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A Smart Hybrid System Combining Wind and Solar Power with a Fuel Cell Along with Solar Tracking and Panel Cleaning Syste.

Shreyash S. Narole[1], Vipul D. Dekate[2], Arnav A. Pakhale[3], Rohini R. Dhawale[4], Achal B. Jangade[5], Dr. Aniket P. Munshi[6]

Students, Department of Electrical Engineering[1,2,3,4,5]

Guide, Department of Electrical Engineering[6]

Yeshwantrao Chavan College of Engineering, Nagpur, India

Abstract: *Access to electricity in non-electrified rural areas remains a significant challenge due to the limitations and infeasibility of extending the conventional grid. Additionally, escalating oil prices and the adverse effects of conventional energy sources on users and the environment are phasing out traditional solutions like fuel genset based systems from rural development agendas. To address this issue, this paper proposes a solution: "Hybrid Power Generation Using Solar and Wind Energy with Hydrogen Fuel Cell." Hybrid systems have demonstrated their potential as the optimal choice for delivering high-quality power. This study explores the potential of harnessing solar and wind energy in tandem with hydrogen fuel cells to create a reliable and sustainable energy solution for rural areas. By integrating renewable energy sources, the hybrid system mitigates the challenges posed by the unavailability of grid connectivity, economic constraints, and environmental concerns. In conclusion, hybrid power generation using solar and wind energy with hydrogen fuel cell technology presents a promising solution to reach non-electrified rural populations. This innovative approach addresses the limitations of conventional grid extension and fossil fuel-based systems, offering a pathway towards sustainable rural electrification, economic growth, and environmental conservation.*

Keywords: Sustainable electrification, Economic growth, Environmental conservation, Escalating oil prices

I. INTRODUCTION

A smart hybrid system combining wind and solar power with a fuel cell, along with solar tracking and panel cleaning systems, is an innovative and sustainable approach to power generation. By integrating multiple renewable energy sources, such as wind turbines and solar panels, with a fuel cell technology, this system maximizes energy efficiency and minimizes reliance on non-renewable energy resources. Additionally, the inclusion of solar tracking technology ensures optimal solar energy capture by adjusting the angle and position of solar panels throughout the day. Furthermore, a panel cleaning system helps maintain the performance of the solar panels by removing dirt and debris that may hinder their efficiency. This smart hybrid system offers an eco-friendly and reliable solution for various applications, promoting energy security, reducing emissions, and contributing to a greener future.

II. LITERATURE SURVEY

Once the necessities for the task are known, the next step is to analyze the unruled and comprehend its framework. This phase involves two main activities: studying the present system and understanding the rations and domain of the new system. While both events are alike vital, the first activity provides the foundation for establishing functional specifications and successfully designing the proposed system. Understanding the properties and requirements of a new system can be challenging and needs artistic thinking and understanding.Also, comprehending an present system can be difficult, and a lack of proper understanding can lead to a aberration from the solution. To design the planned system, we have shown research paper analysis as part of the process.

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[1] "Design and optimization of a smart hybrid renewable energy system" by S. Rahman et al. (2019):
This study presents the design and optimization of a smart hybrid system integrating wind turbines, solar panels, a fuel cell, and battery storage. The authors analyze the system performance under different scenarios and propose an optimization algorithm to achieve cost-effective operation.
[2] "Techno-economic analysis of a smart hybrid system for residential applications" by M. Azadeh et al. (2020):
The research investigates the techno-economic feasibility of a smart hybrid system for residential applications. The study considers wind and solar resources, along with a fuel cell and battery storage, and analyzes the system's economic viability, levelized cost of electricity, and payback period.
[3] "Modeling and control of a wind-solar-fuel cell hybrid power system" by M. Chen et al. (2018):
This study focuses on the modeling and control of a wind-solar-fuel cell hybrid power system. The authors propose a control strategy to optimize the power flow among the renewable sources, fuel cell, and battery storage, aiming to improve system efficiency and stability.
[4] "Performance analysis of a smart hybrid renewable energy system with solar tracking and cleaning mechanism" by K. Pandit et al. (2020):
The research investigates the performance of a smart hybrid system with solar tracking and panel cleaning mechanisms. The authors evaluate the energy generation, efficiency, and cleaning effectiveness, highlighting the benefits of solar tracking and panel cleaning in enhancing system performance.
[5] "Environmental impact assessment of a smart hybrid system combining wind, solar, and fuel cell technologies" by N. Gupta et al. (2019):
This study assesses the environmental impact of a smart hybrid system through life cycle assessment (LCA). The authors evaluate greenhouse gas emissions, energy consumption, and other environmental indicators to quantify the environmental benefits of the system.

