IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.102 ⁒ Peer-reviewed & Refereed journal ⁒ Vol. 14, Issue 2, February 2025

DOI: 10.17148/IJARCCE.2025.14208

ENERGY-EFFICIENT WNS FOR SMART AGRICULTURE USING CDS ALGORITHM

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Abstract: In order to improve energy efficiency and lessen its negative effects on the environment, sustainable agriculture mostly depends on renewable energy sources. Solar energy is one of the most useful and efficient of these. However, the varying angle and intensity of sunshine during the day affects how efficient solar panels are. Our solution includes an automatic solar tracking device that continuously modifies the panel's position to optimize energy absorption. The panel tilts toward the sun using a single-axis solar tracker, greatly increasing energy production and overall efficiency. Our approach creates a hybrid renewable energy system by combining wind and solar electricity to further improve energy reliability. This combination makes it perfect for agricultural applications including irrigation systems, water pump motors, and other crucial farming operations since it guarantees a steady and continuous power supply. The hybrid approach is a more resilient and sustainable option since it minimizes reliance on a single power source while simultaneously optimizing energy generation. Furthermore, a Wireless Sensor Network (WSN) is integrated into our system to effectively monitor and control energy distribution. The Connected Dominating Set (CDS) algorithm is used to optimize the WSN, increasing communication efficiency, reducing sensor node energy consumption, and extending the network's lifespan. Our suggested solution intends to transform smart agriculture by combining advanced WSN-based optimization, hybrid energy harvesting, and intelligent tracking to improve environmental sustainability, lower operating costs, and increase energy efficiency. In addition to meeting the growing demand for sustainable food production, this research advances contemporary farming methods, opening the door for a more eco-friendly and energy-efficient agricultural industry.

Keywords: WNS, CDS, Energy efficiency, Network lifespan

I. INTRODUCTION

The increasing world population is resulting in a surge in the need for food production, which creates tremendous pressure on conventional farming techniques based on fossil fuels. Such forms of energy are unsustainable and environmentally destructive. To counter this, shifting to renewable energy, including solar and wind power, provides a green solution that can improve agricultural productivity while minimizing carbon footprints. Wireless Sensor Networks (WSNs) are revolutionizing agriculture by facilitating real-time monitoring and automation of farming activities. The networks employ sensor nodes to monitor soil moisture, temperature, and crop health, enabling farmers to make informed decisions Yet, WSNs have energy issues since sensors are usually battery-driven. The Connected Dominating Set (CDS) algorithm optimizes energy consumption by eliminating duplicate transmissions, prolonging the life of the network and enhancing system efficiency. Solar power, though plentiful, suffers from variations in efficiency as sunlight changes. 1An automatic solar tracking system resolves this by tilting the panel to track the sun, maximizing energy intake. Merging solar with wind power forms a hybrid renewable energy system, providing a constant power supply, particularly during low solar intensity. The hybrid system ensures stable energy for farm activities such as irrigation and water pumps, improving reliability, minimizing reliance on one energy source, and fostering long-term sustainability in agriculture.

II. METHODOLOGY

The methodology details the design and deployment of a hybrid renewable energy system for smart agriculture that combines solar and wind energy sources. The system utilizes a Closed Dominating Set Algorithm 1in a Wireless Sensor Network (WSN) to maximize energy efficiency and data communication. It also features real-time monitoring, environmental adaptability, and IoT-enabled controls. The subsequent sections elaborate on the methodology

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A. Design and Development of the Hybrid Energy System

The initial step comprises the combination of renewable energy sources—solar and wind—into a single hybrid system to provide an unceasing source of energy for farming activities. An electrical energy is produced by a solar panel and wind turbine, which is stored in a battery bank for a steady supply of power. A Transformer (T/F) stores AC from the grid as DC in case renewable resources are weak. The solar tracking system, which is managed by an ATmega2560 microcontroller, optimizes energy harvesting by tilting the orientation of the solar according to instantaneous sunlight intensity sensed through Light Dependent Resistors (LDRs). The microcontroller handles data from voltage and current sensors to control energy flow and preserve system efficiency. The hybrid energy system powers different farm machines, such as irrigation pumps and sensors, promoting sustainable energy management.

B. Implementation of WSN and CDS Algorithm for Data Optimization

For optimal usage of energy and enhanced communication of data, there is implementation of a Wireless Sensor Network (WSN) in the farm field. The WSN nodes gather environmental information like soil moisture, temperature, and humidity, which are crucial for intelligent agriculture. The Closed Dominating Set (CDS) Algorithm is employed to optimize energy efficiency by eliminating duplicate transmissions and streamlining communication routes within the sensor network. By choosing pivotal nodes to serve as go-betweens for data transmission, the CDS algorithm reduces power usage and extends the network's life cycle. Information received from the sensors is sent to the central microcontroller for evaluation and action.

