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MPPT Based Grid-Tied Z-Source Inverter with PV System

A. Latha, C. Dhinesh Kumar

PG Student [PSE], Arulmigu Meenakshi Amman College of Engineering, Tiruvannamalai, Tamil Nadu, India

Head of the Department [EEE], Arulmigu Meenakshi Amman College of Engineering, Tiruvannamalai, Tamil Nadu, India

ABSTRACT: Maximum Power Point Tracking (MPPT) method for a grid-tied Z-Source Inverter (ZSI) that interfaces Photovoltaic (PV) sources to the grid. The proposed MPPT method maximizes the energy harvest by guaranteed convergence to Maximum Power Point (MPP) under dynamic weather condition from the PV panels by the ZSI as a Power Electronics Interface (PEI). The proposed method uses the concept of Model Predictive Control (MPC) in conjunction with Extreme Seeking (ES) optimization to track the true maximum power point and can operate without prior knowledge of the PV panel parameters or ambient condition. At the grid side, the system injects to the grid maximum harvested energy from the PV panel obtained using the proposed MPPT algorithm. In addition, the ratio of active/reactive power injected to grid is controlled (power factor control). The optimal switching signal is determined and applied to the ZSI by minimizing the developed MPC cost function, thus eliminating the need for a modulator which simplifies the controller schematic for ZSI and can be implemented with reasonable processing effort on an in expensive digital controller. The proposed method in this project features: fast dynamic response to change in ambient PV panel condition, true and guaranteed convergence to MPP, negligible oscillation around MPP, and simple control structure without requirement of many cascaded control loops.

KEYWORDS: Maximum Power Point Tracking, PV System, Z Source Inverter.

I.INTRODUCTION

Photovoltaic systems are one of the most promising renewable electric power generation systems due to their low environment impact and high availability of solar irradiation in most geographical locations. However, the downside to the PV power systems is the cost of the required equipment. To compensate for the high initial cost of the PV infrastructure, it is imperative that a solar-generation system always operates near its most efficient operating point, thus Maximum Power Point Tracking (MPPT) for PV systems is essential.

Grid tied PV systems commonly use a two-stage power electronics interface: an upstream dc/dc power conversion stage from the PV module to a dc link energy buffer element, and a downstream dc/ac power conversion stage from the energy buffer element to the grid. Commonly, in these PV systems architectures, the MPPT is implemented in the upstream dc/dc conversion stage and is only responsible for transferring the maximum available energy from the PV panel to the intermediate energy buffer.

The responsibility of the downstream stage is to control the flow of energy to the grid by generating controllable ac voltages synchronized with the grid voltage. The use of a two-stage topology is necessitated due to the inherent limitation of the dc/ac inverters for stepping up/down the voltage freely. Therefore, a conventional dc/ac inverter in general, cannot both step-down and step-up the voltage freely. As mentioned above, the MPP voltage of a PV module is not constant and needs to be tracked by the PV harvesting system. This voltage can be higher/lower than the grid

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voltage based on the environmental conditions, necessitating a power conversion system that can step up/down the voltage freely to track the MPP accurately.

II.SYSTEM MODEL

Maximum Power Point tracker with guaranteed convergence under fast dynamic change in the ambient condition of the PV panel. It can operate without a priori knowledge of the PV panel parameters. Single stage PEI based on impedance source inverter for PV applications with the capability to converge to true MPP operation. A new discrete-in-time ES based predictive MPPT algorithm is proposed for PV power harvesting systems using ZSI. The mathematical proof of convergence of the proposed method was provided to guarantee its effectiveness for tracking the MPP.

Photovoltaic systems are one of the most promising renewable electric power generation systems due to their low environment impact and high availability of solar irradiation in most geographical locations. However, the downside to the PV power systems is the cost of the required equipment. To compensate for the high initial cost of the PV infrastructure, it is imperative that a solar-generation system always operates near its most efficient operating point, thus Maximum Power Point Tracking (MPPT) for PV systems is essential.

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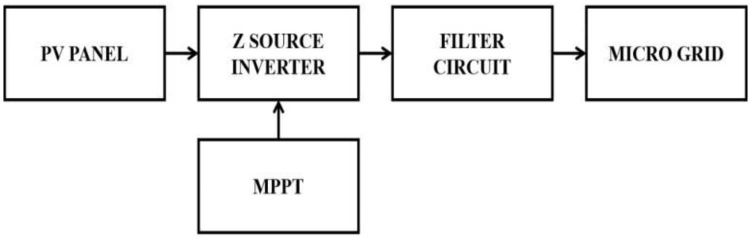

Fig 2.1 Block Diagram

This voltage can be higher/lower than the grid voltage based on the environmental conditions, necessitating a power conversion system that can step up/down the voltage freely to track the MPP accurately. Hence, the dc/dc stage in the conventional systems is used to step up/down the dc link voltage freely when necessary. Recently a new converter topology, denoted as the impedance-source converter, is developed by the researchers that undermine the limitations with the conventional VSIs and CSIs. These new converters provide several advantages for a variety of applications with different input-output requirements.

