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GWO And MPPT Based Modified PV System Configuration for Under Mismatch Conditions

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ABSTRACT: The nonlinear characteristics and low efficiency of photovoltaic (PV) systems remain critical challenges that necessitate advanced solutions. This study proposes two innovative Maximum Power Point Tracking (MPPT) algorithms based on the Whale Optimization Algorithm (WOA) and Grey Wolf Optimization (GWO). The primary advantage of these methods lies in their adaptive step-size optimization, leveraging multiple criteria to determine the optimal step size. This study was carried out to investigate which of the smart methods used was more efficient when performing global maximum power point tracking of PV energy systems under complex partial shading conditions. For this reason, a system was designed in MATLAB-Simulink software. The intelligent algorithms, CSA, GWO, MIC, and PSO, were used as MPPT methods in the designed system. As a result of the simulations, these algorithms were compared in terms of power, convergence speed, efficiency, and oscillation criteria. These algorithms were run under five different uniform and complex partial shading conditions with six PV panels connected in series and a DC–DC boost converter. Since each PV panel was exposed to different irradiance values, six different peaks occurred. Only one of these peaks was the global maximum power point and the others were local maximum power points. Therefore, under this six-peak complex condition, it was even more difficult for the algorithms to catch and track the global maximum power point.

KEYWORDS: global maximum power point (GMPP), Grey Wolf Optimization (GWO), Maximum Power Point Tracking (MPPT), DC–DC boost converter, photovoltaic (PV)

I. INTRODUCTION

With traditional energy sources diminishing rapidly and their adverse effects on the environment becoming more apparent, the power industry sector must promptly shift towards clean and sustainable energy alternatives. As a result, renewable energy sources (RESs) such as solar, wind, biomass, tidal, and geothermal energy are emerging as viable alternatives for energy generation. Solar photovoltaic (PV) energy, in particular, is widely utilized in various engineering applications due to its abundance, ease of implementation, cost-effectiveness, noise-free operation, and eco-friendliness [1, 2]. Furthermore, advancements in PV technology have significantly reduced the cost of electricity generation per unit over recent decades. However, the nonlinear behaviour of PV cells poses challenges for PV-based systems, limiting their energy conversion efficiency [3-5]. Additionally, fluctuations in environmental conditions, such as sunlight intensity and temperature, impact the output voltage and current of PV systems.

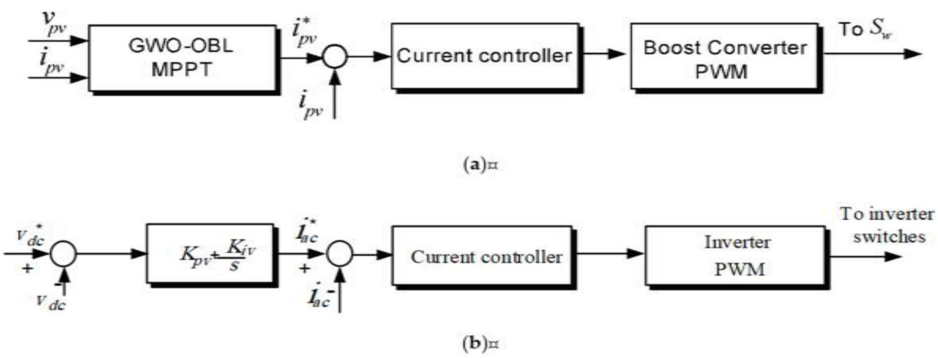

Fig 1: MPPT for a PV Grid-Connected System to Improve Efficiency under Partial Shading Conditions

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PV systems typically consist of interconnected PV panels arranged in both series and parallel configurations to meet the power demands of the load. However, when PV modules are connected in series, they often experience different levels of sunlight exposure throughout the day. This variation affects the shape of the power–voltage (P–V) curve, which normally exhibits a distinct maximum power point (MPP) under consistent environmental conditions. With changing sunlight exposure, the MPP shifts along the P–V curve. This continuous change in the position of the MPP results in fluctuating output power from the PV array. Partial shading (PS) occurs when certain PV modules receive non-uniform sunlight due to factors like cloud cover, building shadows, vegetation, dust accumulation, and PV cell degradation. This PS condition significantly reduces the efficiency of power generation in PV systems. To mitigate the impact of PS, bypass diodes are often installed in parallel with PV modules [4]. However, this arrangement leads to a complex P–V characteristic with a global MPP (GMPP) and multiple local MPPs (LMPPs).

