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A study of development and perspectives of a hybrid solar-wind system.

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Abstract: A photovoltaic-wind hybrid electrical power supply system was designed to serve off-grid locations where installinga traditional grid connection would be in- convenient or costly due to the unpredictability of natural energy resources & seasonal imbalances. If the hybrid system is connected to the grid, the homeowner can even sell any extra energy back to the electric company. The proposed infrastructure includes photovoltaic solar cells, a wind generator mounted on a mast, lead-acid storage batteries, a DC-to-AC inverter unit, electrical lighting loads, electrical heating loads, multiple fuse & junction boxes, associate wiring, & test instruments to measure voltages, currents, power factors, & harmonic contamination data. The suggested hybrid solar-wind power generating system has significant potential for application in demonstrating electrical concepts in practical laboratories & throughout the Industrial Technology curriculum. The purpose of this study is to provide an examination of local PV-wind hybrid systems that can provide electricity to a private home, farm, or small business, depending on the requirements of the site. Explanations of the system's main parts, its operating principle, and its current configuration are represented.

Keywords — ***Hybrid Power, Photovoltaic, Renewable Energy, Solar Power, Wind Power***

I. INTRODUCTION

A hybrid power plant (HPP) is a power generator that uses primary renewable energy to produce electricity & consists of multiple power-generating modules, a network, & connection points. Considering the intermittent nature of both solar and wind power, hybrid systems are able to provide a more stable power source all year round. [1] Solar

energy generation is best in the months with longer days of sunlight. For about three to four months out of the year, solar radiation is at its lowest in most places. In moreover, the direction in which your panels should face varies with the times of year [2]. However, wind variables (such as density, speed, & turbulence) & turbine pitch have a greater impact on wind system efficiency than does sunlight [3]. Additionally, as nighttime is windier than daytime, wind energy generation is preferred at night, although peak solar generation is enabled during the day due to sunlight [4]. Power generated by renewable sources must be stored so that it can be used during times of low production. The costs associated with large-scale electricity storage are very high [5] [6]. That's why, according to Grandview Research 2021, hybrid systems that include solar & wind are the most effective. The number of households adopting renewable mini-grids increased dramatically between 2008 - 2016, according to the available data. In Asia, the number of consumers increased by 3 million to 8.8 million, or in Africa by 0.2 million to 1.3 million. IRENA data shows that these consumers favored mini-grids and other distributed cost-effective renewable energy option available right now.

Solar cells, often known as photovoltaic (PV) cells, use the sun's rays to generate direct current (DC). When compared to other forms of renewable energy, PVs are advantageous

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because they produce little noise so need minimal upkeep. Although solar energy is familiar to students (it is, for example, included in most calculators), the underlying operating principles and regulating connections are not as easily explained in a classroom setting as wind turbines. Essentially, they are based on the similar semiconductor principles that govern diodes & transistors. There is a simple explanation of how they work, which could make many of the principles taught in semiconductor electronics courses more accessible.

DC power is provided by wind turbines & PV cells, while AC power is needed for most industrial applications. In order to make the change from DC to AC, a power inverter, a semiconductor-based device, is utilized. This device's straight- forward operation serves as an excellent example of a wide range of power electronics concepts.

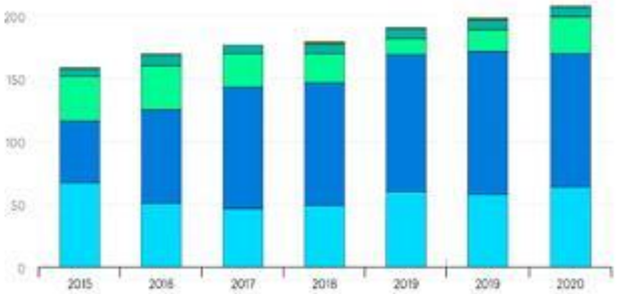

Figure. 1. Predicted energy expansion by energy source

II. STRUCTURE ANALYSIS

Project requirements for a PV-wind hybrid system:

The most compelling argument in favor of a hybrid energy system is the unreliability & seasonal variation of renewable energy sources. The PV-wind hybrid system is optimal in regions with seasonal variations in both sun & wind, such as those in the Northern Hemisphere,, where summer days are long & sun light is robust sufficiently, while winter days are shorter & there are more clouds, but there is generally a moderate wind resource that could supplement the solar resource.