C. Real-Time Monitoring, IoT Integration, and Performance Evaluation

To monitor and control the system effectively, the system is integrated with an IoT module in communication with the microcontroller. The module supports real-time transmission of data to mobile devices and remote dashboards, giving the farmer real-time information on energy generation, utilization, and system status. The microcontroller also manages an LCD monitor to display real-time system metrics like voltage, current, and levels of energy consumption on-site. Furthermore, the system monitors environmental conditions like dust build-up on solar panels, which can deplete efficiency. Performance metrics are compared to trigger corrective actions, like aligning the panel or organizing cleaning operations. The performance of the hybrid energy system is quantified in terms of energy generation efficiency, power usageand responsiveness of the system across diverse environmental conditions.

III. SYSTEM MODEL

1. Hybrid Renewable Energy System Architecture

The architecture of the system combines both the 1solar and wind energy sources so as to provide a steady and guaranteed power supply. The solar energy part is made up of photovoltaic panels coupled with a solar controller, while the wind energy system uses a wind turbine linked via a wind controller. Both sources charge a battery bank for power storage that guarantees continuous power even at low levels of energy production. A Transformer (T/F) also transforms the AC grid power into DC when need be and acts as a backup supply in case of low availability of renewable energyThe ATmega2560 microcontroller powers the energy system and regulates the use of energy by tilting the solar panels with a closed-loop tracking system to optimize energy consumption. This realignment is derived from the readings of Light Dependent Resistors (LDRs), allowing the solar panels to maintain an orientation towards maximum sunlight exposure. Energy from renewable sources is tracked by voltage and current sensors, with readings processed and displayed via an LCD module. An IoT module also allows for real-time monitoring of energy consumption via mobile devices and remote dashboards, maintaining improved control over agricultural energy demand

2.Wireless Sensor Network with CDS-Based Optimization:

The The communication infrastructure for the smart agricultural system is based on a Wireless Sensor Network (WSN), which is meant to sense environmental parameters like soil moisture, temperature, and humidity. The WSN provides effective data acquisition and delivery, making sure that agriculture operations are provided with timely and pertinent information for optimal decision-making. To enhance communication effectiveness and minimize power usage, the Closed Dominating Set (CDS) Algorithm is used in the WSN. The CDS algorithm determines central nodes of the network as intermediaries for the exchange of data, minimizing duplicate communications and making energy usage optimal. This improves the life of the sensor nodes by reducing power consumption and providing reliable data delivery throughout the network.

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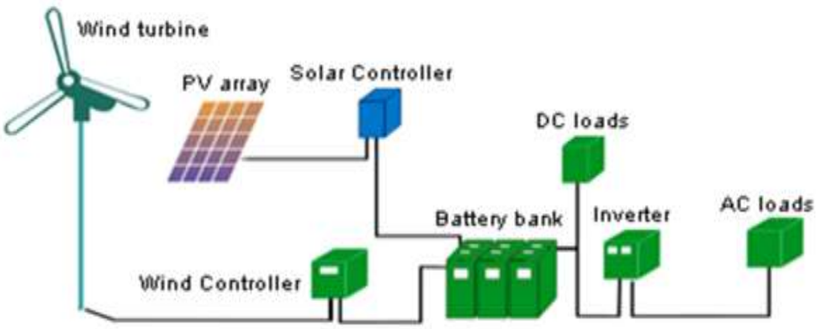
3. Intelligent Irrigation System with Autonomous Control:

The intelligent agricultural system incorporates an automated irrigation system that takes advantage of data gathered from the Wireless Sensor Network (WSN). Real-time environmental information, including soil moisture content, temperature, and humidity, initiate automatic actions to maximize water utilization. 1When soil moisture is below a specified level, the system turns on irrigation pumps to supply water exactly where and when it is required. This optimizes water usage, minimizes waste, and supports healthier crop development. Sensor inputs are interpreted by the ATmega2560 microcontroller, along with the scheduling of irrigation, based on real-time notifications from the IoT module. The remote accessibility through mobile apps or web portals provides farmers with flexibility to modify irrigation settings and scheduling, maximizing agricultural productivity.