III. PROPOSED HARDWARE

1. Arduino uno R3

The Arduino Uno R3 is an upgraded version of the Arduino Uno microcontroller. It is based on the same ATmega328P chip as the unique Uno, but it contains new features and improvements. The board takes 14 digital input/output pins, 6 analog inputs, a USB linking, a power knave. The R3 version also has a retune button and a new header pin layout, making it easier to connect additional modules and shields. One of the key benefits of the Arduino Uno R3 is itschallenging and needs artistic thinking and understanding. compatibility with a wide range of shields and modules, allowing users to add new functionalities to their projects with ease. The R3 version is also backward compatible with the original Uno, so users can continue to use their remaining projects and amors without any adjustments. The Arduino Uno R3 is user-friendly and flexible. It is programmed using the Arduino Combined Development Environment (IDE), which ropes C and C++ software design languages.

Figure 3.1 Arduino uno R3 ATmega328p

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2.Mppt solar charge controller

An MPPT (Maximum Power Point Tracking) solar charge controller is a device used in solar power systems to optimize the charging efficiency of batteries from solar panels. It is designed to track and extract the maximum available power from the solar panels and deliver it to the batteries for charging.Solar panels produce electricity in direct current (DC), but batteries and most appliances require alternating current (AC) or a regulated DC voltage. The MPPT controller's primary function is to maximize the power harvested from the solar panels.The solar charge controller takes the higher voltage DC power generated by the solar panels and converts it to the required voltage for charging the batteries. This conversion is important because solar panels often operate at higher voltages than batteries.Once the MPPT controller determines the maximum power point, it regulates the charging process to match the battery's requirements. It monitors the battery voltage and temperature to prevent overcharging or undercharging, ensuring the batteries are charged safely and efficiently.

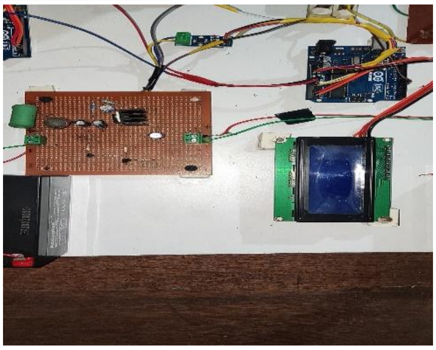

Figure 3.2 Mppt based solar charge controller

3. Wind charge controller

A wind charge controller is a device used in a wind power system to regulate and control the charging of batteries or the power output to the grid from wind turbines. It acts as an intermediary between the wind turbine and the battery bank or grid, managing the flow of energy to ensure safe and efficient operation The primary function of a wind charge controller is to regulate the charging process of batteries. It monitors the battery voltage and adjusts the charging current from the wind turbine to prevent overcharging or undercharging, thus optimizing battery performance, and extending its lifespan.Overall, a wind charge controller plays a critical role in the safe and efficient operation of wind power systems by regulating battery charging, protecting components, optimizing power flow, and providing monitoring and control features

