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Efficiency enhancement in hybrid renewable energy system using polycrystalline silicon cell

Mugachintala Dilip Kumar[1], D. Himabindu[2], Yarrem Narasimhulu Vijaya Kumar[3], Thota Mohana[1], Ramagiri Shashank[1], Bodapati Venkata Rajanna[1]
[1]Department of Electrical and Electronics Engineering, MLR Institute of Technology, Hyderabad, India
[2]Department of Electrical and Electronics Engineering, Sri Padmavati Mahila Visvavidyalayam, Tirupati, India
[3]Department of Electrical and Electronics Engineering, Sri Venkateswara College of Engineering and Technology (A), Chittoor, India

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ABSTRACT

Accessing the unelectrified rural population is currently not possible through grid expansion, as connectivity is neither economically viable nor encouraged by large companies. Additionally, conventional energy options, such as broom-based systems, are being gradually phased out of rural development programs because to growing oil prices and the unbearable effects of this energy source on consumers and the environment. A hybrid generator using solar and wind can solve this issue. Proven hybrid systems are the best choice for delivering high-quality power. Nowadays, hybrid renewable energy systems are becoming popular. The power system provides electricity to remote and isolated areas. Villages and residents in the forest area had their electricity cut off due to the forest environment. While creating a renewable energy source near the load. Solar power and wind power are renewable sources, solar power works in the morning and wind can make morning and night time to synchronize both output voltage and frequency to provide provides the ability to charge continuously, without interruption. The main objective of the project is to provide mixed renewable energy without interruption.

Corresponding Author:

Mugachintala Dilip Kumar
Department of Electrical and Electronics Engineering, MLR Institute of Technology
Dundigal Police Station Road, Hyderabad, Telangana 500043, India
Email: dilipkumar@mlrinstitutions.ac.in

1. INTRODUCTION

Concern over global warming and the depletion of fossil fuel reserves has many people searching for sustainable energy options to safeguard the earth for future generations [1]. The two energy sources that have the most potential to meet our energy demands, aside from hydropower, are solar and wind. Even while wind energy has the potential to produce large amounts of power on its own, it is very unpredictable since it may emerge one moment and vanish the next [2]. Similar to this, solar energy is present throughout the day, but the intensity of the sun's rays and the irregularly shaped shadows cast by items like clouds, animals, and other objects cause variations in the quantity of solar irradiation [3]. Wind and solar systems have the same underlying drawback of being intermittent and hence unreliable. However, combining these two sporadic sources and using maximum power point tracking (MPPT) algorithms can significantly improve the system's power transfer efficiency and reliability [4]. When one energy source is insufficient or unavailable to meet load requirements, another energy source might fill the void. Numerous hybrids using PV and wind power systems have been proposed and explored in publications [5]. The majority of systems described in the literature use a DC and DC boost converter that are individually connected at the rectifier stage in parallel to implement MPPT control for each renewable energy power source [6]. It has been suggested to combine the sources from the DC-end and still achieve MPPT for each renewable energy source by using a simpler multi-input structure [7]. The proposed architecture integrates buck converters and buck-boost converters. To eliminate the high frequency harmonic current, the wind turbine generators are introduced using the technologies described in the literature, passive input filters are needed. The generator current's harmonic content shortens its life and increases power loss from heating. For solar/wind hybrid energy systems, a different multi-input rectifier structure is suggested in this research [8].

2. METHOD

Figure 1 shows the block diagram of hybrid renewable energy systems using photovoltaic cells and vertical axis wind turbines. It consists of a solar panel, wind turbine, inverter, batteries, and charge controller. Solar PV panels convert sunlight directly into electricity. Wind turbines harness the kinetic energy of the wind and convert it into electrical energy. Both solar and wind outputs are connected to controllers. These charge controllers regulate the charging of batteries from solar panels and wind turbines. They prevent overcharging and extend the lifespan of the batteries. And these batteries store excess electricity generated by renewable sources for use during periods of low renewable energy generation or high demand. Inverters convert the direct current (DC) electricity generated by solar panels, wind turbines, and batteries into alternating current (AC) electricity.