As a result, various techniques have been developed to address these challenges and optimize power extraction. The conventional MPP tracking (MPPT) methods [6, 7] encompass a range of techniques such as constant voltage (CV), incremental conductance (InC), open-circuit voltage (OCV), short circuit current (SCC), hill climbing (HC), perturb and observe (P&O), enhanced P&O), and lookup table approach. These approaches are straightforward to implement due to their algorithmic simplicity. They prove most effective under consistent irradiation situations since the PV system only produces a single MPP in such conditions. However, these approaches struggle to identify the global GMPP among the multiple peaks present in the P–V characteristics under PS conditions. Advanced intelligent techniques [6, 8] encompass a variety of strategies, including fuzzy logic control (FLC), artificial neural networks, sliding mode control, MPPT approaches based on the Fibonacci series, and those based on the Gauss–Newton method to effectively track the GMPP. These algorithms rely on past data for their search criteria, which means that storing and processing a significant amount of training data can slow down convergence. Additionally, their performance is compromised by factors like the absence of training data and inconsistencies in the available data, resulting in inaccurate outcomes.

II. BACKGROUND WORK

In energy electronics systems, renewable energy generation in an infinite number of industrial and social applications has become increasingly relevant. The PV systems have become very popular for electricity supply solutions worldwide from all renewable energy sources due to their suitability. Furthermore, [18] notes that energy harvested by photovoltaic systems is expected to be a great choice for both advanced and developing economies as demand for energy will increase by 30% in 2040. (according to [10,16]). Photovoltaic systems are an alternative to conventional energy production in almost every country in the world such as reduced emissions of Greenhouse gas, inexhaustible solar fuel, green nature and so on. India also targets 100 GW of electricity in large and small solar parks by 2022 to meet increasing energy demand [1,3].

The PV system is equally present in single or two-diiodide models and is worked at a maximum power point (MPP) because of its low efficiency to achieve maximum power output [5]. Varied atmospheric conditions impact PV systems, one of these phenomena is partial shading of PV modules (because of cloud passage, Shadows, bird waste, etc. construction). In PSC, its non-linear properties are subject to multiple maximum performance points due to operation PV systems of the bypass diode across shaded modules [2], so operational at a global MPP is necessary. A great deal can be done to mitigate the PSC effect. This task is to run the PV system on the global MPP on PSCs using MPPT controllers. MPPT controllers, PV array resetting's, Power Converter settings, etc [4,5]. Despite traditional MPP techniques, like Perturb & Observe (P&O), Hill Climbing (HC) and others, MPPs are easily tracked under uniform shadow conditions [18]. In literature, several writers have used intelligence-based techniques, including the ANN method and the Fuzzy system to derive full power from the PSC system [9,10].

Meta-heuristic techniques based on MPPT have recently become common due to their accuracy and dependence on the system [3]. Several authors suggested MPPT algorithms focused on the Specific Swarm Optimization [6,7], Ant Colony optimization [14], Firefly [12], Grey Wolf Optimizer [8], and Whale Optimization Algorithms [11,18]. MOP algorithms were also proposed by some writers. MPPT techniques are usually divided by the MPP monitoring section into direct and indirect control methods. All these algorithms vary greatly in precision, performance, time, and complexity of the tracks [13]. It explains that premature convergence problems and even the complexity of the algorithm have limited the use of the algorithm on real PV systems, which must be modified in PSO-based MPPT.

The premature algorithm convergence has also been studied in [17], when results show that the classic PSO-based solution might collapse into a local solution to generate larger oscillations as a consequence of the required re-

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initialization of the algorithm following irradiation changes. (as validated in [11]). In conventional GWO Algorithms, δ and ω, these wolves are not much contributing to the hunting of the prey, as they are subordinated to α and β [15]. This paper deals with alpha and all wolves as the α and β wolves, where alpha is the cattle's chief and the best option, are eliminated by Enhanced MPPT Gray Wolf Optimizer (MGWO). The proposed MGWO, therefore, contributes to a rapid search method to track global MPPs in less time.

III. METHODS

PV energy systems have some disadvantages as well as all these advantages. These are low energy efficiency, high production cost, and high initial investment cost. The characteristic curve of the PV panel is not linear. In other words, it depends on the irradiation level and temperature factors. Therefore, the value of power at the maximum power point in a PV energy system varies depending on weather conditions. To eliminate all these negativities and increase efficiency, tracking the maximum power point has been considered as a way forward. The MPP defines the maximum possible power that can be produced from a PV panel. Maximum power point tracking (MPPT) is desired to operate the panel at the point where the highest possible power will be provided. If the operating point is close to the MPP, low power losses are observed, and if it is distant from it, high-power losses are observed. Therefore, proper tracking of the MPP in changing weather conditions is essential to ensure maximum power is drawn from the PV panels.

