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# Design of Stand-Alone Integrated Hybrid Renewable Power Generation

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**ABSTRACT:** The Hybrid Power Generation Project aims to design, develop, and implement an innovative energy generation system that combines the strengths of solar and wind energy technologies. This project seeks to harness the complementary nature of these renewable energy sources to create a reliable, efficient, and sustainable power supply. The primary components of the hybrid system include 12V 10W solar panels, a custom-designed 3D printed vertical wind turbine, AC and DC dynamos, a solar charging controller, buck and boost converters, a 12V 7Ah battery, and various monitoring and control devices. The integration of these components allows for optimized energy capture, conversion, and storage, ensuring seamless operation and consistent power output. Key objectives of the project include the design and development of efficient solar and wind energy systems, system integration and optimization, performance evaluation through comprehensive testing, and promoting sustainability and environmental awareness. With a keen eye on scalability, adaptability, and future growth, this project emphasizes its potential to meet evolving energy needs and technological progress. Through thorough planning, design, and rigorous testing, it seeks to showcase the practicality and efficiency of hybrid renewable energy systems as a credible substitute for conventional fossil fuel-based sources. By advocating for renewable energy adoption and fostering awareness of sustainable energy practices, the Hybrid Power Generation Project endeavors to play a pivotal role in shaping a greener and more sustainable energy landscape.

**KEYWORDS**: Solar energy, Wind energy, Renewable energy, PV cell, Hybrid power system.

## I. INTRODUCTION

In today's rapidly evolving energy landscape, the demand for sustainable and renewable energy sources has never been higher. The need to reduce our dependence on fossil fuels and mitigate the adverse effects of climate change has led to an increased interest in alternative energy solutions. This project seeks to capitalize on the growing demand for sustainable energy by integrating solar and wind power into a hybrid generation system. By combining these renewable sources, the project aims to enhance reliability and efficiency in energy production, thereby contributing to the global shift away from fossil fuels and towards a greener future. This project's main concept is to use a vertical wind turbine that has been 3D printed with 12V/10W solar panels to generate wind and solar energy, respectively. Our goal is to combine these two renewable energy sources to produce a more reliable and sustainable power source that can meet different energy needs, particularly in regions with variable weather. A solar charging controller, boost and buck converters, a 12V 7Ah battery, AC and DC dynamos, a full-wave bridge rectifier, an inverter module, and numerous monitoring and control tools like voltage indicators, multimeters, and LED indicators are important parts of the hybrid power generation system. We will examine the phases of design, construction, and testing in this project, outlining the procedures necessary to establish a working hybrid power generation system.

This project seeks to demonstrate the viability and efficacy of hybrid renewable energy systems in delivering a sustainable and environmentally friendly energy solution for a variety of applications by combining solar and wind energy technologies. But since wind and solar energy are erratic resources, using a hybrid systems approach would offer a higher chance for consistent power production. Their outcomes were also evaluated in terms of technical and financial elements against a hybrid PV/WT system. The findings of the authors demonstrated that installing these systems separately was far less efficient than creating an integrated PV-WT and storage system. These systems have the potential to significantly influence how the global energy landscape develops in the future by utilizing the

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complementing qualities of various renewable energy sources.

## II. LITERATURE REVIEW

The literature on the design of standalone integrated hybrid renewable power generation systems encompasses studies investigating the optimal combination of renewable energy sources, such as solar, wind, and hydroelectric power, along with energy storage technologies, to create reliable and sustainable off-grid energy solutions. Researchers have explored various aspects, including solar panel placement and tracking systems, wind turbine design optimization, micro-hydro integration, energy storage technologies, control strategies, techno-economic analysis, and environmental impact assessment, highlighting challenges, opportunities, and future directions in achieving efficient and environmentally friendly standalone hybrid systems.

1. "Design and control of a stand-alone hybrid power system". International Journal of Engineering Research and General Science Volme 4, Issue 2, March-April, 2016. This work focuses on creating a hybrid energy system that integrates both solar and wind power sources to maximize efficiency and versatility. The system utilizes carefully designed circuitry to harness energy from these renewable sources and employs inverters to convert the electrical energy generated into usable power according to specific demands. By combining solar and wind energy, the system takes advantage of the complementary nature of these sources, ensuring a more consistent and reliable power supply. Additionally, the designed circuitry enhances the efficiency of energy capture and conversion, optimizing the overall performance of the system.