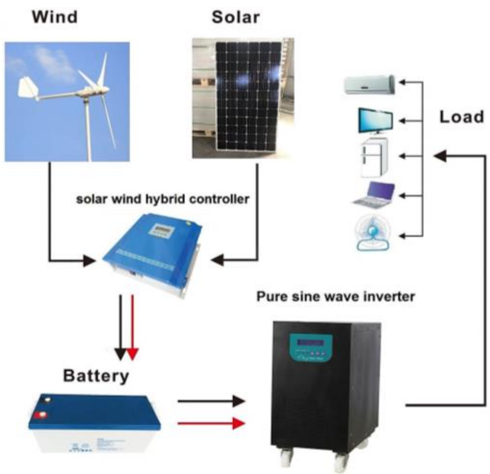

Figure 1. Block diagram of hybrid renewable energy systems

2.1. Solar panel

A solar panel is a base-mounted array of electrically connected solar photovoltaic modules. A photovoltaic module is a collection of solar cells that are joined together in a bundle [9]. As a component of a larger photovoltaic system, the solar panel may generate and supply electricity for use in domestic and commercial applications. A photovoltaic system consists of a panel or array of solar modules, an inverter, and possibly a battery, sun tracker, and connecting wires [10]. Solar energy may be used to produce electricity in a variety of ways, including photovoltaic cells and panels. They are not the most effective, but on a small to medium size, they are the most convents to use. Silicon, the same material used in computer "chips," is utilized to make PV cells [11]. Despite silicon's high mineral abundance, the production of solar cells likes that of computer chips requires an extremely sterile environment. Costs of production are high as a result of this. The two kinds of silicon that make up a PV cell generate a voltage differential when exposed to solar radiation, which, when coupled with an electrical circuit, results in current flow. A "module" made up of a few solar cells will be joined together and often enclosed in glass while placed on a frame. To create a certain voltage, a module's cells can be connected in parallel or series. What is commonly referred to as a 12-volt panel may produce roughly 16 volts in direct sunlight to charge a 12-volt battery [12].

2.2. Wind turbine

A wind turbine is a three-bladed fan that spins in response to wind flow; the direction of the wind turbine's axis of rotation must match the direction of the wind flow. Due to the fact that it is utilized to physically transmit energy from one device to another, a gear box is a very precise mechanical system.

Although there are many other types of wind turbines, the two most prevalent types are horizontal axis turbines and vertical axis turbines [13]. The graphic shows several parts of the wind turbine producing system. An electrical generator that is linked to a wind turbine is referred to as a "wind turbine generator". There are several types of wind turbine generators, and under certain circumstances, these generators can be connected directly to loads, batteries, or the power grid [14].

2.3. Inverter

The voltage to the motor is also adjusted via an inverter. Six different power devices are controlled by a complex electrical circuit used in this operation. They switch on and off to provide a fictitious three phase AC voltage [15]. This switching action is also known as inverting the voltage and current on the DC bus into the AC waveforms that are applied to the motor. Thus, the term "inverter" was created. For the remainder of this explanation, "inverter" will be used in place of "adjustable speed drive" [16]. Most inverters have a variable voltage, variable frequency construction. They consist of a converter, a bus capacitor, and an inverting component. The converter component uses semiconductor devices to convert the incoming fixed voltage, a 3-phase AC power with fixed frequency, to DC voltage, which is stored in the bus capacitor bank [17]. It then turns into a reliable supply of current for the electrical equipment located in the so-called inverting portion. A 3-phase induction motor's speed is often adjusted by inverting, which receives power from bus cap bank of DC and inverts it into back and simulates with 3-phase AC sine waves for varied voltage and varying frequency [18].

2.4. Solar charge controller

A charge controller or charge regulator mainly serves as a voltage and/or current regulator to prevent batteries from overcharging [19]. It regulates the voltage and current that leaves the solar panels and enters the batteries. Since the majority of "12 volt" panels emit between 16 and 20 volts, the batteries would be overcharged and suffer damage. Most batteries need a voltage of between 14 and 14.5 volts to fully charge. Usually, though not always. The panels, such as 1 to 5-watt panels, typically do not require a charge controller [20]. A general guideline is that you do not need one if the panel produces 2 watts or less than that, for every 50-battery amp-hours. There are different types, sizes, features, and price points for charge controls. From the modest, SunGard can be controlled up to 60 to 80 amps, and MPPT programmable controllers with computer interfaces are available. Two or more 40 to 80 amps units are frequently connected in parallel when currents greater than 60 amps are needed. Although many of the more contemporary MPPT controls, like outback power Flomax, can handle up to 80 amps, all battery-based systems normally use controllers in the range of 4 to 60 amps [21].