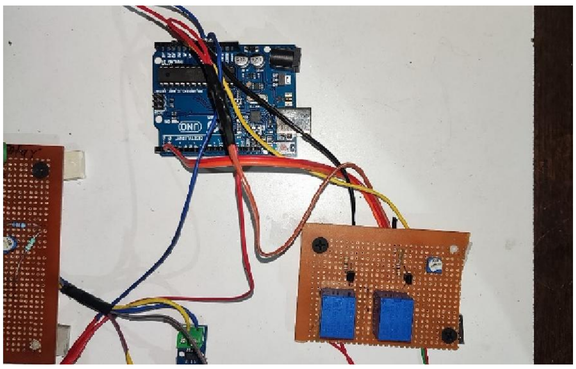

Figure 3.3 Wind charge controller

4. Boost converter

A boost converter, also known as a step-up converter, is a type of DC-DC converter that increases the voltage level from a lower value to a higher value. It is commonly used in various electronic systems to efficiently step up the voltage of a power source to match the requirements of a load or to store energy in a higher voltage battery.

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The basic operation of a boost converter involves the use of an inductor, a switch (typically a transistor), a diode, and a capacitor. When the switch is closed, current flows through the inductor, storing energy in its magnetic field. When the switch is opened, the energy stored in the inductor is released, causing the voltage across the inductor to rise. The diode prevents the current from flowing back to the input source, and the capacitor filters the output voltage.

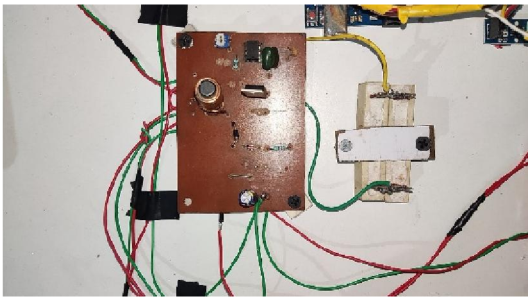

Figure 3.4 Boost converter

The specification of the DC-DC boost converter are

1. Module properties : non-isolated constant voltage module
2. Rectification : non-synchronous rectification
3. Input Voltage : 0V-35V
4. Output Current : 3A maximum
5. Output Voltage : 1.3V-30V
6. Conversion efficiency : 92% (maximum)
7. Switching frequency : 150KHz
8. Output ripple : 50mV (maximum) 20M-bandwidth
9. Load regulation : ± 0.5 %
10. Voltage regulation : ± 2.5%
11. Operating temperature : -40 °C to +85 °C
12. Size : 48x23x14 mm

5. Buck converter (LM2956)

The LM2596 is a popular buck converter integrated circuit (IC) manufactured by Texas Instruments. It is designed to efficiently step-down voltage from a higher input voltage to a lower output voltage. The LM2596 operates as a switch-mode power supply, offering high conversion efficiency and regulated output voltage. The LM2596 can handle a wide range of input voltages, typically up to 40V. The output voltage can be adjusted using external resistors or potentiometers to meet specific application requirements. The LM2596 allows for adjustable output voltage through external components. By selecting appropriate resistors or potentiometers, the output voltage can be set to the desired value within the operating range. The LM2596 is commonly used in various applications such as power supplies, battery chargers, LED drivers, and other low-voltage systems. Its efficiency, adjustable output voltage, and built-in protection features make it a popular choice for voltage step-down applications

Figure 3.5 LM2956 Buck converter

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6.LDR Module

LDR sensor module is a low-cost digitalsensor as well as analogsensor module, which is capable to measure and detect light intensity. This sensor also is known as the Photoresistor sensor. This sensor has an onboard LDR (Light Dependent Resistor), that helps it to detect light. This sensor module comes with 3 terminals. Where the "DO" pin is a digital output pin and the "AO" pin is an analog output pin. The output of the module goes high in the absence of light and it becomes low in the presence of light. The sensitivity of the sensor can be adjusted using the onboard potentiometer.