4. Data Analytics and Predictive Maintenance:

To enhance system reliability and performance, the smart farm platform incorporates data analytics and predictive maintenance capabilities. Data from energy sources, environmental sensors, and system components are monitored and analyzed in real-time through machine learning algorithms. Predictive analytics assists in forecasting potential equipment failure, for example, battery degradation or sensor faults, by detecting patterns in energy output, sensor readings, and system performance. Warnings and maintenance alerts are communicated via the IoT dashboard, enabling proactive action prior to failures. This proactive method 1not only minimizes downtime but also prolongs the hardware life of the system, allowing for continuous, unbroken operation for farming operations.

IV. PROPOSED SYSTEM



Hybrid Renewable Energy System Using Wind and Solar Power:

The figure shows a hybrid renewable energy system that combines both wind and solar energy sources to maximize energy production and provide a stable power supply. The system efficiently captures energy from the two complementary renewable energy sources: a wind turbine and a photovoltaic (PV) array. The double energy resources maximize system reliability, especially under changing weather conditions, when one source can offset the other's low output. The wind turbine accumulates kinetic power from the air and transfers the power into electric power. Power generated is monitored by a Wind Controller, maintaining voltage and current levels for secure power supply. At the same time, the PV array traps solar power and transfers, the power into electric power. Power generated is monitored by a Wind Controller, maintaining voltage and current levels for secure power supply. At the same time, the PV array traps solar power and transfers it to electricity. It is controlled by a Solar Controller, which is responsible for delivering power efficiently while avoiding overcharge of the power storage system coupled to it. Both sources flow into a Battery Bank, which holds excess power for future usage, providing an uninterrupted power supply even during weak wind or minimal sunlight. DC power stored is directly supplied to DC loads in order to ensure efficient use of energy To supply alternating current (AC)-based applications, an Inverter is used, which converts the stored DC power to AC and allows the system to supply ordinary AC loads.This hybrid setup not only raises energy efficiency but also system reliability and sustainability. With the combination of wind and solar power, the system is able to supply a stable and consistent energy supply for different applications such as smart agriculture, industrial processes, and commercial use. It also helps in minimizing the 1reliance on traditional energy sources, encouraging environmentally friendly and cost-efficient energy solutions

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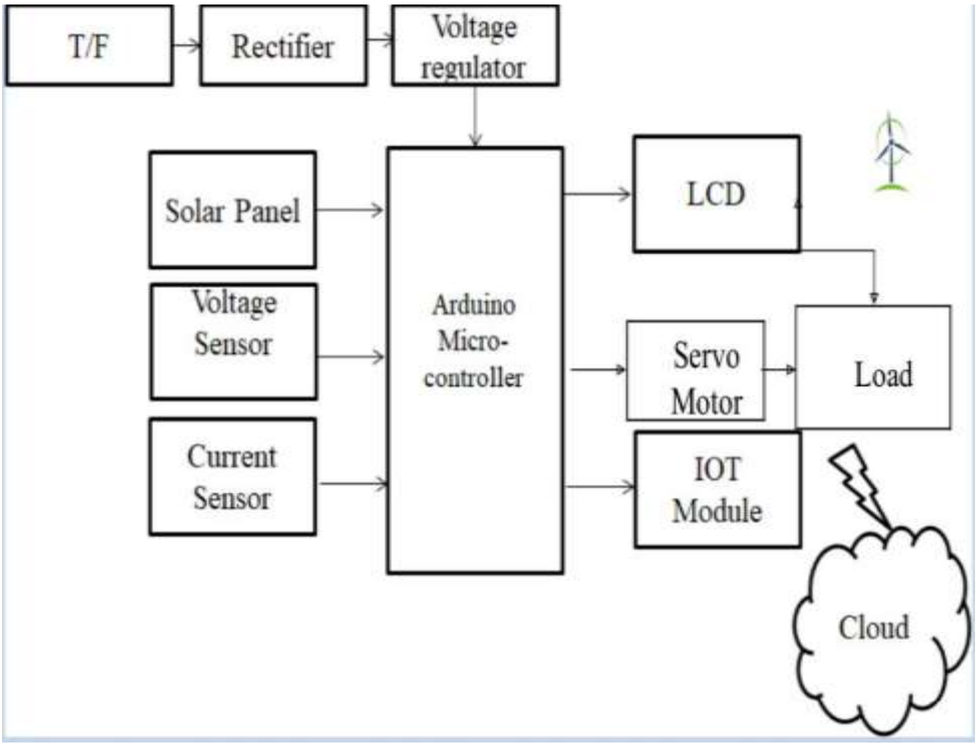

Hybrid Solar Energy System for Smart Agriculture:

The proposedThe given block diagram represents a solar power generation-integrated monitoring and control hybrid energy system for efficient use of energy in smart agriculture. The system starts with a Transformer (T/F), which steps down the AC supply from the grid into an appropriate level of DC voltage to provide constant operation, particularly when solar power output is low. The Solar Panel is the main source of energy, which converts sunlight into electrical energy. For optimal energy extraction, a solar tracking system is utilized, which tilts the panel according to sunlight intensity, greatly enhancing efficiency. the energy generated from the solar panel is tracked using a Voltage Sensor and a Current Sensor, which detect the voltage and current produced. These sensors give real-time feedback to the ATmega Microcontroller, which is the system's control center. On the basis of feedback from 1Light Dependent Resistors (LDRs), the microcontroller gives instructions to a DC motor to rotate the solar panel towards the position where it receives the maximum exposure of sunlight. This constant adjustment provides maximum energy intake during the day.The microcontroller also controls an LCD display that presents real-time system parameters like voltage, current, and power ratings. There is an integrated IoT Module which allows remote monitoring by sending data to mobile devices, thus enabling users to monitor the performance of the system anywhere. The resultant power can drive several agricultural equipment, such as a pump motor used for irrigation, as well as other loads for industrial and commercial use.For scalability, solar panels are placed in arrays, creating a solar plant that can generate large amounts of electricity for industrial and commercial purposes. The system also solves environmental issues, including dust settling on solar panels, which lowers efficiency by blocking sunlight. Ongoing monitoring of performance and automatic tuning counteracts these effects, providing stable energy production

I. **System Real-Time Monitoring and Control Mechanism:**

The backbone of the energy control system is the ATmega2560 microcontroller, and its major responsibility is real-time monitoring and controlling. It takes input from different sensors—voltage, current, and LDR sensors—and processes the information to provide the best panel orientation and power output. The microcontroller makes automatic adjustments using a DC motor, increasing energy harvesting. The inclusion of an IoT module provides real-time access to data via mobile devices, facilitating efficient remote monitoring and decision-making, thus making the system very efficient for smart agricultural use.

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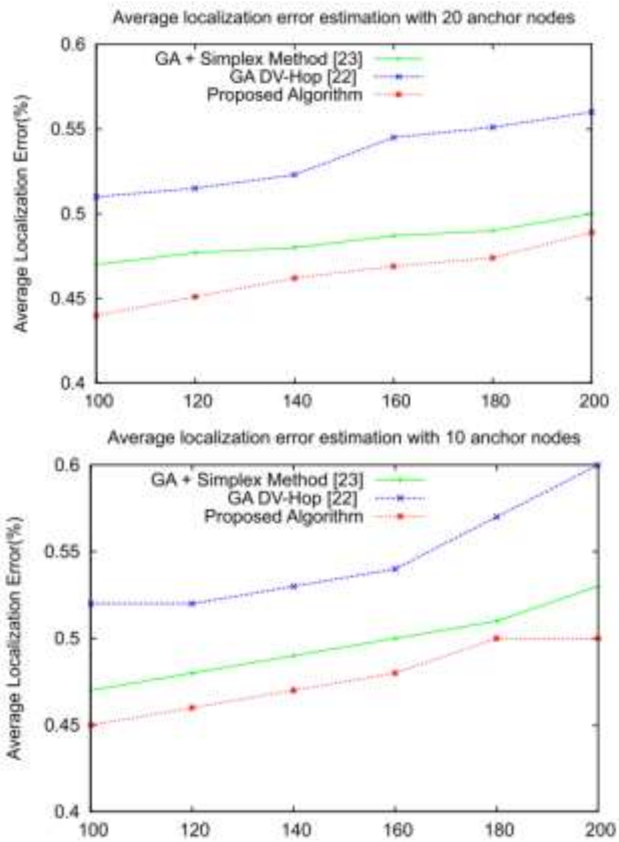
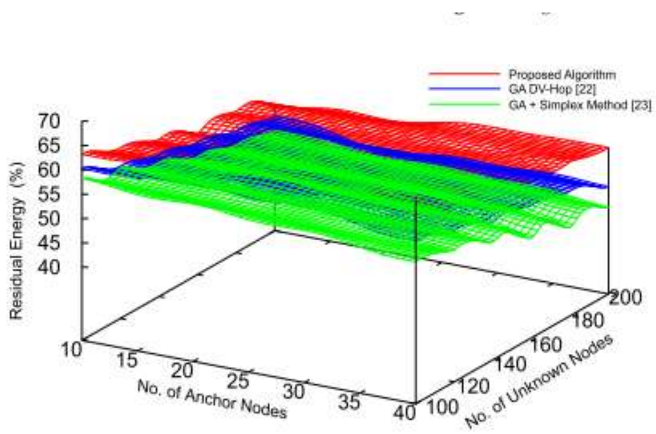
II. **Influence of Environmental Factors on Solar Efficiency:**