2.5. Batteries

The system's electrical output needs to be fully utilized or stored, whichever comes first. It is not feasible to fully use all of the energy produced by the system at all times [22]. Therefore, it ought to be kept rather than squandered. Electrical batteries are the most practical, cost-efficient, and efficient means to store electrical energy in the form of a chemical reaction [23]. Therefore, batteries are preferred. The planned project's energy output should be preserved, and then you require two batteries. One is connected to a wind turbine and requires a 120-amp battery to meet the target with sufficient storage capacity. A second 80-amp battery is good for storing solar energy [24], [25]. However, depending on your application/storage and needs, the battery capacity is variable.

3. WORKING

- Wind and solar are renewable energy sources, are now chosen for power generation in order to reduce pollution and preserve non-renewable energy resources like coal and petroleum. Hybrid power systems, which combine renewable energy sources, may also be utilized to produce electricity. In this essay, we'll talk specifically about how a solar-wind hybrid system operates.
- Electricity is produced by tiny wind turbine generators and solar panels in hybrid power systems. These solar-wind hybrid systems often have limited capacities. Solar wind hybrid systems typically have power generating capacity between 1 kW and 10 kW. Before briefly describing the solar and wind hybrid power system, it is important to understand how solar power generation and wind power generation work.
- Watts or kilowatts are the units used to measure the electric power produced by solar panels. There are several output ratings available for these solar panels, including 5, 10, 20, and 100 watts. As a result, we may choose an appropriate solar panel depending on the required output power.
- The solar photovoltaic (SPV) effect uses a collection of solar panels to convert solar energy into DC power. This DC electricity may be utilized to power AC loads by using an inverter, which converts DC current into 120-volt AC current. It can also be stored in the batteries seen in the image.

- Wind energy is one of the renewable energy sources that may be utilized to generate electricity using wind turbines and generators. It is possible to produce electricity using wind turbines, supply mechanical power with windmills, pump water using wind pumps, and more with the use of wind energy.
- Electricity may be produced by large wind turbines that are designed to revolve along with the wind. When a generator is connected to the electricity grid, the lowest wind speed needed is referred to as the cut in speed, and when it is disconnected from the grid, the highest wind speed needed is referred to as the cut off speed. Typically, the speed range where wind turbines operate is between the cut in and cut off speeds.

Figure 2 shows the hardware model of hybrid renewable energy systems. It is a combination of solar photovoltaic cells and vertical wind turbines, which provides continuous power supply with the help of batteries and inverters. The hardware components of a hybrid renewable energy system are typically interconnected through control and monitoring systems to optimize energy generation, storage, and distribution. A hardware model of a hybrid renewable energy system typically involves the integration of multiple renewable energy sources and energy storage systems to meet the energy demands of a particular application.

Figure 2. Hardware model of hybrid renewable energy system

4. RESULTS AND DISCUSSION

As a result, the system's experiment results were carried out by mounting it on a rooftop (refer Figure 3). From 10:00 am to 5:00 pm, the table which is shown above indicates the output values at different time internals. The tabular column (refer Table 1) and graphical representation (refer Figure 4) shows the performance of solar energy at different time intervals in a day.

