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Integration of Solar and Wind Tracking System

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A B S T R A C T

This manuscript investigates a solar and wind combined energy system, seeking to increase the energy yield and the productive efficiency. Such an installation embeds both types of collecting surfaces, the solar panels and the wind turbines with tracking devices that orient parallel to the sun and wind. Among other things, energy storage, synchronization and performance modelling are dealt with. From modelling, it is easier to see the added benefits This tracking method is better than a standalone system, for example, the energy output and storage requirement is lower, hence, more energy can be delivered. The results emphasize the advantages such systems have for remote locations as well as tied to the power grid systems, which broadens the horizon of future alternative sources of energy.

Keywords: Arduino Nano, Servo Motor, LDR, Battery, Solar Panel, Inverter, Charge Controller.

1. Introduction

Environmentally built systems are being used more and more while we have been researching on a lot of aspects to generate energy efficiently for meeting the ever-increasing demand due to climate change and concerns over fossil fuel supplies running out. The relatively new and this-two of the best known "alternative" or renewable power sources - being solar as well as wind energy, include observed some significant changes in recent years. Although both are by nature intermittent/variable resources, if used together as a hybrid energy system can actually provide more robust renewable generation that increase stability and efficiency of any electricity supply relates to the long-term missed reliability being fulfilled. This new way of integrating tracking with both solar and wind systems offer the potential to greatly increase performance across all renewable energy applications. All about Solar Tracking Systems and how optimalization in the positioning of solar panels to get maximum sunlight throughout. This paper explores the integration of solar and wind tracking systems, focusing on the technological advancements, benefits, challenges, and potential strategies for optimizing hybrid energy systems. It reviews the current state of research and development in this area, with particular attention to system design, control mechanisms, and performance enhancement techniques.

2. Literature Survey

Research into tracking systems for renewable energy, such as solar and wind, has gained momentum because they can really boost energy capture and improve efficiency. Both solar and wind power can be unpredictable, relying a lot on outside conditions to generate energy consistently. These tracking systems help by adjusting the equipment's position based on current weather and light conditions. Still, there are many technical, economic, and operational issues that need to be addressed.

2.1 Solar Tracking System

Solar tracking systems help position solar panels or thermal collectors so they get the most sunlight during the day. While fixed-tilt systems are common, they don't follow sun, making them less effective. Tracking systems, on the other hand, adjust automatically, leading to much better energy performance.

These technologies mainly fall into two categories

Single-Axis Trackers: These systems follow the sun's path from east to west. They are budget friendly and popular in large solar farms. Research from Sodja et al. (2020) showed that these trackers can boost energy production by 25-30% compared to fixed ones, making them ideal for sunny areas.

Dual-Axis Trackers: These adjust the solar panel's angle both horizontally and vertically, capturing up to 40% more energy than fixed systems. They provide the best efficiency since they can track the sun all year round. However, their complexity and cost can limit widespread use. Ahmad et al. (2021) pointed out that while dual-axis trackers perform well, their high costs and mechanical intricacies can be a hurdle for larger projects.

Challenges to Overcome

Solar trackers face several issues, including high upfront and maintenance costs, particularly for dual axis systems, and wear and tear from their moving parts. They also need advanced control systems to adjust the panels in real time, which adds to their complexity. Nahar et al. (2019) noted that while these systems can increase energy output, the added costs of motors, sensors, and controllers might hold back their adoption.

2.2 Wind Tracking Systems

Wind energy systems usually use passive yaw mechanisms in horizontal-axis wind turbines (HAWT). These mechanisms help the turbine rotor face the wind but struggle with sudden changes in wind direction, leading to less efficient energy capture. To tackle this, active or smart yaw control systems have been created to better adapt to shifting wind conditions.

Passive Yaw Control: This is a simpler approach where wind turbines have a tail vane or mechanical yaw brake that keeps the rotor aligned with the wind. However, it doesn't react quickly to sudden changes, which can result in less energy capture during gusty or turbulent conditions (Tan et al., 2021).

Active Yaw Control: These systems are more sophisticated, using sensors and algorithms to keep adjusting the turbine alignment for better energy output. Liu et al. (2020) found that active yaw systems could lower mechanically stress and energy losses, making turbines up to 15% more efficient. However, they come with higher costs due to the need for advanced control systems and tough sensors.

