

The review comprehensively examines hybrid renewable energy systems that combine solar and wind energy technologies, focusing on their current challenges, opportunities, and policy implications. Despite the individual merits of solar and wind energy systems, their intermittent nature and geographical limitations have spurred interest in hybrid solutions that maximize efficiency and reliability through integrated systems. A critical analysis of available literature indicates that hybrid systems significantly mitigate energy intermittency issues, enhance grid stability, and can be more cost-effective due to shared infrastructure. The review identifies key challenges, such as system optimization, energy storage, and seamless power management, and discusses technological innovations like machine learning algorithms and advanced inverters that hold the potential for overcoming these hurdles. Importantly, the review elucidates the role of policy in accelerating the adoption of these systems by highlighting successful case studies of government incentives, public-private partnerships, and regulatory frameworks that have fostered investments in hybrid renewable energy systems. The study concludes with the outcomes obtained that signify the potential for hybrid renewable energy systems to not only meet but exceed future energy demands sustainably, provided there is concerted effort in research, investment, and policymaking [2].

C. *An overview of the environmental, economic, and material developments of the solar and wind sources coupled with the energy storage systems [3].*

There is a constant growth in energy consumption and consequently energy generation around the world. During the recent decades, renewable energy sources took heed of scientists and policy makers as a remedy for substituting traditional sources. Wind and photovoltaic (PV) are the least reliable sources because of their dependence on wind speed and irradiance and therefore their intermittent nature. Energy storage systems are usually coupled with these sources to increase the reliability of the hybrid system. Environmental effects are one of the biggest concerns associated with the renewable energy sources. This study summarizes the last and most important environmental and economic analysis of a grid connected hybrid network consisting of wind turbine, PV panels, and energy storage systems. Focusing on environmental aspects, this paper reviews land efficiency, shaded analysis of wind turbines and PV panels, greenhouse gas emission, wastes of wind turbine and PV panels' components, fossil fuel consumption, wildlife, sensitive ecosystems, health benefits, and so on. A cost analysis of the energy generated by a hybrid system has been discussed. Furthermore, this study reviews the latest technologies for materials that have been used for solar PV manufacturing. This paper can help to make a right decision considering all aspects of installing a hybrid system [3].

D. *Cost–benefit analysis of remote hybrid wind–diesel power stations: Case study Aegean Sea islands [4].*

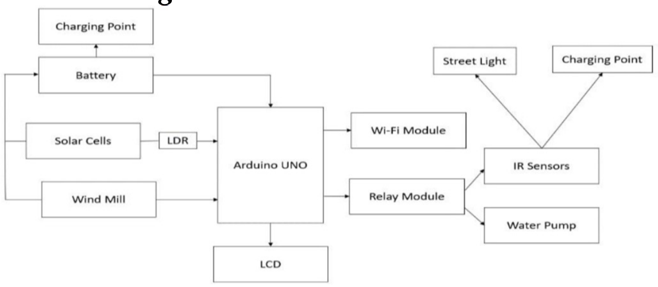
More than one third of world population has no direct access to interconnected electrical networks. Hence, the electrification solution usually considered is based on expensive, though often unreliable, stand-alone systems, mainly small diesel-electric generators. Hybrid wind–diesel power systems are among the most interesting and environmentally friendly technological alternatives for the electrification of remote consumers, presenting also increased reliability. More precisely, a hybrid wind–diesel installation, based on an appropriate combination of a small diesel-electric generator and a micro-wind converter, offsets the significant capital cost of the wind turbine and the high operational cost of the diesel-electric generator. In this context, the present study concentrates on a detailed energy production cost analysis in order to estimate the optimum configuration of a wind–diesel-battery stand-alone system used to guarantee the energy autonomy of a typical remote consumer. Accordingly, the influence of the governing parameters—such as wind potential, capital cost, oil price, battery price and first installation cost—on the corresponding electricity production cost is investigated using the developed model. Taking into account the results obtained, hybrid wind–diesel systems may be the most cost-effective electrification solution for numerous isolated consumers located in suitable (average wind speed higher than 6.0 m/s) wind potential regions[4].