In modern renewable PV energy systems, this process is provided by MPPT algorithms. In other words, a DC–DC converter is used that controls the duty cycle value depending on the voltage and current values obtained from the panel. In addition, through the MPPT system, the operating point can be adjusted to produce the highest maximum power. Therefore, considering this information, the MPPT system can be defined as an electronic system designed to produce maximum power by changing the duty cycle of PV panels. Numerous methods have been developed and studies have been conducted on maximum power point tracking in the last decade in the literature. These methods were compared in terms of criteria such as convergence speed, tracking accuracy, efficiency, complexity, and cost. A PV panel shows only one MPP when exposed to constant irradiation and using any of the traditional MPPT methods this point can be easily tracked. Examples of classic MPPT methods include perturbed and observed (P&O) [9], incremental conductivity (IC), open-circuit voltage, and short-circuit current. Research on these has generally focused on the speed of convergence to MPP and high tracking accuracy. However, the panels may not receive homogeneous irradiation at all hours of the day due to many environmental factors, such as moving clouds, shade from buildings and trees, and dusting. When partial shading conditions occur, more than one maximum power point occurs in the PV curve. In this case, classic methods will fail to track the appropriate GMPP.

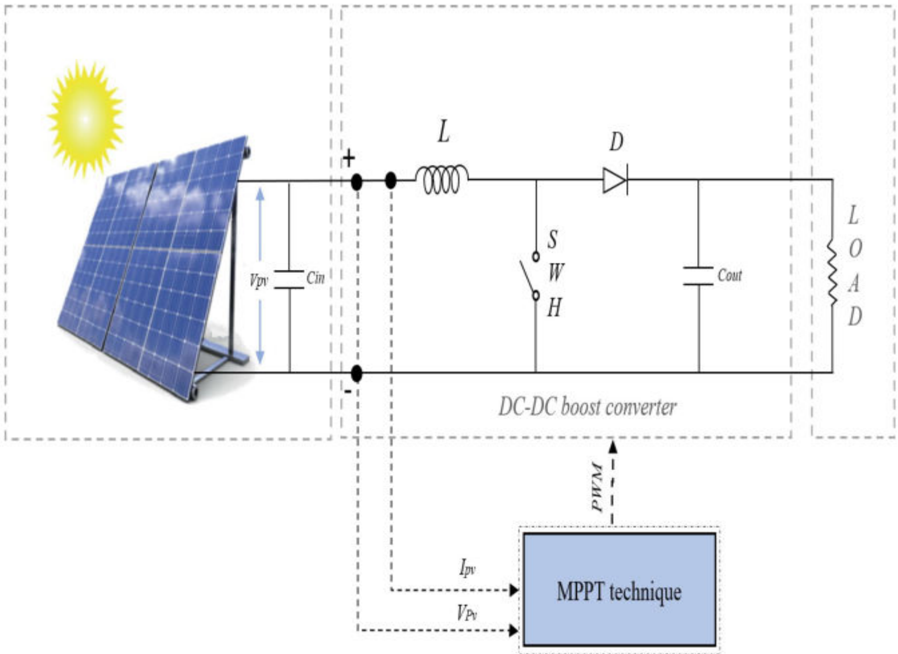

Fig 2: A New MPPT-Based Extended Grey Wolf Optimizer for Stand-Alone PV System

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The two most important factors that determine the maximum power that can be obtained in PV energy systems are the solar irradiation and the temperature. The power obtained from the PV panel is calculated by multiplying the panel voltage and the current. There is a standard test condition for PV energy systems. This condition is used to assess the efficiency of PV energy systems. In the datasheets of PV panels, there are generally values in these standard test conditions. In the power–voltage characteristic curve, there is a maximum power generated for a given voltage and current value. Standard test conditions are defined as 1000 W/m^2 irradiance and 25 °C temperature. Panels may operate under partial shading conditions due to environmental factors, such as the shadows of clouds, tall buildings, tree branches, or other objects moving on the PV panels. In such a case, solar panels with less irradiation on them will receive less current than other panels. The reduced current of the panels will cause a decrease in the output power value. In this case, the high current obtained in the panels that are not under shading damages the panels operating under partial shading. To prevent this harm, bypass diodes connected in parallel are added to all PV panels. Thus, the high current to be obtained will proceed through the bypass diode circuit and prevent damage to the PV panels operating under partial shading conditions.