Figure 3.6 LDR Module

7. Current sensor

Sensing variable current flow is a major requirement in frequent electronics systems and the strategies to do so are as an assortment of the applications themselves. A sensor is a unit that can determine a physical phenomenon and compute the latter, in other words, it gives a measurable demonstration of the wonder on a particular scale or range. A current sensor is a device that recognizes electrical current in a wire or a system whether it is high or low and creates an indicator relative to it. It might be then used to presentation the measured current in an ammeter or might be archived for further classification in a data acquisition system or might be used for control purposes. The current sensor is "disturbing" as it is an incorporation of some of the sensors, which may cause system performance.

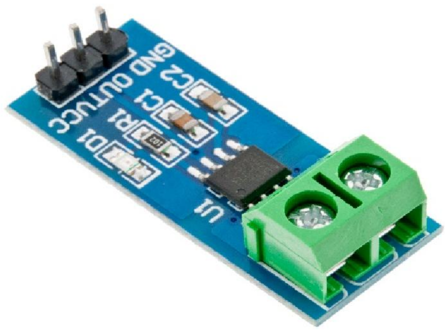

Figure 3.7 Current sensor

8.Servo motor

A servo motor is a rotary actuator that allows for precise control of angular position. It is a closed-loop system, meaning it continuously receives feedback on its current position and adjusts its operation to reach and maintain the desired position. Servo motors are commonly used in applications that require accurate and controlled motion, such as robotics, industrial automation, CNC machines, and remote-controlled devices. They offer high precision, variable speed and torque capabilities, and are typically paired with a servo drive to provide the necessary control signals and power.

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Figure 3.8 Servo motor

9.DC motor

A DC motor is any of a class of rotary electrical machines that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current flow in part of the motor.

DC motors were the first type widely used, since they could be powered from existing direct-current lighting power distribution systems. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings. Small DC motors are used in tools, toys, and appliances.

Figure 3.9 Motor

10. Solar panel

Solar panels, also known as photovoltaic (PV) panels, are devices that convert sunlight into electricity. They are made up of individual solar cells, which are typically made of silicon or other semiconducting materials.When sunlight hits the solar cells, the photons (particles of light) transfer their energy to the electrons in the semiconductor material, causing them to become energized. This generates a flow of direct current (DC) electricity within the solar cells. To make this electricity usable in homes and businesses, the DC electricity generated by solar panels is usually converted into alternating current (AC) electricity using an inverter. AC electricity is the type of electricity commonly used in buildings and appliances. Solar panels can be installed on rooftops, ground-mounted structures, or integrated into building materials like solar tiles or solar shingles. They require exposure to sunlight to generate electricity effectively, so their placement is important to maximize their energy production.

Figure 3.10 Solar panel

Specification of the solar panel:

1. Material : Silicon
2. Wattage : 10W

3. Type : Polycrystalline
4. No of Cells : 64
5. Output Voltage : 21.5V
6. Short circuit current: 0.65A
7.voltage at maximum power: 17.5 V
8. Current at max. Power: 0.58 A
9. Tollerance : 5%

11. DC submersible pump-

The DC-1020 is a simple and practical 5.5V-12V DC 3W mini adjustable water pump, which is designed fully submersible in fresh water and salt water

DC submersible pumps are commonly used in solar panel cleaning systems to circulate water for cleaning purposes. These pumps are ideal for such applications because they can be powered directly by the solar panels themselves, eliminating the need for an additional power source or inverter.

Figure 3.11 DC submersible pump

12.LCD display-

I2C_LCD is an easy-to-use display module, It can make display easier. Using it can reduce the difficulty of make, so that makers can focus on the core of the work. We developed the Arduino library for I2C_LCD, user just need a few lines of the code can achieve complex graphics and text display features.