Figure 3. Prototype testing

Table 1. Performance of solar panel

Time (Hours)	Voltage (V)	Current (A)	Power (W)
10 am	14	0.98	13.72
11 am	18.5	1.4	25.9
12 pm	20	1.54	30.8
01 pm	23.5	1.66	39.01
02 pm	25	1.7	42.5
03 pm	24.5	1.68	41.16
04 pm	17.5	1.3	22.75
05 pm	12	0.81	9.72

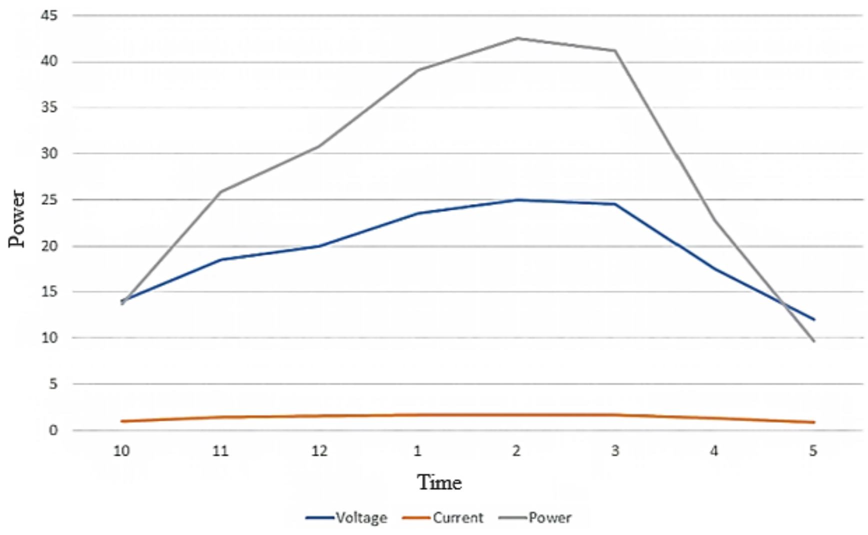

Figure 4. Graphical representation of solar panel

The output values at various time intervals are presented in above table. For solar panels, the average power generated is 18.5 W. And the efficiency obtained is 98.66%. Solar panels offer greater output power and present an effective system to collect solar energy. At 2 o'clock, the solar panel reached their peak power, voltage and current outputs. From 10:00 am to 2:00 pm, power is growing with increase in time. From 2:00 pm to 5:00 pm, power is reducing again. At noon, the power reaches its peak value, which is 42.5 W for performance of solar panels.

The tabular column (refer Table 2) and graphical representation (refer Figure 5) shows the performance of wind energy at different time intervals in a day. The output values at various time intervals are presented in Table 2. For wind turbines, the average power generated is 3.106 W. And the efficiency obtained is 40.33%. Wind turbines offers greater output power and presents an effective system to collect wind energy. At 2 o'clock, the wind turbines reached their peak power, voltage, and current outputs. From 10:00 am to 2:00 pm, power is growing with increase in time. From 2:00 pm to 5:00 pm, power is reducing again. At noon, the power reaches its peak value, which is 4.2 W for performance of wind turbine.

From Figure 5, individual outputs of solar and wind, the observation is that, the average power generated by solar panels is more as compared to wind turbines. That is, average power of solar is 18.5 W which is greater than 3.106 W (average power of wind). Also, the efficiency is also more in solar panel when compared to wind turbine. The tabular column (refer Table 3) and graphical representation (refer Figure 6) shows the performance of hybrid source energy at different time intervals in a day.