III. METHODOLOGY AND BLOCK DIAGRAM

A. *Methodology*

The methodology of this project involves several steps. Firstly, the system design and configuration are determined based on power requirements and energy demand. Suitable solar panels, wind turbines, and energy storage units are selected. Power electronics and control systems are designed to optimize energy conversion and management. Performance analysis is conducted through simulation studies, validated by field experiments and measurements. Optimization techniques and control strategies are explored to maximize power generation. Economic analysis assesses the feasibility and costs of the system. An environmental impact assessment evaluates the system's environmental benefits. This methodology provides a systematic approach to designing, implementing, and evaluating the hybrid solar and wind system for efficient and sustainable power generation.

B. *Block diagram*



The proposed project aims to create a system that can generate power using a combination of hybrid solar and wind system. The project will be divided into two stages, with the first stage being focused on energy generation. In this stage, the design of the solar panels will be developed, and the optimal placement of the wind mill. The generated power will be used efficiently and stored onto the battery in accordance with the request strategy. The second stage of the project will involve energy monitoring. The power generated by the renewable source of energy will be monitored and by using relay module that energy are used to run the water pump using AC motor, charging station and LDR and IR sensor for controlling street light.

IV. OVERVIEW OF THE RESEARCH

A. *Component list*

- Solar Energy (Solar Panel)
- Wind Energy (Wind Blades)
- Dynamo
- Pole
- Charging Circuit
- DC Battery Source

V. MODULE DETAIL

A. *solar panel: Solar Energy (Solar Panel) – 20-Watt, 12 Volt:*

Solar panels are the medium to convert solar energy into the electrical energy. Solar panels can convert the energy directly or heat the water with the induced energy. PV (Photo-voltaic) cells are made up from semiconductor structures.

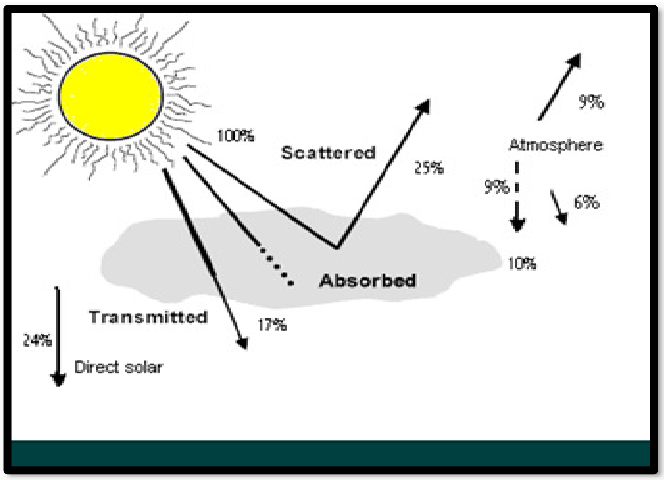


Fig.1 Solar Radiation

Originates with the thermonuclear fusion reactions occurring in the sun. Represents the entire electromagnetic radiation (visible light, infrared, ultraviolet, x-rays, and radio waves). The surface receives about 47% of the total solar energy that reaches the Earth. Only this amount is usable. As in the computer technologies. Sun rays are absorbed with this material and electrons are emitted from the atoms. This release activates a current. Photovoltaic is known as the process between radiation absorbed and the electricity Induced.

Fig.2 Solar Panel

Solar power is converted into the electric power by a common principle called photo electric effect. The solar Cell array or panel consists of an appropriate number of solar cell modules connected in series or parallel based on the required current and voltage. Almost 90% of PV technology is based on silicon which is mostly used in crystalline silicon solar panel. There are many factor to use the silicon in photovoltaic technology but the important one is purity of silicon, which mines the more purification, the more ability of solar panel to convert sun light in to electricity as an output power.

- There are two types of solar panel
    1. Poly crystalline
    2. Mono crystalline

The average life of crystalline solar panel about 25 years.

B. Connection of Solar panel:

The back side of solar panel and its junction box. Connection from solar panel junction box. Fig.7 clearly show that we can get 12 Volts through the left one Negate and the right one positive. Note that this 20 Watts, 12 Volts, and 2.5 Amperes panel but We use for 17 Ah battery with 12-15 A charge controller.