The PV-wind hybrid systems are ideal for outlying areas where it is difficult or expensive to connect to the main power grid. To maximize solar energy production, the PV array must face south. Considerable attention must be paid to the direction & velocity of the wind when installing a wind turbine. The turbine needs to be installed higher than any trees or other impediments so that it is exposed to smooth, unobstructed airflow.

Structure Components

The core part (PV modules & wind turbine), the PV modules mounting, the wind turbine tower, the DC-AC inverter, the safety equipment (fuses, connectors, & lighting arrestors), the measuring devices, the batteries, the charge controller/regulator, the backup power resource for battery storage systems, the connection wires, switches, & sockets, and so on and so forth make up a local cost-efficient, safe, & long-lasting PV-wind hybrid system.

PV modules can be connected by wiring to create a photo- voltaic array. When modules are wired in parallel, the current is raised, but when modules are wired in series, the voltage is increased. The output of power is the same either way. In direct sunlight, a standard PV module (often measuring around 1.5 by 3.5 feet) generates roughly 75 watts of DC power. Wind turbines are the antithesis of fans. Wind turbines are generators that harness the power of the wind to generate electricity. Two- or three-bladed turbines are the norm. Upwind operation is used for these three-bladed wind turbines. The two-bladed, downwind wind turbine is the other typical design. Blades are turned by wind, which in turn spins a shaft, which in turn is connected to a generator, which in turn creates electricity. The output of utility-scale turbines typically falls between 50 and 750 kW. Homes, satellite dishes, & water pumps often use single turbines with outputs of less than 50 kilowatts. A DC-AC inverter converts low-voltage direct current (DC) electricity, such as that generated by a PV or wind turbine or stored in a battery, to high-voltage alternating current (AC) at 120 or 240 VAC & 50 or 60 hertz. Unlike in the past, when blackouts and brownouts were common, today's "modern sine wave" inverters provide constant power. Inverters can range in power from 250 watts and up to more than 8,000 watts. Modified sine wave inverters are more affordable and suitable for most common residential uses. However, some electrical devices & cellphones may buzz when using these inverters. It's worth pointing out that inverters have come a long way in terms of both efficiency & cost in recent years. With the use of an inverter, a renewable energy system can be connected to the utility grid, permitting for the sale of any excess energy. Numerous modern inverters also function as battery chargers, allowing you to keep your batteries fully charged when you're disconnected from the grid or using your generator.

Mounting options for PV modules include ground mounts that could be installed on either rooftops or the ground, and pole mounts that can be used to elevate the modules above ground level. The PV array may be aimed at an optimal angle toward the sun with the help of both of these features. Since the sun's angle varies throughout the year, many owners may reposition their rising racks twice or 4 times a year to get the most out of their setup. The modules could be fixedly put on the roof without the need for an adjustable rack if the rooftop has a good angle to the sun. Trackers, that are pole mounts that move with the sun all day long, are another type of PV mounting option. The wind turbine tower needs to be high enough (at least 9 meters higher than anything else within 120 meters) so that the blades point into the wind without creating turbulence. The guy wires need to be able to be anchored securely, thus there should be ample room.