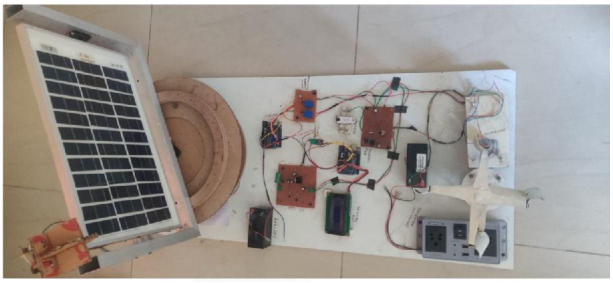
Figure 3.12 LCD Display

IV. WORK DONE

A smart hybrid system combining wind and solar power with a fuel cell, along with solar tracking and panel cleaning systems, can provide a reliable and efficient renewable energy solution. Let's break down each component and discuss their benefits.

- Wind Power: The system incorporates a wind turbine to harness wind energy. Wind power can generate electricity when there is sufficient wind speed. Wind turbines are most effective in areas with consistent wind patterns and can complement solar power by producing electricity during periods of low solar generation, such as at night or on cloudy days.
- Solar Power: Solar panels are utilized to convert sunlight into electricity. Solar power is a clean and abundant energy source, making it an excellent choice for renewable energy generation. By harnessing solar energy, the system can generate electricity during the day, reducing reliance on other energy sources.
- Fuel Cell: A fuel cell is an electrochemical device that converts the chemical energy of a fuel, such as hydrogen, into electricity. It can be integrated into the system as a backup power source or to provide continuous power during periods of low wind and solar energy production. Fuel cells are efficient and produce electricity with minimal emissions, offering a clean and reliable energy option.
- Solar Tracking: Solar tracking systems ensure that solar panels follow the movement of the sun throughout the day. By tracking the sun's position, solar panels can maximize their exposure to sunlight, optimizing energy generation. This technology enhances the overall efficiency of the solar power component in the hybrid system.
- Panel Cleaning System: Solar panels can accumulate dirt, dust, and debris over time, reducing their efficiency. To maintain optimal performance, a panel cleaning system can be integrated into the hybrid system. This system may use automated or manual methods, such as robotic cleaners or water sprays, to remove contaminants and keep the solar panels clean.
- The benefits of combining these components into a smart hybrid system include:
- Increased Reliability: By integrating multiple renewable energy sources and a fuel cell backup, the system becomes more reliable. It can provide a continuous power supply, even during periods of low wind or solar availability.
- Enhanced Efficiency: Solar tracking systems improve the efficiency of solar panels by maximizing their exposure to sunlight. Additionally, regular panel cleaning ensures optimal performance by minimizing losses caused by dirt and debris.
- Reduced Environmental Impact: The system relies on clean, renewable energy sources, such as wind and solar power, which significantly reduce greenhouse gas emissions compared to traditional fossil fuel-based power generation. The use of a fuel cell also contributes to cleaner energy production.
- Cost Savings: By utilizing renewable energy sources and reducing dependence on traditional energy grids, the smart hybrid system can lead to long-term cost savings. Over time, the system can pay for itself through reduced electricity bills and potentially generate excess electricity that can be sold back to the grid.

Overall, a smart hybrid system combining wind and solar power with a fuel cell, along with solar tracking and panel cleaning systems, offers a sustainable and efficient solution for generating renewable energy while ensuring a reliable power supply