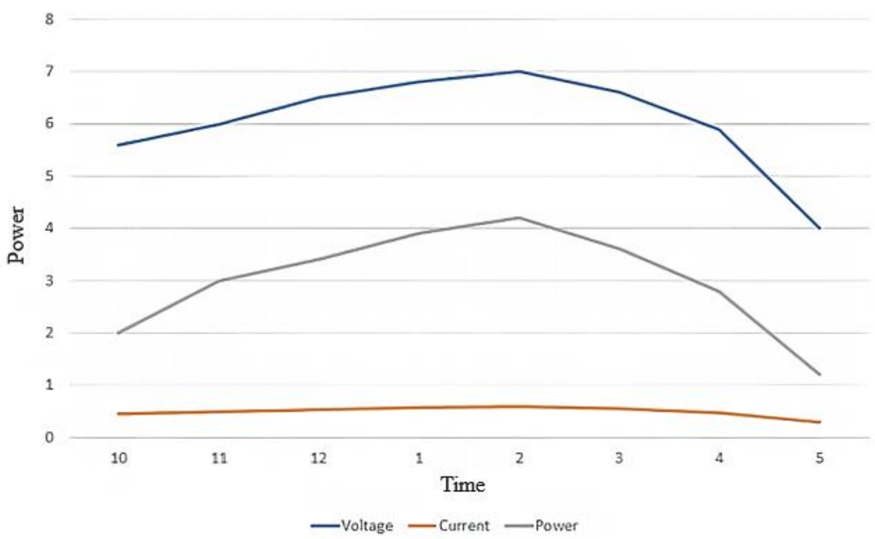

Figure 5. Graphical representation of wind

Table 2. Performance of wind

Time (Hours)	Voltage (V)	Current (A)	Power (W)
10 am	5.6	0.45	2.52
11 am	6.0	0.5	3.0
12 pm	6.5	0.53	3.445
01 pm	6.8	0.58	3.944
02 pm	7.0	0.6	4.2
03 pm	6.6	0.55	3.63
04 pm	5.9	0.48	2.832
05 pm	4.0	0.3	1.28

Table 3. Performance of hybrid system

Time (Hours)	Voltage (V)	Current (A)	Power (W)
10 am	28	1.9	53.2
11 am	29.5	2.05	60.47
12 pm	30.2	2.07	62.51
01 pm	30.8	2.15	66.22
02 pm	31	2.17	67.27
03 pm	30.5	2.11	64.35
04 pm	28.1	2.01	56.48
05 pm	27	1.7	45.9

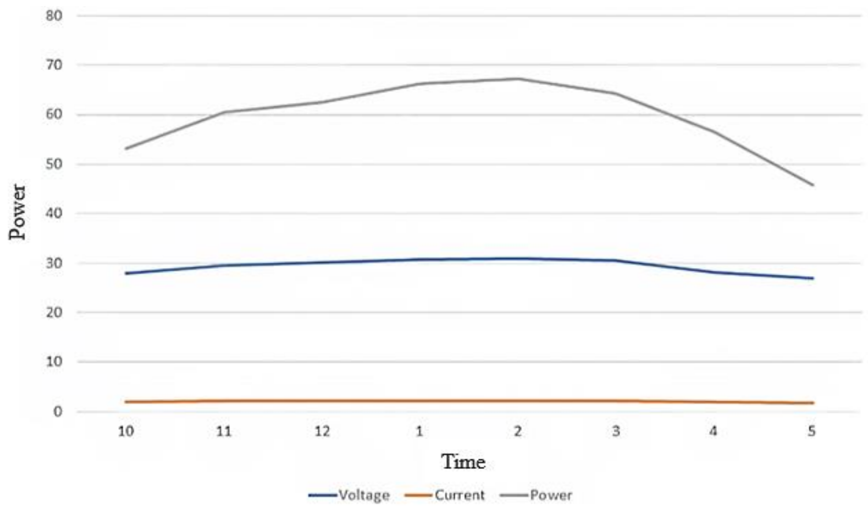

Figure 6. Graphical representation of hybrid system

The output values at various time intervals are presented in above table. For hybrid systems, in which the combination of solar and wind exist. The average power generated is 56.55 W and the efficiency obtained is 70.59%. On comparing with the individual solar and wind outputs, the hybrid system provides maximum output power on average. At 2 o'clock, the hybrid system reached their peak output power. From 10:00 am to 2:00 pm, power is growing with increase in time. From 2:00 pm to 5:00 pm, power is reducing again. At noon, the power reaches its peak value, which is 67.27 W for performance of hybrid systems. Though the individual efficiency of solar is more than efficiency of hybrid systems. There is a need of hybrid systems because, as solar can't work throughout the day and nights, the combination of solar and wind provides necessary output power. Also, the wind power depends on the speed of turbines. So, the efficiency obtained here is not constant. It may be high during high winds. Thus, the hybrid system provides maximum output power i.e., nearly 60 W and efficiency of 70%.