Overcurrent & lightning protection components are included in the safety gear. In the case of a short circuit, the system's wiring & components will be safe thanks to the inclusion of over-current safety components such fuses & fused disconnect- tors. Fusing prevents damage from overloads, and disconnect switches make it possible to turn the power off to individual parts of the system without endangering anyone. The current capacity of fuses & fused disconnections is specified in amperes. Currents can range

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from a few amperes in the case of measuring equipment to 400 amperes in the inverter. Several installations of renewable energy sources are situated in regions prone to frequent electrical storms. In any rural region, the wind turbine will almost certainly be the tallest structure. To further fortify the system's electronic components against lightning, commercial lightning arrestors can be used. Electrical traffic between the grid & renewable energy system, if linked, can be monitored in addition to battery voltage, power consumption, & battery charge status by means of measuring equipment. For hybrid systems, two battery banks can be monitored with two separate instruments, or one battery bank can be monitored with two separate instruments. Batteries are able to store the electrical energy supplied by the renewable energy source in a reversible chemical reaction. Lead-acid batteries, often housed in plastic, are commonly used in renewable energy systems are connected in series & parallel. A battery's capacity is measured in amp-hours, where one amp-hour is equal to continuously discharging one amp for one hour. The battery capacity of a standard 12-volt system could be 800 amp-hours.

When completely emptied and beginning with a fully charged condition, this is comparable to 1,200 watts for 8 hours. Renewable energy systems can use batteries from a wide variety of manufacturers, with L- 16 and golf cart sizes being the most prevalent.

The PV array and wind turbine are unable to overcharge the battery thanks to the charge controller/regulator. Electronic system voltage regulation is achieved by most modern controllers by modulating the width of DC pulses sent to the batteries (this is called pulse width modulation or PWM). This means that more juice is being pumped into the batteries the wider the pulse is. Shunt type controllers are another type that reroute surplus power to a "shunt load." Wind and hydro systems, which should not be run open circuit and hence require controllers, employ these more frequently. Most wind and hydro turbines do not have an on/off switch like a PV module. The term "maximum power point tracking" describes a feature of the latest PV controllers. By changing both current and voltage, they extract the maximum amount of power from the module.

When there is an excessive demand for energy or not enough renewable energy being fed into the system, a generator or the utility grid can be used as a backup power resource. However, the hybrid system may prevent the second scenario, and an appropriate approach to energy use may help with the first.

III. HYBRID ENERGY SYSTEM

Most importantly, a hybrid energy supply system is necessary due to the presence of intermittent energy sources & unbalance of energy sources. As both solar radiation & wind patterns are seasonal, a hybrid system that combines the two is ideal. [7] Since neither the wind nor the sun blows steadily throughout the day, relying on just one of them isn't an option. Power from the wind & sun, combined & stored in a battery, could be a more stable & practical energy source. Even if there is no external source of energy like the sun or the wind, the load can still be powered by the energy stored in the batteries. When designing new systems, hybrid architecture is often used [8] because it allows for the best of both worlds: reduced costs & increased dependability. Solar PV cells are not cost-effective for big-volume production because of their high retail price. In this context, the wind turbine is a useful tool, with its primary advantage being a low price compared to PV cells. To use the energy generated by the sun & wind at night, a battery system is required. The presence of wind at night is a plus, as it boosts the system's dependability. During the monsoon season, when the sun's power is diminished, a hybrid wind & solar system is a suitable alternative.

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Photovoltaic Solar Power

The panels that absorb the sun's rays and transform them into electricity are called solar panels. Solar panels can either directly convert the energy or use the induced energy to heat water. The components of PV (Photovoltaic) cells are semiconductor structures, just like those used in computing. By absorbing the sun's rays, the atoms in this substance release electrons. A current is triggered by this release. Absorption of light and subsequent conversion to energy is what gives photovoltaics their name. The photoelectric effect is the universal principle by which solar energy is transformed into usable electricity. The solar cell array or panel is made up of solar cell modules wired in series or parallel to produce the requisite current & voltage.