In particular, a class of dc/ac inverters designed based on the concept of impedance-source conversion, denoted as Z-Source Inverter (ZSI), can step up/down the voltage freely, and thus are very well suited for designing single-stage PV harvesting systems. Moreover, the ZSIs feature several additional advantages over the conventional inverters that makes them even more appealing for energy harvesting systems such higher efficiency and reliability. Although very resourceful, the ZSIs operate differently than conventional inverters due to incorporation of energy storage elements in their input port and thus require new and innovative control strategies to boost their performance.

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A new MPPT method that maximizes the amount of power extracted by the ZSI from the PV panel based on the concept of Model Predictive Control (MPC) in conjunction with Extreme Seeking (ES) optimization algorithm. An overview of existing MPC based MPPT techniques is published. The authors are estimating the PV voltage of ZSI at sampling time (k+1) assuming two possible scenarios; the PV voltage is either going up or down at (k+1) sampling. Then based on an observer the MPP operating point is calculated. However, this approach do not use MPC to achieve MPPT and control the ZSI. The authors developed a MPC-MPPT method based on conventional perturb & observe (P&O) or Incremental Conductance (INC) to identify MPP. The P&O/INC algorithm generates reference current or voltage points at MPP. Then a MPC algorithm is used to regulate the PV current/voltage to the generated reference points.

III. WORKING PRINCIPLE

The PV voltage and current of the ZSI are directly made through a predictive control approach and taking advantages of ES optimization algorithm. The proposed method is a true maximum power point tracker with guaranteed convergence under fast dynamic change in the ambient condition of the PV panel.

It can operate without a priori knowledge of the PV panel parameters, which are typically unknown and subject to change with ambient condition variation. It worth to mention that, we are not forecasting the PV ambient condition nor the PV model. We are looking into how PV ambient condition fluctuation affects the PV power harvesting through predictive model of the power electronics interface (ZSI) and the proposed extreme seeking maximum power point tracking algorithm. At the grid-side, the proposed controller for ZSI inject the maximum available power determined by the MPPT algorithm to grid with adjustable power factor (p.f.) by minimizing the MPC cost function to determine the switching signals for the inverter.

The main features of the proposed system are: (a) True maximum power point tracking under dynamic ambient condition with fast dynamic response and negligible oscillation around MPP, (b) A predictive optimal controller based on ES algorithm is proposed without needing a modulator that can be implemented with reasonable processing effort on an inexpensive digital controller, (c) High efficiency and reliable operation due to the single power conversion ZSI, (d) Simple control architecture without needing many cascaded loops as in classical linear control methods for ZSIs.

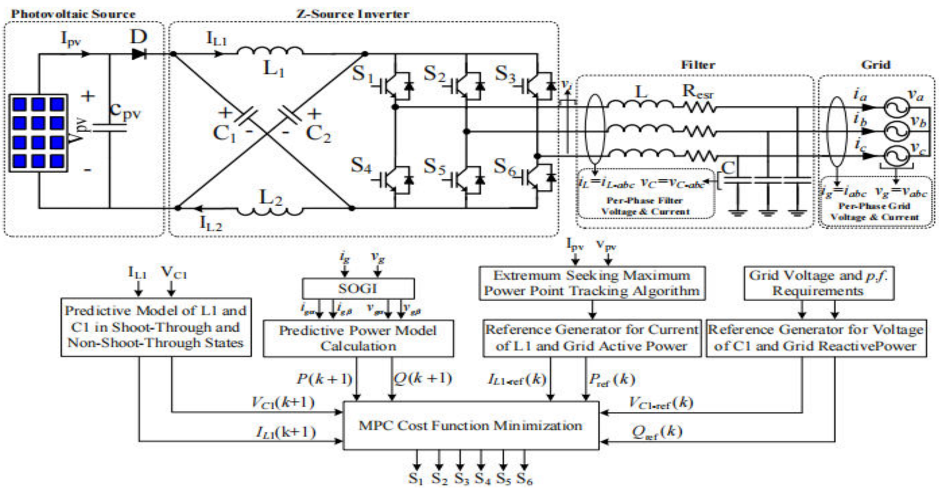

Fig 3.1 Circuit Diagram

The PV panel which provide the DC voltage to Z source inverter which consists of three phase output to grid through the filter. Filter is used to filter the surge from the z-source inverter to get the pure AC voltage at maximum level. General schematic of the proposed power electronics interface based on grid-tied z-source inverter for photovoltaic application.