5. CONCLUSION

Renewable energy is now one of the finest, if not the only, possibilities for delivering power in isolated areas or at specific distances from the grid. Indeed, renewable energy sources are already making a significant contribution to the achievement of important economic, environmental, and social goals by enhancing the security of the energy supply, reducing greenhouse gases and other pollutants, and creating local employment, which enhances overall social welfare and living conditions. In order to provide energy services with high-quality to rural regions at the lowest possible cost and with the most possible environmental and social advantages, hybrid systems have shown to be the ideal solution. In fact, developing nations may reduce their CO_2 emissions while boosting consumption due to economic and emotional benefits by embracing renewable energy.

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BIOGRAPHIES OF AUTHORS

Dr. Mugachintala Dilip Kumar Currently working as associate professor at Department of Electrical and Electronics Engineering, MLR Institute of Technology, Dundigal, TS, India and obtained his B.Tech. in Electrical and Electronics Engineering from AITS, Rajampet, M.Tech. and Ph.D. from JNTUA College Engineering, JNTU University Anatapuram. He published 10 international journals and 10 national and international conferences. Area of interest are power system stability, application of FACTS devices in transmission and distribution systems, power system stability studies, real time application of power system studies with soft computing techniques. He can be contacted at email: mdk206@gmail.com.

Mrs. D. Himabindu currently pursuing Ph.D. in the Department of Electrical and Electronics Engineering, JNTUA University, Anantapur and also working as an Assistant Professor in the Department of Electrical and Electronics Engineering at SOET, Sri Padmavati Mahila Visvavidyalayam, Tirupati AP, India. She published 8 international journals and attended 2 IEEE conferences. Her research interests include power electronics, electrical machines and modelling and analysis of AC-drives. She is a life-member of 'ISTE'. She can be contacted at email: sribindu262004@gmail.com.

Dr. Yarrem Narasimhulu Vijaya Kumar is a professor of Electrical and Electronics Engineering department in SVCET (autonomous), Chitoor. He obtained his B.E. in Electrical and Electronics Engineering from GITAM Visakapatnam, M.E. in Power Electronics and Industrial Drives from Sathyabama University, Chennai. He had received his Ph.D. degree in the area of power systems from JNTUK University, Kakinada. He has published over 32 technical papers in national and international journals as well as 9 patents published in national levels. He is a life member of Indian Society of Technical Education and life members of International Association of Engineers. He has published text book on hybrid electric vehicles principles and applications. He can be contacted at email: yn.vijaykumar@gmail.com.

Thota Mohana currently pursuing B.Tech. in Department of Electrical and Electronics Engineering in MLR Institute of Technology, Dundigal, Hyderabad, India. She has actively engaged in the national initiative of Smart India Hackathon and has efficaciously presented a groundbreaking concept-"LI-FI called as Light Fidelity". Moreover, she has undertaken diverse projects, including the development of an automatic street light system. Her areas of expertise and keen interests revolve around the domains of power electronics and semiconductor devices. She can be contacted at email: mohanathota79@gmail.com.

Ramagiri Shashank currently pursuing B.Tech. in Department of Electrical and Electronics Engineering in MLR Institute of Technology, Dundigal, Hyderabad. He did his Diploma in Department of Electrical and Electronics Engineering at Government Polytechnic Warangal, State Board of Technical Education and Training, Telangana, India. He did his research projects on energy transformation devices, internet of things. His current research focuses on renewable sources and power electronics devices. He can be contacted at email: ramagirishashank4@gmail.com.

Dr. Bodapati Venkata Rajanna received B.Tech. degree in Electrical and Electronics Engineering from Chirala Engineering College, JNTU, Kakinada, India, in 2010, M.Tech. degree in Power Electronics and Drives from Koneru Lakshmaiah Education Foundation, Guntur, India, in 2015 and Ph.D. in Electrical and Electronics Engineering at Koneru Lakshmaiah Education Foundation, Guntur, India, in 2021. Currently, he is working as an Associate Professor at MLR Institute of Technology, Hyderabad. His current research includes, dynamic modeling of batteries for renewable energy storage, electric vehicles and portable electronics applications, renewable energy sources integration with battery energy storage systems (BESS), smart metering and smart grids, micro-grids, automatic meter reading (AMR) devices, GSM/GPRS, and power line carrier (PLC) communication and various modulation techniques such as QPSK, BPSK, ASK, FSK, OOK, and GMSK. He can be contacted at email: rajannabv2012@gmail.com.