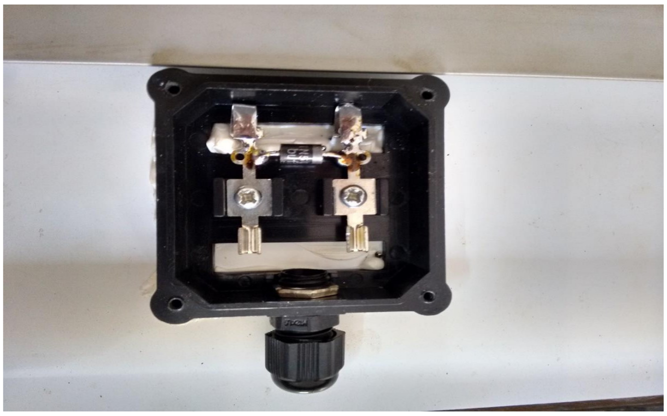


Fig.3 Junction Box

One diode which have connected in forward bias from solar panel to output battery charging. Suppose battery is charging through solar panel. When battery is fully charged. Then at night when solar panel is not active, in other words, battery will supply voltage to the solar panel again. But Diode is connected a From Solar Panel to Battery = Forward Bias & from Battery to Solar Panel = Reverse Bias

C. wind blades:

A wind turbine is a rotating machine which converts the kinetic energy in wind into mechanical energy. If the mechanical energy is used directly by machinery, such as a pump or grinding stones, the machine is usually called a windmill. If the mechanical energy is then converted to electricity, the machine is called a wind generator, wind turbine, wind power unit (WPU), wind energy converter (WEC), or aero generator. The wind energy is a renewable source of energy. Wind Turbines are used to convert the wind power into electric power. Electric generator inside the turbine converts the mechanical power into the electric power.

Fig.4 Wind Turbine (Wind Blade)

Wind turbine systems are available ranging from 50W to 3-4 MW. The energy production by wind turbines depends on the wind velocity acting on the turbine. Wind power is able to feed both energy production and demand in the rural areas. It is used to run a windmill which in turn drives a wind generator or wind turbine to produce electricity. In the case of designing or choosing the blade, the diameter of the larger wind-rotor is around 8 feet [2.4 m]. The smaller machine has 4' diameter [1.2 m]. Mostly The blades are, made of unsaturated polyester, fiber-reinforced epoxy composite material. The energy produced by wind turbines depends on the swept area of the blades. The shapes of the blades are important near the tip but much less so near to the root (the larger, inner end of the blade). They can convert only up to 25 -35% of the wind pressure to make a mechanical movement with blades. The diameter is one of the main criteria when the diameter of the blade increases automatically the power may be doubled. The speed of the blade is decided by the amount of load is put on to it by air, Rotor blades are designed with speed in mind, relative to the wind. This is said to be the tip speed ratio (tsr). Tip speed ratio is the speed the blade tips travel divided by the wind speed at that time. The number of blades also plays a vital role in the speed developed by the rotor, multi-blade has low tip ratio it creates a high torque but power does not increase. The speed should be more than the torque to generate electricity.

Classification:

- Wind turbines can be separated into two types based by the axis in which the turbine rotates.

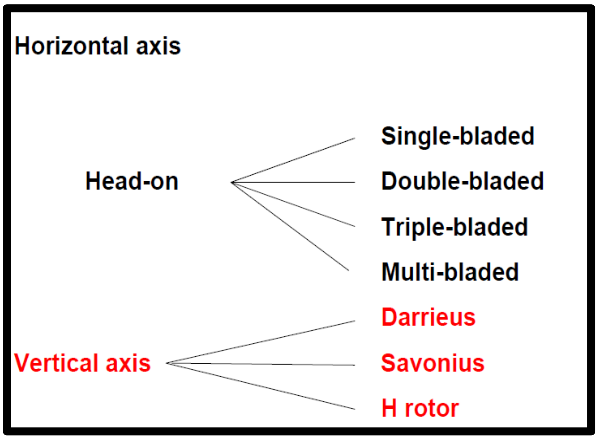


Fig.5 Classification of Wind Blade

- Turbines that rotate around a Horizontal axis are more common.
- Vertical-axis turbines are less frequently used.