IV. RESULT ANALYSIS

As a result, the physical structures of the PV panels due to overheating are damaged. To prevent such undesirable situations, bypass diodes are added to all PV panels in parallel. Bypass-connected diodes are passive in normal operation, where they are not subject to partial shading. That is, they do not affect the system. However, when exposed to partial shading, diode circuits connected to the bypass in the PV panels with shading become active and take precautions against the hot-spot event. In addition to all these benefits of bypassing connected diodes, they also have different problems. One of these problems is the inability to produce power or energy on the PV panel, which is exposed to partial shading where the bypass-connected diode circuit operates. Thus, the maximum power value decreases. Due to the presence of bypass-connected diodes, peaks occur in the power–voltage characteristic curve of the PV energy system as often as the number of different irradiations. As a result, the system becomes complex.

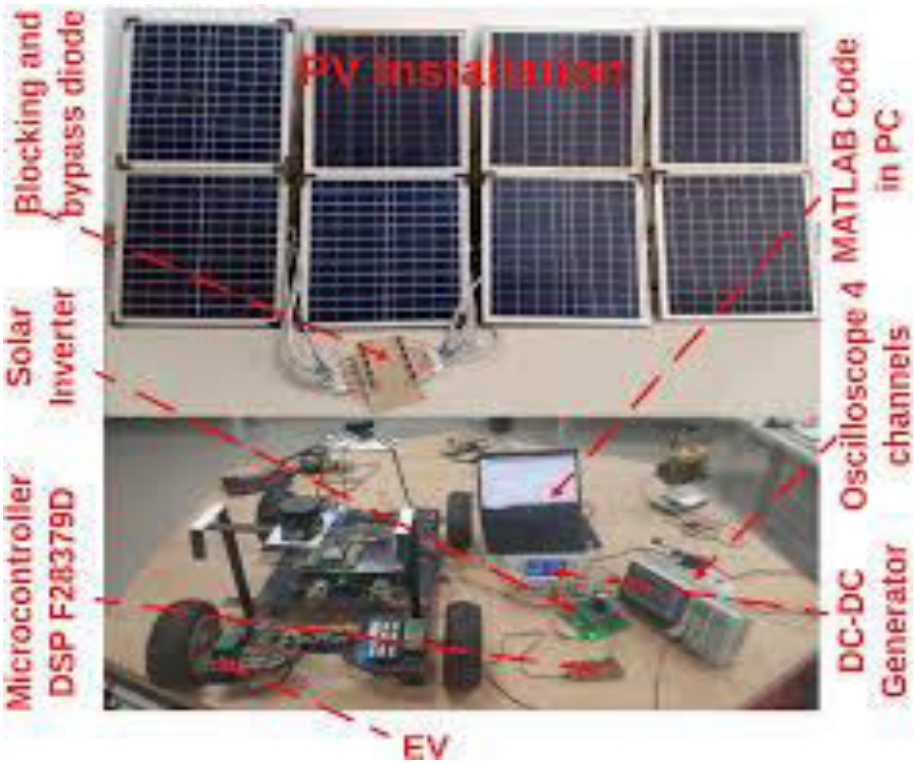

Fig 3: Hybrid GWO MPPT

DC–DC converters are electronic circuits that are widely used to convert unregulated DC input power to regulated DC output power at different voltage and current levels. They are used to adjust and control the varying output power of solar panels to ensure that the operating point is always at MPPT. This can be accomplished using one of the MPPT techniques to change the duty cycle (D) applied to drive the converter. The DC–DC boost converter is one of the most widely used topologies among power electronics circuits. It is used in applications where the output voltage is required to be higher than the input voltage. The desired output voltage can be obtained by changing the duty cycle applied to the switch under a fixed frequency.

When using a boost converter to regulate a PV array, either an open or closed loop can be utilized. When operating at constant current and low irradiance, a photovoltaic array's dynamic resistance is at its lowest. The stability and dynamic response are terrible. A single-loop PI voltage controller cannot close-loop control the array voltage because the system's dynamic response depends on the operating point and environmental conditions. Inner control requires a boost converter inductor current loop. Two PI controllers and a costly current sensor are required for this solution. It is most common to control a boost converter in an open loop. There is no feedback in this approach; the proper input voltage is obtained by comparing the input and output voltages of the converter. This method eliminates the need for an expensive current sensor by not measuring the inductor current. The system response may result in more transient and steady-state errors than the closed-loop method. In PV MPPT, sampling time is a key parameter. Before applying a new command voltage V_{in}^{ref} to the converter after the system's transient response has stabilized, a voltage and current sample must be taken from the array. So, sampling must take longer than the settling time.