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V. BLOCK DIAGRAM-

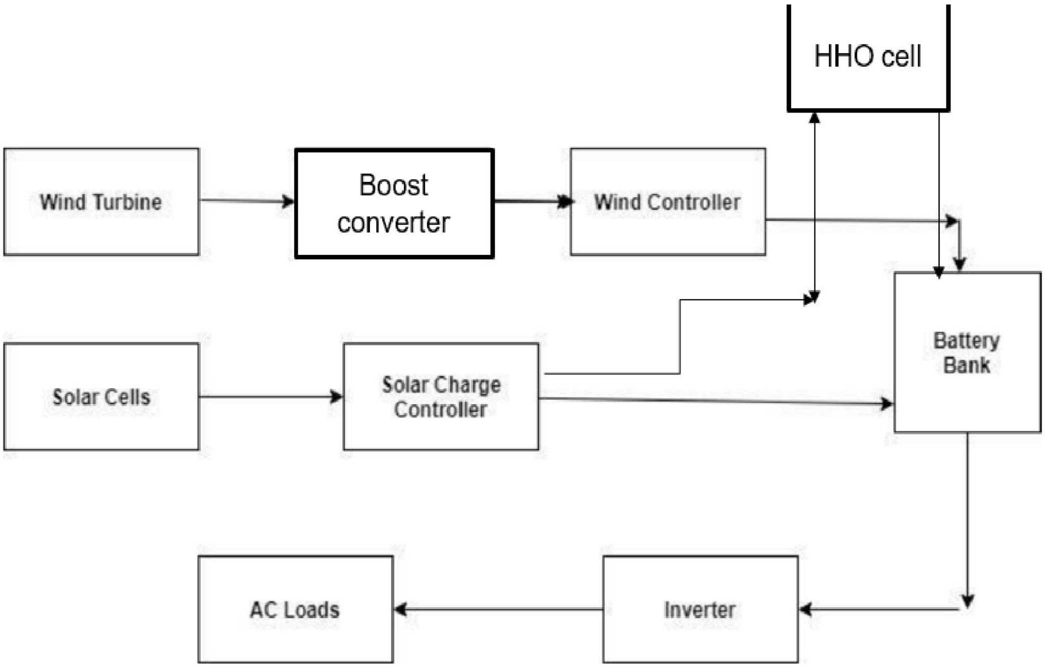

Figure 3.11 block diagram of the smart hybrid system

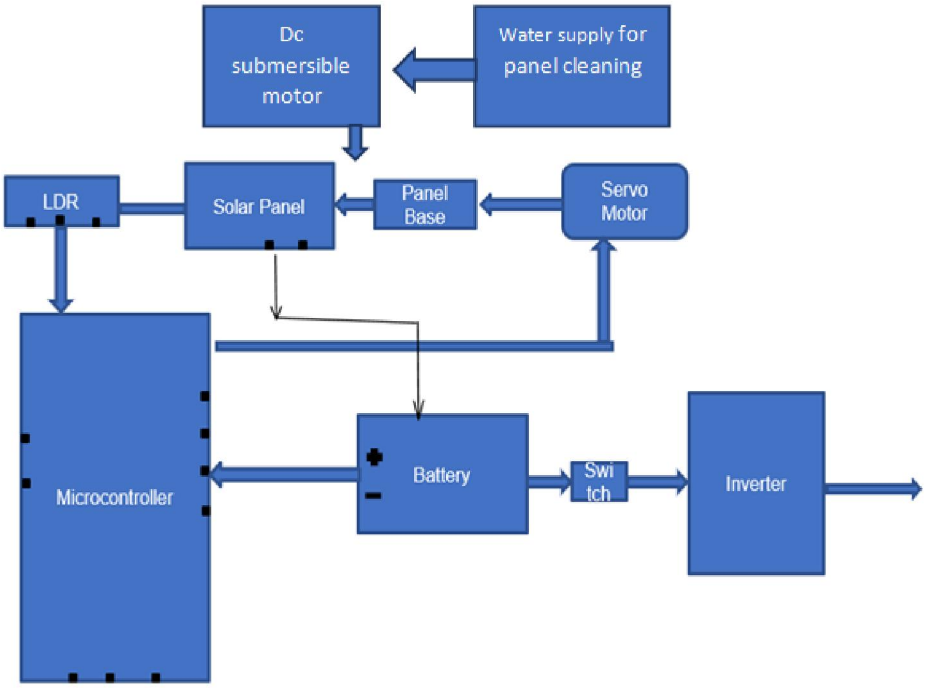

Figure 3.12 block diagram of the solar tracking system and panel cleaning system

VI. CONCLUSION-

In conclusion, a smart hybrid system combining wind and solar power with a fuel cell, along with solar tracking and panel cleaning systems, offers numerous benefits and opportunities in the renewable energy sector. This integrated system harnesses the complementary nature of wind and solar energy sources while utilizing a fuel cell for clean energy generation and storage. The inclusion of solar tracking and panel cleaning systems further enhances the efficiency and performance of the overall system.