2. "Design of Wind Turbine (Aeroleaf)". Prince mohamud bin fahd university January 2017. This Design of Aeroleaf Wind Turbine is about designing and manufacturing a Vertical Axis Wind Turbines VAWT to transfer the wind speed to a rotational motion using these turbines. This type of turbine is not commonly use and its applications for obtaining useful energy from air stream is still considered as an alternative source. Low wind speed start-up, working with any wind direction and the less noise are some advantages of VAWT- Savonius model.

3. "PV-Wind-Battery based Bidirectional DC-DC Converter for Grid Connected Systems". IOP Conference Series: Materials Science and Engineering 2020. This project implements a sophisticated control strategy to manage the power flow from solar panels, wind turbines, and batteries connected through bi-directional DC to DC converters in a grid-connected system. The primary goal is to ensure that the combined output from these sources meets the demand of the load without compromising essential power needs. To achieve this, a half-bridge boost converter coupled with a transformer is employed to efficiently harvest power from the wind source. Simultaneously, a bi-directional buck-boost converter is used to gather power from both the solar panels and the battery, facilitating charging and discharging operations as required. This bidirectional converter also enables communication with the grid, ensuring seamless integration and interaction with the broader electrical network.

4. "Hybrid Power Generation (Solar and Wind Energy)", Samiksha S. Patil, Vol-4 Issue-2 2018. This paper aims to address the increasing demand for electricity while mitigating the negative impacts of conventional energy sources on the environment. By harnessing renewable energy from both wind and solar sources, a hybrid energy system is created, ensuring a sustainable and uninterrupted power supply without harming nature. Through the integration of solar panels and wind turbines, electricity generation becomes more affordable and accessible, offering a clean and eco-friendly alternative to conventional energy sources. This endeavor represents a crucial step towards achieving energy sustainability and preserving the delicate balance of nature.

5. "Hybrid inverter with solar battery charger". RCC Institute of Information Technology 2022. A solar inverter's main job is to convert DC power generated from the photovoltaic cell into AC power. Hybrid inverters go a step further and work with batteries to store excess power as well. But this solar inverter system is inefficient in charging the battery during cloudy weather condition. The battery requires more than 1 Ampere current for proper charging and due to low capacity of the battery, when solar power is not available. the battery dies out with the use of heavy load appliances. To solve this problem, we made a "Hybrid Inverter with Solar Battery Charging". This project is designed in such a way that it overcomes the limitation by the use of only solar energy.

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## III. METHODOLOGY

To achieve the best possible performance, dependability, and efficiency, an integrated hybrid solar and wind power production system must take into account a number of important factors. This is a comprehensive guide to assist you in creating such a system: The first stage is to design the model's general architecture as well as the inverters and wind blades. The groundwork for further implementation stages is laid at this first stage.

The importance of renewable energy sources like wind and photovoltaic systems in averting disasters is becoming increasingly apparent. A hybrid power system uses a combination of renewable energy sources, such solar panels and wind generators, to charge batteries and meet energy demands while taking the local topography and other environmental factors into account.

Because wind and solar energy depend on unpredictable weather patterns and other natural events, combining them can double system efficiency. locating the high wind and solar potential spot in the rural or urban area. Construct and put into action a hybrid solar-wind system.

PLA (polylactic acid) wind turbine blades are designed with consideration for the wind turbine's overall structural integrity, the aerodynamics of the blades, and the mechanical properties of PLA. In 3D printing, PLA is a polymer that is both renewable and biodegradable. After comparing the input from the two power systems, the charge controller sends a signal to the appropriate relay, which charges the DC battery.

An inverter circuit converts the DC voltage to an AC supply. The secondary of the centre-tapped transformer is linked to the MOSFET (IRF 540). The transformer's primary winding receives an AC supply when the MOSFET is triggered alternatively, which also results in an alternative current flow in the primary winding.

Electrical loads get energy from the battery through the inverter, which transforms DC power into AC power. The inverter is equipped with built-in safety against overload, reverse polarity, low battery voltage, and short circuit.

By combining the outputs of solar panels and wind turbines, a circuit for hybrid solar and wind power generation can effectively feed power into a shared energy storage system or grid. These are the approaches that help you with integrated circuit design, like Selection of Components: Select wind turbines and solar panels based on the system's energy needs. Choose the right inverters, charge controllers, and other auxiliary parts.