Wind Power

Wind power is a sustainable alternative to fossil fuels. The wind is harnessed by turbines that generate electricity. The turbine's electric generator takes mechanical energy

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and trans- forms it into electrical power. Available wind turbine systems generate anywhere from 50W up to 3-4 MW. Wind turbines' ability to generate electricity is proportional to the speed of the wind buffeting the turbine. Wind energy can provide both the supply & demand for electricity in remote places. In order to generate energy, it is put to use in a windmill, which in turn turns a wind generator. [8]

Batteries

The system's batteries are responsible for storing any excess energy produced by the wind or solar panels. Batteries can be connected in series or in parallel to get the desired capacity. Batteries of the maintenance-free, dry-type that make the most of solar & wind power systems' potential use of those sources' advantages use particular electrolytes. The performance of these batteries is ideal for deep discharges.

Inverter

When electrical loads require electricity, they connect to the inverter, which transforms the DC power stored in the battery into AC power. The inverter is safeguarded against common problems such as short circuits, reverse polarity, low battery voltage, & overload by including these features as standard.

Microcontroller

After comparing the two power sources' inputs, the micro- controller activates the appropriate relay & charges the DC battery. Inverter Circuit is used to change the DC voltage into AC Supply. The secondary winding of a center-tapped transformer is linked to the MOSFET (IRF 540). The primary winding of the transformer is where the alternating current (AC) is supplied because the MOSFETs are alternately triggered.

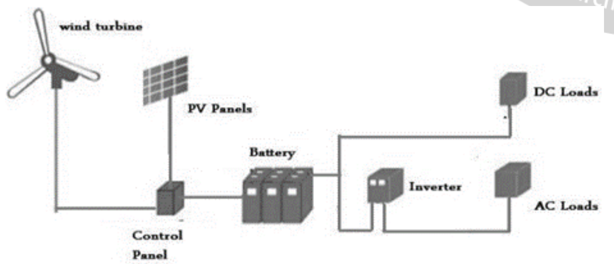

Figure. 2. Hybrid Energy System

IV. THE SYSTEM'S FORMATIONAL PROCESS

There is a crucial first step involved in setting up the energy supply system (Figure 3). Before anything else is done, the installed system's desired load & site's available resources should be determined. The total amount of power used by all of the devices connected to the grid is tallied in a load analysis. The structure, efficiency, & cost of a system are all impacted by how well resources are measured. [11] Having the necessary expertise & experience is essential for the system's design & installation. [12]

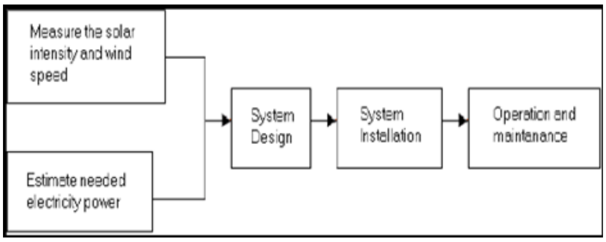

Figure. 3. Steps for establishing a Hybrid Solar & Wind Plant

A. Methodology

The following aims notify the perception & development of the system, which aims to remedy the limitations of conventional methods of teaching about electrical power systems:

To study the conventional instruments used in physics & chemistry laboratories that deal with electricity.

To have close ties to practical, real-world concerns in the power sector of industry, such as power quality.

B. Formation of a Wind/PV Hybrid Unit

The hybrid unit is composed of two independent power generators—a PV solar cell plant & wind turbine system. A 120V AC line is linked in parallel with these power sources. Power from the PV panels is fed through a DC/AC inverter, which supplies electricity to a single-phase, 120V AC load. Figure 1.4 depicts the overarching framework of the project. Figure 1.5 displays the DC voltage (12 V DC) observed across all PV modules. The steel tower that holds the wind turbine measures 18.3 meters in height & 8.9 cm in diameter. Digital panel meters are used to track the generator's outputs on the instrumentation panel shown. The brush-less alternator & internal governor is two of the turbine's low- maintenance characteristics. Carbon fiber reinforced composite blades are designed to deliberately bend as the turbine reaches its maximum power. Because of the alteration in the blade's shape brought on by this deformation effect, the blade enters a stall mode, reducing the alternator's maximum rotational speed and protecting it from overheating. The wind turbine also has a high-tech internal regulator that constantly monitors the line voltage & makes adjustments for low voltage situations.