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The combination of wind and solar power allows for a more consistent and reliable energy generation, as the variations in one energy source can be compensated by the other. The addition of a fuel cell provides a clean and sustainable source of energy with minimal environmental impact. It offers a means for energy storage and can provide backup power during periods of low renewable energy generation.

Solar tracking systems ensure that the solar panels are always aligned with the sun's position, maximizing solar energy capture and increasing overall energy output. Panel cleaning systems help maintain the efficiency of the solar panels by removing dust, debris, and other contaminants that may accumulate over time.

The smart hybrid system offers several advantages, including reduced dependence on non-renewable energy sources, minimized fuel emissions, increased eco-efficiency, and enhanced energy security. It promotes the optimal utilization of renewable energy resources and contributes to a cleaner and more sustainable energy future.

The future scope of this system lies in advancements in control systems, energy storage technologies, solar tracking mechanisms, panel cleaning techniques, and grid integration. Ongoing research and development efforts are focused on improving efficiency, reliability, and cost-effectiveness of the system, making it more accessible and commercially viable.

Overall, a smart hybrid system combining wind and solar power with a fuel cell, along with solar tracking and panel cleaning systems, presents a compelling solution for clean and efficient energy generation. Its integration of multiple renewable energy sources and innovative technologies paves the way for a greener and more sustainable energy landscape.

VII. FUTURE SCOPE-

- Advanced Control Systems: Further advancements can be made in the control algorithms used in the hybrid system. This includes the development of more sophisticated control strategies that optimize the power generation, storage, and distribution within the system. Intelligent algorithms can be implemented to enhance the efficiency and reliability of the system.
- Energy Storage Optimization: The integration of advanced energy storage technologies can improve the performance and reliability of the hybrid system. The future scope involves the development of more efficient and cost-effective energy storage solutions, such as advanced batteries or other emerging energy storage technologies. This would enable better management of fluctuating renewable energy sources and ensure a more stable power supply.
- Enhanced Solar Tracking Systems: The future scope includes the development of more efficient and accurate solar tracking mechanisms. Advanced tracking algorithms, sensors, and actuators can be implemented to maximize solar energy capture by precisely aligning the solar panels with the sun's position throughout the day. This would result in increased energy generation and improved system performance.
- Improved Panel Cleaning Techniques: Research and development can focus on developing innovative and automated panel cleaning techniques. This includes the use of advanced cleaning mechanisms such as robotic systems, self-cleaning coatings, or automated water-based cleaning systems. Efficient and reliable panel cleaning would ensure optimal performance and longevity of the solar panels.
- Integration of Internet of Things (IoT) and Data Analytics: The future scope involves the integration of IoT technology and data analytics to enhance the monitoring, control, and optimization of the hybrid system. Real-time data collection, analysis, and predictive maintenance can be employed to optimize system performance, identify faults or inefficiencies, and enable remote monitoring and control.
- Hybrid System Scalability and Grid Integration: Future developments can focus on designing scalable hybrid systems that can be easily expanded or modified based on energy requirements. Integration with the existing power grid infrastructure can also be explored, allowing for bidirectional energy flow and improved grid stability through energy exchange.
- Environmental Sustainability and Life Cycle Analysis: The future scope includes conducting comprehensive life cycle assessments to evaluate the environmental impact of the hybrid system. This analysis would consider

factors such as embodied energy, carbon footprint, and waste management, enabling the development of more environmentally sustainable solutions.

- Cost Reduction and Commercial Viability: Ongoing research and development efforts aim to reduce the overall costs associated with the hybrid system components, installation, and maintenance. Future scope involves exploring cost-effective materials, manufacturing processes, and system designs to make the technology more economically viable and accessible.