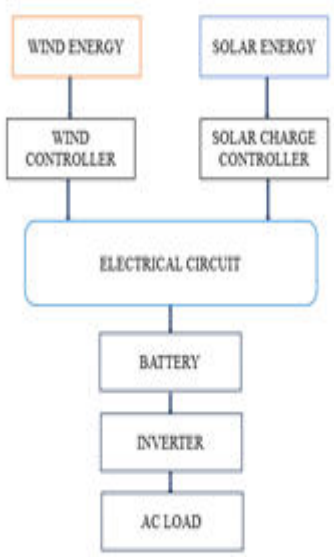


Fig 1: Simple schematic diagram for the proposed solar PV-WT hybrid power generation system.

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## IV. BLOCK DIAGRAM AND WORKING

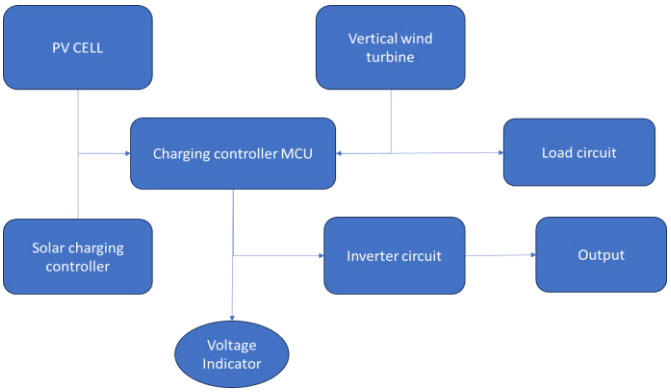


Fig 2: Block Diagram of project.

WORKING

In order to provide a dependable, effective, and sustainable energy generation system, the Hybrid Power Generation Project combines solar and wind energy technology. The operational characteristics, design considerations, and functioning principles of the hybrid system are expounded upon in this section.

1. Solar Energy System:

a) Solar Panel Configuration and Operation: The project utilizes 12V 10W solar panels arranged in an optimized layout to maximize sunlight capture. These solar panels convert sunlight into direct current (DC) electricity through photovoltaic cells. The generated DC electricity is then fed into the solar charging controller.

b) Solar Charging Controller: The solar charging controller regulates the charging of the 12V 7Ah battery by controlling the voltage and current from the solar panels. It ensures efficient charging while preventing overcharging and discharging of the battery, thereby extending its lifespan.

2. Wind Energy System:

a) 3D Printed Vertical Wind Turbine: A custom-designed vertical wind turbine with 3D printed blades is used to harness wind energy. The turbine blades are designed to capture wind from any direction, making it suitable for varying wind conditions. The rotational motion of the blades drives the dynamo to generate electricity.

b) AC and DC Dynamos: The wind turbine is connected to both AC 3-phase and DC dynamos to convert mechanical energy into electrical energy. The AC dynamo generates alternating current (AC), while the DC dynamo produces direct current (DC). These dynamos play a crucial role in converting the rotational energy from the wind turbine into usable electrical power.

3. Hybrid System Integration:

a) Voltage Regulation and Conversion: The generated AC and DC electricity from the dynamos are connected to a full-wave bridge rectifier to convert the AC power into DC, ensuring compatibility with the battery and other DC components. The buck converter 2566 and booster 6009x are used for voltage regulation and optimization, respectively. The buck converter regulates the voltage to a suitable level for battery charging, while the booster increases the voltage if needed.

b) Battery Management System: The 12V 7Ah battery serves as an energy storage unit, storing the excess energy generated by both solar and wind systems. A battery management system monitors the battery's state of charge (SOC) and controls the charging and discharging processes to optimize battery performance and lifespan.

4. Inverter and Energy Utilization:

a) Inverter Module: The DC electricity stored in the battery is converted into alternating current (AC) using an inverter module. This AC power is suitable for powering household appliances, tools, and other electrical devices, making the system versatile and adaptable for various applications.

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b) Monitoring and Control Systems: Various monitoring and control devices, including voltage indicators, multimeters, LED indicators, and a voltage controller, are integrated into the system to monitor the energy output, system performance, and battery status. These devices provide real-time data and allow for manual control and adjustments to optimize the system's operation.

## V. HARDWARE REQUIREMENTS

A dependable and effective energy generation system is created by the Hybrid Power Generation Project, which incorporates a number of components. The necessary hardware parts are listed in full below, along with a description of each.

a) SOLAR PANEL

Solar panels serve as the primary mechanism for converting solar radiation into electrical energy. Within each photovoltaic (PV) cell, incident light energy is absorbed, prompting the generation of charge carriers within the material. These carriers, typically electrons and holes, are then separated at the junction within the cell, creating a potential gradient. Under the influence of this electric field, the charge carriers flow as current through an external circuit, thereby producing usable electrical power.