When it comes to systems that use power inverters, poor power quality is one of the biggest issues. [13] If the inverter employed in the system does not have a proper sinusoidal waveform output, then harmonic contamination & poor voltage regulation will occur, both of which are quite problematic. IEEE guidelines allow for total harmonic distortion from inverter outputs of up to 4%. However, the harmonic distortion at the outputs of many inverters is far higher than permitted levels. Two power quality analyzers (types 39 & 41) are utilized to monitor & record the voltage, current, power, & harmonic contamination data in this setup. In addition, the system is monitored via AC/DC digital panel monitors that are permanently installed. Power

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quality analyzers connect to a portable computer that can be used to record data while it is being collected.

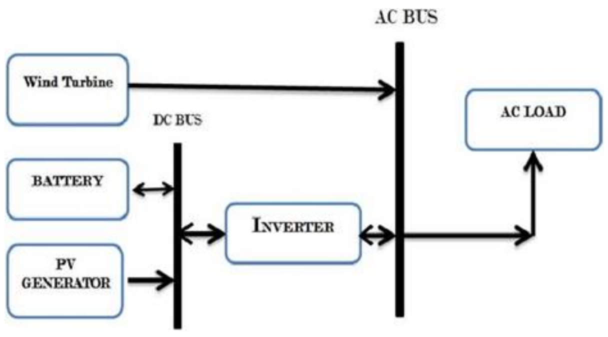

Figure. 4. A simple Solar & Wind System

Many highly automated manufacturing facilities rely on computers and other electronic devices, which can be severely damaged by voltage dips. [14] The AC filter consists of a resistor (R), inductor (L), & capacitor (C). Power quality issues are typically remedied by installing such filters in industrial settings. Standard models of both the inverter & control circuit are included in the PSCAD/EMTDC software suite. The inverter is of the six-pulse type.

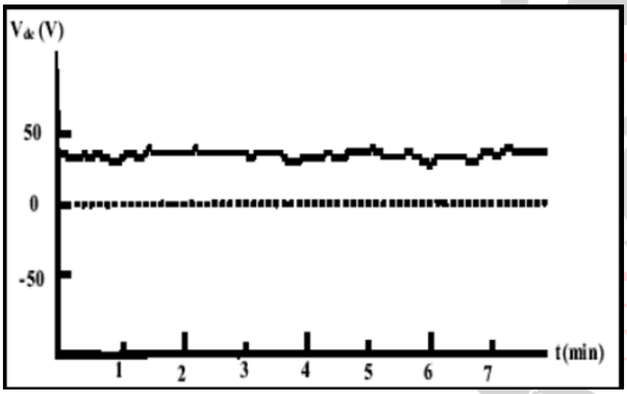

Figure. 5. The DC Voltage measured each PV Unit (12V DC)

V. CONCLUSION

A hybrid solar-wind energy producing system offers a practical & efficient alternative to traditional energy sources. It is effective & can be used in locations where local government has difficulty reaching there. The central idea of this study is that multiple renewable energy sources could be wired together to create a power grid with complicated electrical inter- connections. Many schools' Industrial Technology programs might not be able to afford or manage the time & effort necessary to implement a full hybrid power system like the one outlined. Since solar & wind are becoming increasingly important as power sources in terms of technology, politics, & economy, the option of using a hybrid system to generate electricity from them is a particularly interesting and relevant one for students of electrical technology. Depending on local priorities & resources, many hybrid configurations of wind, solar, geothermal, hydroelectric, tidal, biomass generated, &electricity from burning of solid wastes could be studied.

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