The future scope of a smart hybrid system combining wind and solar power with a fuel cell, solar tracking, and panel cleaning systems is focused on improving efficiency, reliability, and sustainability. Ongoing advancements in control systems, energy storage, tracking mechanisms, panel cleaning techniques, data analytics, and grid integration will contribute to the continued growth and adoption of this technology in the renewable energy sector.

Societal relevance-

Undistributed supply of energy: -

When combining solar, wind and storage, there are other factors that come into play depending on the blend of local conditions of sun, wind, rain, clouds, etc. When the sun is strong and temperatures are high, wind tends to be weak. Conversely, when wind is strong and skies are cloudy with rain and moisture, sunlight is minimal. Therefore, a combination of wind and solar will likely increase energy production during any cycle. Solar power is low in density, requiring large surface areas. Installations require site improvements and lengthy transmission lines. Solar systems are not portable and in order to maximize energy capture throughout the day and over the seasons, must incorporate azimuth tracking at additional expense. If not, then seasonal performance will vary, and customer needs may be curtailed.

Minimize use of fossil fuel: -

Oil, gas, and other fossil fuels come with grave consequences for our health and our future. Digging these fuels out of the ground turns people's backyards and treasured wild places into industrial zones, and burning them causes climate change as well as contributes to asthma, heart disease, and cancer.The critical element will be the development of renewable energy technology that is inexpensive and reliable. The current technologies work but have limits. They also are being subjected to disinformation campaigns fuelled in part by Donald Trump's long-standing hatred of windmills

Economical advantage:-

Landowner Income

Renewable energy also provides an additional source of income for rural landowners and farmers. According to data from the American Wind Energy Association (AWEA), wind farms in the U.S. provide around $222 million every year to rural landowners who host wind farms on their property. Farmers can also make money growing crops to be used as biofuels. Corn ethanol is currently the main avenue by which farmers participate in the energy sector, but other biofuels are starting to get more attention.

Reduced Energy Costs

Switching to renewable energy is an excellent way for residential, commercial, and industrial energy customers to save money on their bills. Installing solar panels on your property allows you to generate your own electricity, theoretically giving you the ability to reduce your energy bill to zero. The exact amount you save depends on many factors, including where you live. According to Energy Sage, the average savings range from $10,483 in Washington to $30,523 in Massachusetts.

Increased Property Value

Installing renewable energy equipment on your property can help increase its value significantly. If you install solar panels on your house, for example, its value rises by approximately $20 for every dollar you save on energy bills. Homeowners may be able to recoup a significant amount of the cost of installing their solar modules when they sell their house. Adding solar panels to your home may also help you sell it faster.

Energy Independence

Using more renewable energy could help the United States achieve energy independence — the ability to meet energy needs domestically, thereby reducing dependence on foreign nations and susceptibility to changing overseas energy prices. Increasing the amount of renewable energy in the U.S. mix could further reduce reliance on foreign oil. Plus, renewable energy resources don't run out, so the country could count on that independence over the long term.

Stable Energy Prices

Installing renewable energy facilities requires a substantial upfront investment, but after installation, they are cheap to operate. This is in large part because they don't require you to purchase fuel. Eliminating fuel costs lowers the cost of the electricity produced. It also means the price of electricity isn't susceptible to changes in the price of fuels, like it is with natural gas or coal. This may lead to more stable energy prices over the long term.

Avoidance of Climate Impacts

According to a recent report from the Universal Ecological Fund, climate change has cost the U.S. economy around $240 billion per year over the last 10 years. Another report, the Fourth National Climate Assessment, which was authored by climate scientists from 13 U.S. federal agencies, found that the U.S. economy will contract by up to 10 percent by the end of the century if climate change continues at its current pace. These economic losses are the result of extreme weather events, worsened air quality, rising sea levels and other effects. Switching from fossil fuels to renewables could help slow down climate change and avoid some of these potential economic losses.

There are many reasons why using more renewable energy and less fossil fuel is beneficial. It's better for the environment and human health, and it also has many positive economic impacts. Together, all these benefits create a very compelling argument for investing more in renewables.

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