A solar array or panel consists of numerous individual PV modules, interconnected in series or parallel configurations to achieve the desired current and voltage levels. Collectively, these panels function as the conduit for transforming solar power into electrical energy, thereby enabling the harnessing of renewable energy from sunlight.

Fig 3: 12V 10W Solar Panel

b) AC AND DC DYNAMOS

The AC 3-phase and DC dynamos convert the rotational energy from the wind turbine into electrical energy. The AC dynamo generates alternating current (AC), while the DC dynamo produces direct current (DC), providing flexibility in energy conversion and utilization. A dynamo motor, also known as a compound motor or compound dynamo, is a type of electrical machine that combines the features of a dynamo (generator) and a motor. It can function as both a generator, converting mechanical energy into electrical energy, and as a motor, converting electrical energy into mechanical energy.

When the dynamometer is operated as a generator, mechanical power is supplied to the shaft, which causes the armature to rotate within a magnetic field. This rotation induces an electromotive force (EMF) in the armature windings, generating electrical energy. The generated current flows through the series winding, which reinforces the magnetic field, resulting in a stronger output voltage.


Fig 4: AC and DC Dynamo.

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c) BATTERY

The 12V 7Ah battery serves as an energy storage unit, storing the excess energy generated by the solar and wind systems. It provides a reliable power source during low or no energy generation periods and ensures continuous energy supply.


Fig 5: 12V 7AH Battery.

d) BUCK CONVERTER

The buck converter regulates the voltage from the dynamos and solar panels to a suitable level for battery charging. It ensures efficient energy conversion and protects the battery from voltage fluctuations. Here we use an LM2596 DC-DC buck converter step-down power module with high-precision potentiometer for adjusting output voltage, capable of driving a load up to 3A with high efficiency.

Fig 6: Buck Converter 2566

e) BOOSTER

The booster increases the voltage if needed to optimize battery charging and system performance. It ensures consistent and reliable power supply by boosting the voltage to the required level.

Fig 7: Booster 6009x

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f) INVERTER MODULE

The inverter module converts the DC electricity stored in the battery into alternating current (AC). This AC power is suitable for powering household appliances, tools, and other electrical devices, making the system versatile and adaptable.

Fig 8: Inverter Module

IMPLEMENTATION OF HYBRID ENERGY SYSTEM

Installing a hybrid energy supply system is crucial because of intermittent energy resources and imbalanced energy resources. The solar PV wind hybrid system works well in environments with varying seasons of sunlight and wind. Using a single source won't be a good idea because neither the wind nor the sun shine continuously throughout the day. A hybrid power system that combines solar and wind energy with battery storage can be a lot more dependable and practical than either one alone. Even in the absence of wind or sunlight, the load can still be powered by the energy stored in the batteries. The system components are as follows.

**A. Design of wind turbine**

Decide on the design's parameters, such as the number of blades, twist angle, chord length, and blade length. These variables are essential to the wind turbine's overall performance. There are a few key considerations that need to be made while choosing wind turbine blades to guarantee performance, safety, and longevity. The blade's substance is the first crucial consideration. Small wind blades are made of a variety of materials, including PVC, carbon fiber, plastic, and metal. PVC is not seen to be a good material for blades since, in strong winds, it might shatter and even explode. The material used for this design is polylactic acid (PLA) filament. And the new design was influenced by the helix form.

**Parts of wind turbine:**

a) CENTRE PIECE

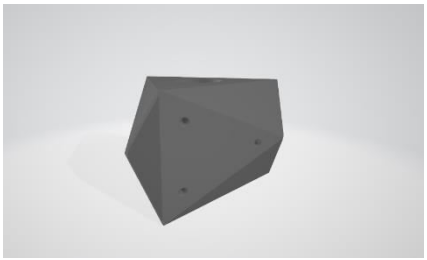

Fig 9: 3D design of wind turbine centerpiece.

b) ARM

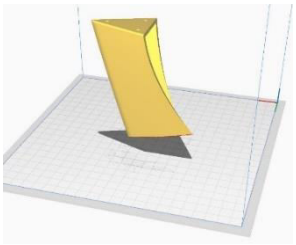

Fig 10: 3D Wind Turbine Arm Design.