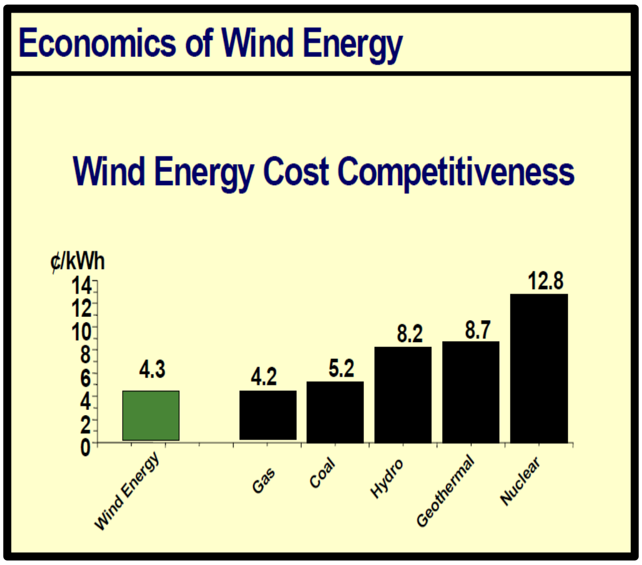


Fig.6 Economics of wind Energy

D. Dynamo:

The dynamo in the bicycle uses rotating coils of wire and magnetic fields to convert mechanical rotation into a pulsing direct electric current through Faraday's law of induction. A dynamo machine consists of a stationary structure, called the stator, which provides a constant magnetic field, and a set of rotating windings called the armature which turn within that field. The motion of the wire within the magnetic field causes the field to push on the electrons in the metal, creating an electric current in the wire. On small machines the constant magnetic field may be provided by one or more permanent magnets; larger machines have the constant magnetic field provided by one or more electromagnets, which are usually called field coils. Thus, by the above mechanism dynamo charges the battery.

Fig.7 Dynamo

Working of dynamo:

Basic principle on which dynamo works is "Faraday's law of electromagnetic induction". According to this law if an object or material that conducts electricity passes through a magnetic field then an electric current will begin to flow through that material.

Construction:

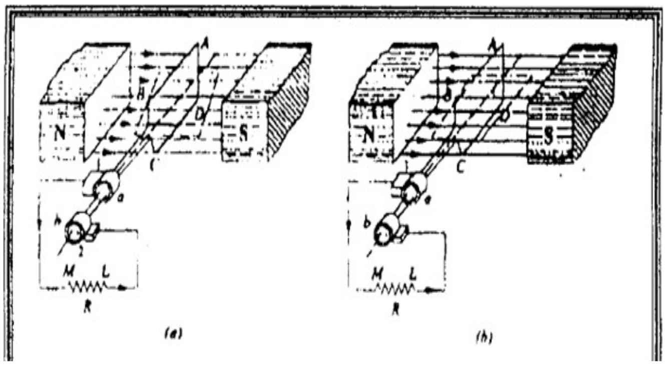


Fig. 8 Construction of Dynamo

fig.8 Shows Single Turn Rectangular Copper Coil Abcd Rotating About Its Own Axis I Magnetic Field Provided by either Permanent Magnet or Electromagnets. The Two Ends of Coil Are Joined to Two Slip Ring "A" & "B" Which Are Insulated From Each Other and From Central Shaft. The Two Collecting Brushes (Carbon or Copper). Press Against Slip Rings. Their Function Is to Collect Current Induced in Coil and to Convey It to External Load Resistance R. The Rotating Coil May Be Called "Armature" and the Magnets Are Called as "Field Magnets".

E. Pole:

7ft iron pole is used for supporting of solar panel and wind turbine. Weight of pole is about 20kilo which is compact and portable so we can used anywhere.

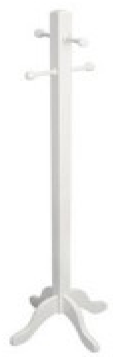


Fig.9 Pole

F. Charging circuit:

Fig. 10 Solar Charge Controller

It is required to control and regulated the voltage generated by the solar panel and wind generator.