V. CONCLUSION

According to the simulation results in this study, it was seen that the first and third cases were the cases where all the algorithms successfully tracked the global maximum power point at the same time. However, the same was not true for the other complex partial shading conditions. Despite this complexity and difficulty, GWO was successful in the simulations. Compared to the other algorithms, it was observed that GWO successfully performed global maximum power point tracking with high convergence ability and tracking speed in all five conditions. It was observed that GWO did not oscillate while tracking the global maximum power point. The fact that GWO did not oscillate reduced power losses and, therefore, increased efficiency. The average convergence speed of GWO to the global maximum power point was obtained as 0.22 s. The average efficiency of GWO was obtained as 99%. All these evaluations show that GWO is a very fast, highly accurate, efficient, and stable MPPT method under complex partial shading conditions. In future studies, it is anticipated that efficiency analyses will be undertaken using the designed system and GWO, running them with real-time data.

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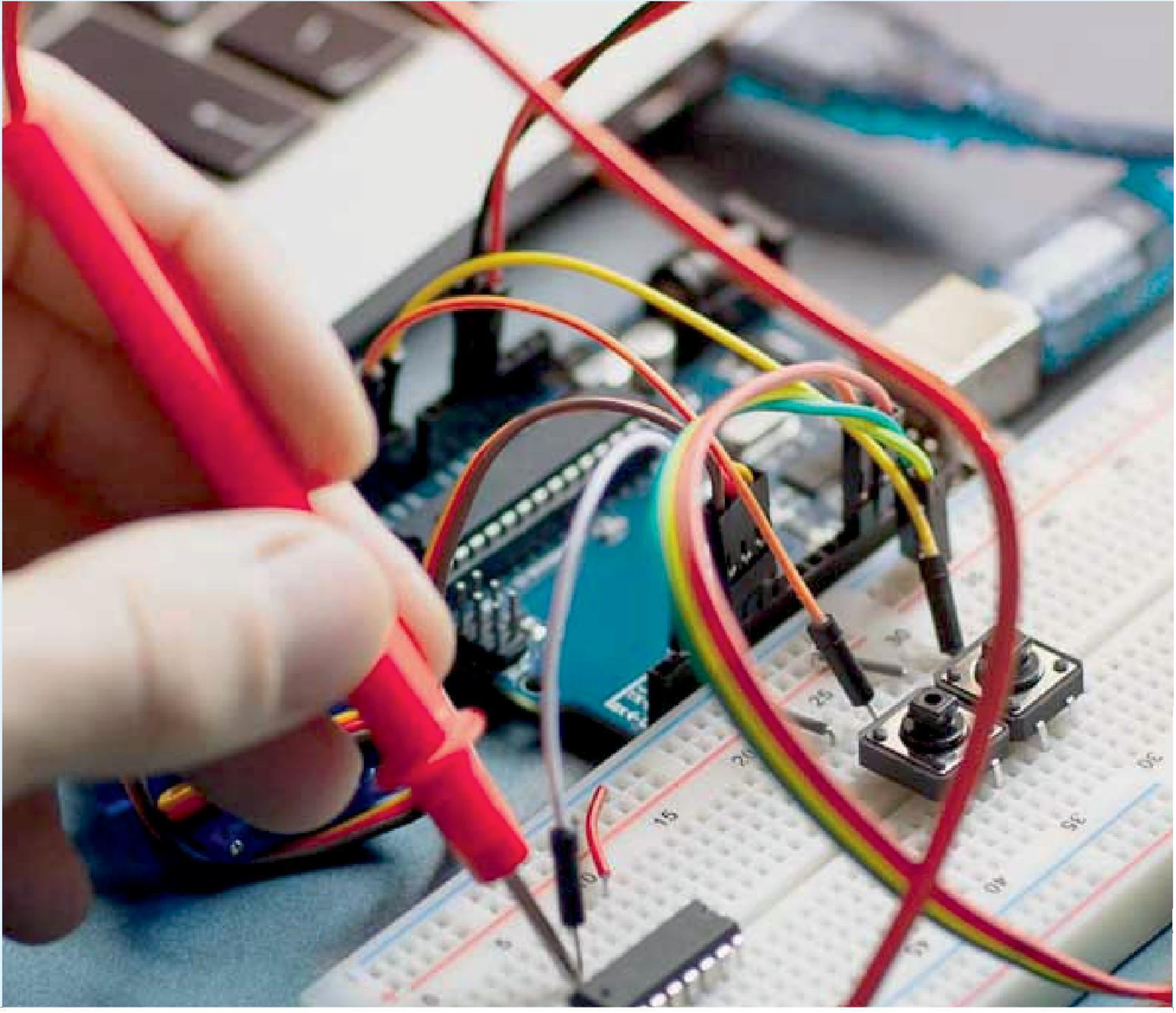

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