c) VANE

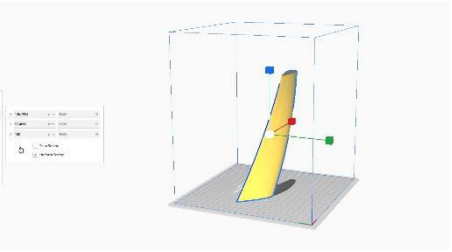

Fig 11: 3D Wind Turbine Vane Design

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FINAL SHAPE OF WIND TURBINE

Fig 12: HELIX shape wind turbine

Decide on an aerodynamic blade profile. You can employ common airfoil profiles, like the NACA series profiles. For best results, take into account the required lift and drag characteristics. Create the blade shape, taking into account the twist angle from root to tip and the chord distribution across the span. In order to minimize aerodynamic loads and maximize efficiency, proper twist distribution is necessary. To make sure the PLA blades can sustain the stresses, aerodynamic forces, and gravity encountered during operation, do a structural analysis. Make use of simulation technologies such as Finite Element Analysis (FEA) to assess stress distribution and deformation in different scenarios.

## VI. RESULT

While wind and solar energy cannot replace conventional energy sources as the exclusive source of electricity in a reliable base-load grid, they can minimize their reliance. A hybrid power plant system offers a number of benefits, including lower costs, more efficiency, and enhanced dependability.

Hybrid power plants are created and built with the advantages that make hybrid systems a desirable answer to the world's expanding need for sustainable energy. Hybrid systems can contribute to increased grid stability by lowering the requirement for costly backup power sources by offering a steady and continuous energy supply.

The results obtained from the above trials were positive. The wind turbine was working at its potential producing decent output voltage. The maximus output voltage seen was about 17 volts, the minimum voltage was a about 6 volts. The solar output voltage is 12 volts. The total output is 150 watts and we connect both AC and DC loads. We were able to light a led bulb which was able spread light to a small room.

| Trial No. | Wind speed In m/sec | RPM | Output voltage |
|---|---|---|---|
| 1 | 5 m/sec | 30 rpm | 7 V |
| 2 | 6 m/sec | 40 rpm | 10 V |
| 3 | 10 m/sec | 55 rpm | 15 V |
| 4 | 13 m/sec | 62 rpm | 25 V |
| 5 | 15 m/sec | 70 rpm | 30 V |

Table 1: Wind Turbine Output

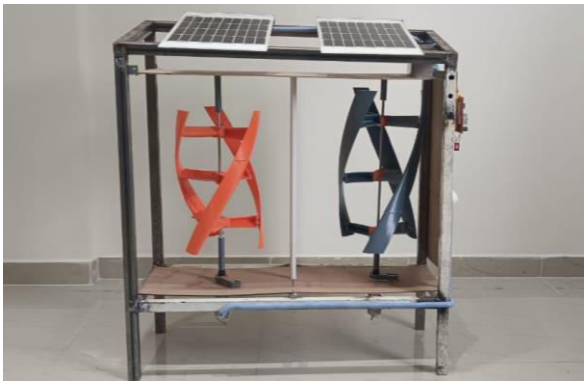

Fig 13: Proposed model.

## VII. FUTURE SCOPE

This small-scale hybrid power generation aids in the construction of hybrid generation plants with the largest generating capacity at the lowest possible cost. Traditionally, a vertical axis wind turbine needed to be excited to start.

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One goal of our project is to create a self-starting wind turbine, and another is to lessen power fluctuations caused by erratic wind. to provide a steady supply of power for us.

Hybrid power plant is developed and designed for the benefits that make hybrid systems an attractive solution for meeting and growing demand of sustainable energy. Hybrid systems can help to improve the stability of the grid by providing a stable and continuous supply of energy, reducing the need for expensive backup power source.

## VIII. CONCLUSION

In essence, the Hybrid Power Generation Project is a comprehensive initiative that blends solar and wind energy technologies to create a sustainable power generation system. Through meticulous planning and integration, it aims to leverage the strengths of both sources to build a reliable, efficient, and eco-friendly energy solution. The project draws on extensive research and expertise in renewable energy assessment, battery management, turbine control, photovoltaic technology, energy storage, smart grids, and integration methodologies to inform its design and implementation. By meticulously identifying hardware and software requirements, the project ensures seamless integration, monitoring, and optimization of the hybrid system. Components ranging from solar panels and wind turbines to monitoring software and communication protocols are carefully selected to fulfil specific roles in achieving project objectives.