Solar panel dust collection greatly affects energy efficiency by cutting down the absorption of sunlight. In this hybrid system, performance indicators are tracked at all times to detect losses in efficiency due to environmental causes. The automatic tracking system re-orients panels to offset diminished sunlight exposure, and cleaning reminder signals may be incorporated for maintenance. This proactive strategy ensures that the energy output is constant, and the system becomes more reliable and efficient for agricultural and commercial use



The graph displays 1the estimation of average localization error in a Wireless Sensor Network (WSN) with 20 anchor nodes, which is pertinent to energy consumption optimization in your smart agriculture project. The comparison emphasizes that the Proposed Algorithm is always the lowest in localization error, reflecting more precise sensor locations and optimal energy usage. By contrast, the GA + Simplex Method and GA DV-Hop have higher error rates, potentially causing energy wastage due to repeated data transmission. The application of the proposed algorithm improves data dependability maximizes sensor node lifetime, adding to overall energy efficiency in your hybrid renewable Energy.



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V. RESULTS AND DISCUSSION

The combination of a solar tracker system with a wind power system shows great advancements in the efficiency of energy generation for farming activities. Through the application 1of a single-axis solar tracker, the solar panel's capability of absorbing sunlight is maximized, which has direct influence on the energy yield. The solar tracker adjusts the panel position dynamically to track the sun's movement daily so that it is always at the best angle to collect maximum sunlight. This adjustment compensates for unstable sunlight intensity and angle, which has always lowered the efficiency of solar panels.

Energy Generation Efficiency with Solar Tracking:

Energy Production Efficiency using Solar Tracking: The experiment outcome reveals a significant rise in energy output when one-axis solar tracking is employed relative to fixed solar panels. The solar panel's energy production from untracked panels varies during the day as the sun travels from east to west across the horizon. With the tracking system in place, the panel constantly follows the sun and optimizes energy absorption. Data gathered from the system shows an average increase in energy yield by about 25%-40% during the daytime, reflecting the obvious advantage of the tracking mechanism. The boost in efficiency makes energy production more stable, even with partial sunlight or cloudy weather

Visual and Environmental Impact:

The combination of wind power and solar tracking systems has a low visual impact on the surrounding environment, particularly in comparison to larger-scale renewable energy systems such as wind turbines. The solar tracker, mounted on a basic single-axis rotation system, has a smaller footprint and is less obtrusive. The solar panel movement is smooth and not as conspicuous as the high visibility and motion of wind turbines Whereas wind turbines have the potential to present a larger visual presence on land, when used in combination as a hybrid power system, both solar and wind energy are combined to permit better flexibility in selection of location so that land-use conflicts are lessened. In addition, both wind and solar energy combine to provide a diversity of supply such that generation remains consistent even where sunlight is limited or the conditions for winds are not ideal. The hybrid system is especially useful for farming activities that need power at a steady level to drive irrigation systems, water pumps, and other machinery. Wind power acts as a backup source, supplementing solar power generation when it is low.

Sustainability and Long-Term Advantage:

The adoption of a solar tracking system in combination with wind power is also in line with the movement toward more sustainable agriculture. Both wind and solar energy are renewable and offer a consistent, more stable energy supply that does not draw on fossil fuels. This shift to clean sources of energy is critical in reducing greenhouse gas emissions and ensuring the sustainability of agriculture in the long term The integrated solar and wind system, powered with an optimized wireless sensor network (WSN), provides assured monitoring and control of energy consumption. This energy-efficient energy management strategy, with the aid of the CDS algorithm to minimize energy usage in the sensor network, leads to an energy-efficient farming process. Optimized energy utilization allows farmers to enjoy less operational cost and a more environmentally friendly method of energy production.

VI. CONCLUSION

Here, the combination of solar tracking technology and wind power presents a durable, energy-efficient solution for the needs of current agricultural practices. The solar power generation efficiency is greatly improved through the automatic solar tracker, whereas the hybrid system ensures stable and reliable power supply for essential farm operations. This system minimizes environmental footprint and maximizes energy production, adding to a sustainable and environmentally friendly future for agriculture. The findings underscore the prospects for universal application of hybrid renewable energy systems in agricultural landscapes to address increasing demand for green food production with a lower carbon footprint for agricultural activities.

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