Application: -

1. Networking DC-DC Power System
2. Automobile Convert System
3. Power Supply etc.

G. Dc battery source:

The total energy stored in a battery can be calculated by multiplying the ampere-hour rating with the battery voltage. Thus, a 17ah battery with 12v can store energy of 204wh or 0.204kwh. The duration of a battery is thus dependent on its discharge rate. Manufacturers provide discharge charts for their batteries. Charging and discharging rates have a major impact on the life of a battery. A battery that is discharged at a faster rate may not deliver the same amount of energy as a battery with a lesser discharge rate. Some manufacturers specify the capacity of a battery as a function of the discharge rate. Temperature, too, influences the capacity of a battery. Batteries at high temperatures will have a better capacity that batteries loaded at low temperatures. Extremely high temperatures, however, can cause damage to the battery and greatly reduce capacity.

Fig.11 DC Battery Source

In addition to these factors, age is also a factor that determines the capacity of a battery. As a battery ages, its capacity reduces. The electrolyte in the battery is a mixture of sulphury acid and water. The amount of water in a battery can fall due to electrolysis or evaporation. This may cause in a drop in the level of the electrolyte and consequently a drop in the battery output. Hence, it is necessary to periodically inspect the level of electrolyte in the battery. If the level of the electrolyte falls below the minimum level, it can be topped up by adding water. Only distilled water should be added as ordinary water may contain a lot of impurities and ions which may contaminate the electrolyte. The level of electrolyte in the battery tends to fall as the battery gets discharged and tends to rise as the battery gets charged. Hence, water should be added to the electrolyte only when the battery is fully charged. If the water is added to the battery when it is in the discharged condition, the level can increase beyond the limit when the battery is fully charged and may overflow.

H. Street light:

Fig.12 LED Street Light

- The energy obtained in to run loads (all are light source). The loads are street light, traffic signal, direction indicator. All the loads are light loads. It's important to choose the type of lamps to be used. Currently at most of the Highway Street lights, they prefer sodium vapor lamp or halogen lamp or CFL, because it has a better scattering property. The use of these lamps consumes more power based on luminance. Each and every lamp varies from other based on high luminance its preferred for street lighting as show in the table.1, below, it give a clear view about the kinds of lamps used in street light with different lumen capacity as per the required watts for luminance.

Table 1:

Types of lights & its lumens/watt

Sr.no.	**Type of light with various Composition**	**Typical luminous Efficiency (Lumen/watt**
1.	Mercury Vapor lamp	35-60
2.	Low pressure Sodium vapor lamp	100-200
3.	High pressure sodium vapor Lamp	85-150
4.	Halogen Lamp	16-24
5.	LED Lamps	30-90

- The sodium vapor lamp consumes 100 - 200W power for an hour
- Power consumed per day = 4800 W
- Power consumed per month = 14, 4000 W. Annually = 17, 52,000 W.

The use of Power LEDs reduces this power consumption being utilized, the luminance effect of power led is almost equivalent and better the present days lighting system. The brightness of LEDs various based on the material used as discussed in, using two types of phosphors-converted white high brightness Led's can be used. This power consuming can be reduced to a larger limit. The power consumption is minimized and rest of the power can be utilized for other purposes. The heating of lamp is another major factor which we need to consider it determines the life and ability of lamps brightness, at temperature between -25'c/125'c, junction temperature increases, with different materials the degradation rate various, most of the failure comes under the same phenomenon. The rectangular design of LED's are quite brilliant and spread the lights evenly throughout the place. The power led gives a better outcome than the normal LED's there are various shapes and designs available for effective brightness and scattering of light over the required area. There are various designs like square, rectangular, circular, strips and soon. The emission of light various from each design available in the manufacturing.

- **APPLICATIONS**
  1. Highways
  2. Near to Rail
  3. Municipal Lighting
  4. Industrial Buildings
  5. Urban Road Construction
  6. Car Parks
  7. Sports Stadiums or Exhibitions Grounds Remote Areas

CONCLUSIONS

The Research work has been studied and implemented a complete working model. The main advantage of the present system is that it is ecofriendly power generation. It requires the initial cost only for designing and installation and not for utilization. Hence, such systems are very much useful for the government to reduce the utilization of renewable source of energy. This initiative will help the government to save the other energy and meet the domestic and industrial needs. It is very efficient and one time investment project less maintaining cost. This research contributes to the knowledge in renewable energy systems and provides valuable insights for the design and implementation of hybrid solar and wind systems, promoting a cleaner and more sustainable energy future.

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