These objectives, which encompass system design, integration, performance evaluation, sustainability, and scalability, are clearly defined to guide implementation and align with desired outcomes. Ultimately, the project seeks to demonstrate the feasibility and effectiveness of hybrid renewable energy systems as alternatives to fossil fuels. By promoting renewable energy adoption and reducing carbon emissions, it aims to contribute to a cleaner, greener energy future.

Through ongoing innovation, research, and education efforts, the project aims to inspire widespread adoption of renewable energy technologies, fostering a more sustainable energy landscape for future generations.

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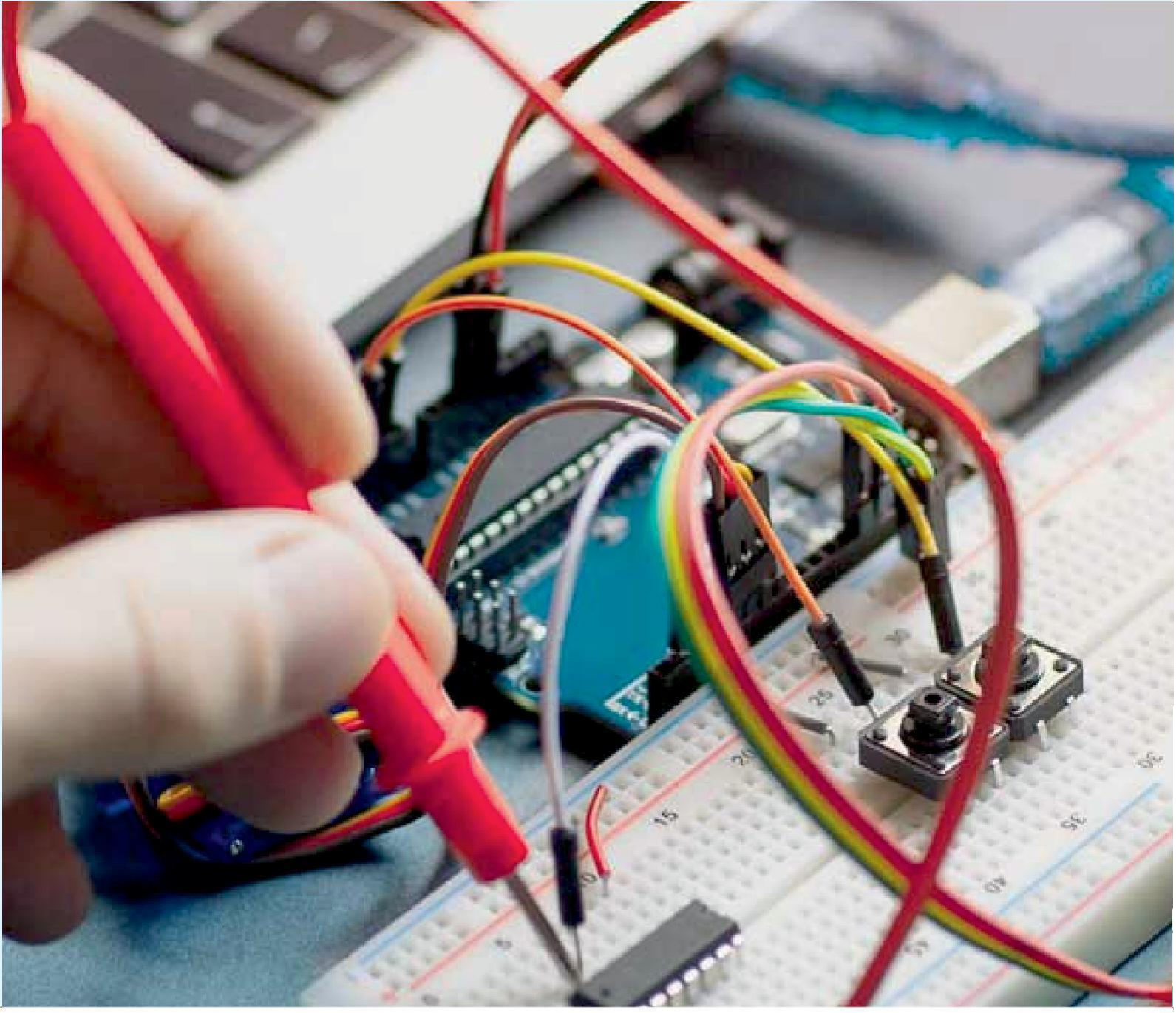

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