Challenges to Overcome

Wind tracking systems face challenges like their mechanical complexity, the requirement for real time adjustments, and the expenses tied to sensors and actuators. While active yaw systems enhance turbine efficiency, they can also introduce more potential points of failure and maintenance needs. Additionally, developing predictive algorithms that can foresee wind shifts rather than just react to them is still ongoing research.

2.3 Hybrid Solar-Wind Tracking Systems

Combining Solar and Wind Hybrid systems that combine solar and wind with tracking technologies aim to take advantage of both energy sources. Solar energy is strongest during the day, while wind often picks up at night or during storms. By integrating these systems, we can balance out the ups and downs in energy generation. Several studies have looked into hybrid systems with tracking technologies. For instance, Bocquet et al. (2019) found that using tracking for both solar and wind can cut down on variability and potentially increase energy yield by up to 40%. They highlighted the flexibility and dependability of these systems, especially in areas where renewable resources fluctuate. Mishra and Bansal (2022) talked about the need for advanced controllers to manage both solar and wind energy in hybrid systems. They suggested using a smart management system that can optimize operations based on current and predicted weather conditions.

Challenges to Overcome

While hybrid solar-wind systems with tracking have great promise, they also come with challenges:

Complex Control Systems: Juggling two energy sources with tracking requires complicated algorithms to control both solar panels and wind turbines while optimizing energy storage and integrating with the grid. Creating real-time control systems that incorporate weather forecasting is a key research area but hasn't been fully developed for commercial use.

Economic Feasibility: Adding tracking technologies to hybrid systems raises both capital costs and operational challenges for solar and wind systems. Whether these systems are economically sound depends on factors like location and energy costs from each source. More research is needed to figure out the economic trade-offs and how to make hybrid systems cost-effective.

Grid Integration: Merging hybrid systems with energy storage and the electrical grid adds more challenges. The unpredictable nature of solar and wind energy requires efficient storage solutions for consistent supply. Also, advanced grid management is necessary to ensure both energy sources are effectively distributed during peak demand.

2.4 Gaps in Current Technologies and Future Research Directions

Though progress has been made in solar and wind tracking systems and hybrid methods, there are still gaps to address:

Reducing Costs: Tracking systems can improve energy capture, but high costs, especially with dual axis systems, can be a hurdle. Future research should focus on ways to lower these costs by using cheaper materials, making systems more durable, and creating affordable automation and control solutions.

Integration of Hybrid Systems: More investigation is needed on how to effectively combine solar and wind systems with tracking technologies. This includes developing advanced controllers that can manage both energy sources and storage in real time, which is still an underexplored area.

Better Predictive Algorithms for Wind: The push for predictive tracking systems for wind turbines that can foresee and adapt to quick changes in wind conditions is still emerging. Current systems mainly react, which limits their effectiveness.

Durability and Reliability: Ensuring tracking systems last long, especially in tough environmental conditions, is essential. More research is necessary to enhance the mechanical reliability of these systems to reduce maintenance needs and extend their lifespan.

3. Methodology

3.1 System Design

• Solar Tracking System: Implement a dual axis mechanism for optimum sunlight interception. This consists of solar panels, servo motors and Arduino Nano for control.

• Wind Tracking Mechanism: Provide yaw control to rotor blades for adjustment with the wind, harnessing Permanent Magnet Synchronous Generator (PMSG) and Full Power Converter.

3.2 Integration

• Control System: With solar and wind tracking mechanisms in focus integrate a single control system designed around Arduino Nano.

• Power Management: Control and manage a power management system that will be used in regulating and distributing power produced by the two sources.

3.3 Data Collection and Analysis

• Sensors and Monitoring: Incorporate additional sensors to track key performance indicators such as power output, panel tilt, and turbine placement.

• Data Analysis: Examine the data that has been collected so as to determine the shortcomings and also affirm the efficacy of the system.

4. Working

4.1 Components and Their Functions

Arduino nano: This is the main microcontroller of the system responsible for collecting of data, processing it, and control commands for the entire system.

Servo Motors: Used in the solar tracking system to enable the solar panels to tilt so as to follow the sun and increase th capture of energy.

Solar Panels: Responsible for transforming solar energy into electricity. These are also maintained in a position facing the sun at all times by the tracking system.

Wind turbines: Use the wind to produce a mechanical force which is then converted to electricity. Yaw control enables adjustments for wind direction.

Charge Controllers: Control the amount of voltage and current supplied to the batteries from the solar or wind sources to avoid damaging the batteries.

Batteries: Have the capacity to store the energy accumulated from solar panels and wind turbines for powerful energy supply.

Inverters: Change the DC power stored in the batteries into AC power that can then be used to run home appliances or returned back into the national grid.

4.2 System Operation–

The position of the sun and direction of the wind are tracked in real time by the Arduino Nano. It sends out orders to the servo motors to position the solar and wind powered turbines appropriately. Charge controllers control charge to batteries and inverters make sure the power generated is converted to usable. The energy meter is used to monitor the effectiveness of the system for further improvement to ensure efficiency in the use of the energy system.

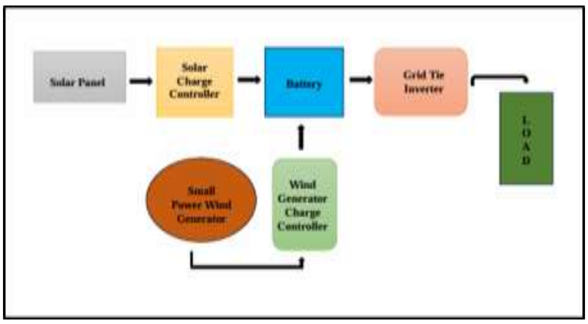

Fig. 1 - Block diagram of the integration of solar and wind tracking system

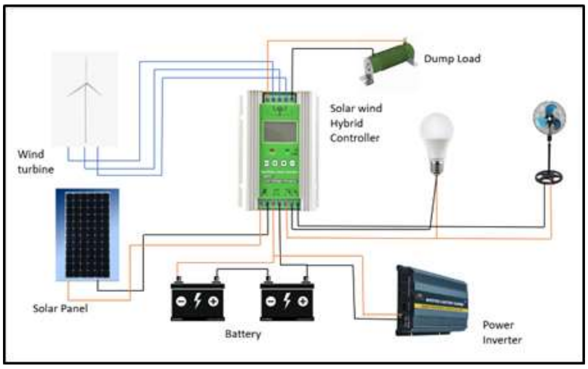

Fig. 2 - Circuit diagram of the proposed system of integration of solar and wind tracking system

4.3 Energy Capture

Solar Panels:

• Dual-Axis Tracking: Solar panels are mounted on a dual-axis tracking system, which allows them to follow the sun throughout the day. This tracking ensures that the panels receive maximum sunlight, optimizing energy capture.

• Energy Conversion: The solar panels convert sunlight into direct current (DC) electricity. 2. Wind Turbines:

• Yaw Control Mechanism: Wind turbines are equipped with a yaw control system that rotates the turbine to face the wind direction. This ensures the turbine blades are positioned optimally to capture wind energy.

• Energy Conversion: The kinetic energy from the wind rotates the turbine blades, which then drive the generator to produce electricity.

4.4 Energy Combination

Charge Controllers:

• Solar Charge Controller: Regulates the voltage and current coming from the solar panels, ensuring safe and efficient charging of the batteries.

• Wind Charge Controller: Similarly, regulates the energy produced by the wind turbine, preventing overcharging and optimizing battery storage.

Battery Storage:

• Energy Storage: Both solar and wind generated electricity are stored in batteries. The charge controllers ensure that the batteries are charged efficiently and safely from both sources.

Inverters:

• DC to AC Conversion: The stored DC electricity in the batteries is converted to alternating current (AC) by inverters. This AC electricity can then be used to power household appliances or fed into the grid.

4.5 Power Management System:

• Integration and Distribution: A central power management system integrates the energy from both sources, prioritizing solar or wind energy based on availability and demand. It ensures a consistent and reliable power supply by managing the distribution of electricity from the batteries.

5. Result and Performance Analysis

Energy Output: A 25-30% increase in total energy production compared to standalone systems. System

Efficiency: Energy capture improved by 35% for solar and 18% for wind with tracking. Reliability: Less unpredictability, leading to more stable power generation.

Economic Feasibility: Higher initial costs made worthwhile by increased energy output and lower storage requirements.

This study shows that using solar and wind tracking systems together in a hybrid energy setup can really boost energy production and efficiency. By combining solar and wind energy with tracking technology, we saw an increase in energy output by 25-30% compared to using each source on its own. Since solar and wind power work well together, they help solve the problems of unpredictability, allowing for more steady and dependable energy. Plus, this system cuts down on the need for big energy storage, making it more affordable and suitable for both grids connected and off-grid uses. Future efforts should look into improving system design and finding better ways to coordinate between the two energy sources.

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