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$$\frac{d}{dt} i_L(t) = \frac{1}{L}(v_i(t) - v_g(t) - i_L(t) R_{esr})$$
$$\frac{d}{dt} v_C(t) = \frac{d}{dt} v_g(t) = \frac{1}{C}(i_L(t) - i_g(t))$$

where iL (t) is the inductor current, vi (t) is the output voltage of the inverter, vg (t) is the ac grid voltage, L and C are the filter's inductance and capacitance values, and Resr is the equivalent series resistance of the inductor. By applying the Euler forward approximation method, they can be discretized.

$$\tilde{i}_L(k+1) = \frac{T_s}{L}(v_i(k) - v_g(k) - i_L(k) R_{esr}) + i_L(k)$$
$$\tilde{v}_C(k+1) = \frac{T_s}{C}(i_L(k) - i_g(k)) + v_C(k)$$

One of the main characteristics of ZSI is its shoot-through mode for flexible boosting of the input (PV) voltage. In this mode, both switches in one leg of the inverter are simultaneously turned ON. The equivalent circuit model of the ZSI for shoot-through mode and non-shoot-through modes (active states) are illustrated. Using these equivalent circuits and Euler forward approximation, the predictive model of the Z source network can be developed.

IV. SIMULINK MODEL

With the detailed Matlab program and with this model we able to get the clear output. Simulation has become a very powerful tool on the industry application as well as in academics, nowadays. It is now essential for an electrical engineer to understand the concept of simulation and learn its use in various applications.

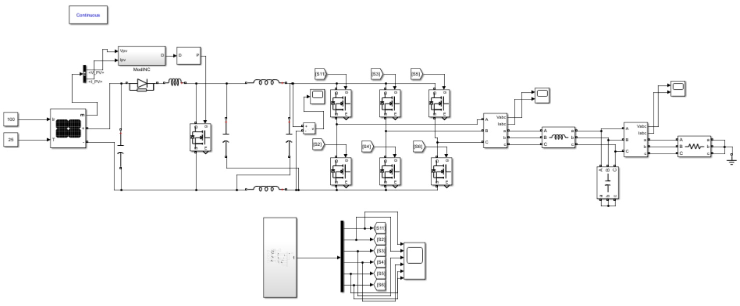

Fig 4.1 Simulink model diagram

Simulation is one of the best ways to study the system or circuit behavior without damaging it the tools for doing the simulation in various fields are available in the market for engineering professionals.

V. SIMULINK RESULTS

Maximum Power Point tracker with guaranteed convergence under fast dynamic change in the ambient condition of the PV panel. It can operate without knowledge of the PV panel parameters. Single stage PEI based on impedance source inverter for PV applications with the capability to converge to true MPP operation. A new discrete-in-time ES based predictive MPPT algorithm is proposed for PV power harvesting systems using ZSI. The mathematical proof of convergence of the proposed method was provided to guarantee its effectiveness for tracking the MPP.

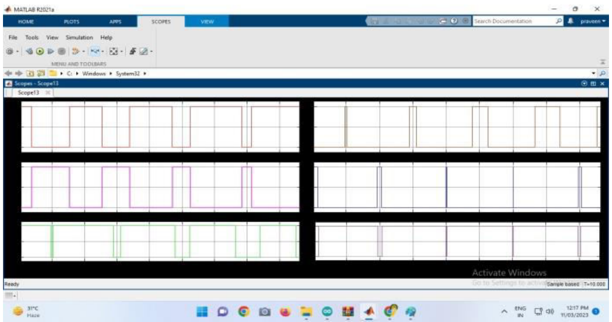

Fig 5.1 Output Pulse

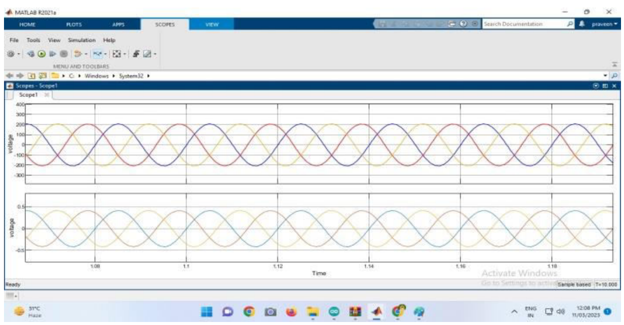

Fig 5.2 Three Phase Output

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The y-axis indicates the voltage level with the scale of 100v per cm and y-axis indicates time. The detailed graph shows the final output of the model. We will get the clear output with filter circuit.

VI. HARDWARE MODEL

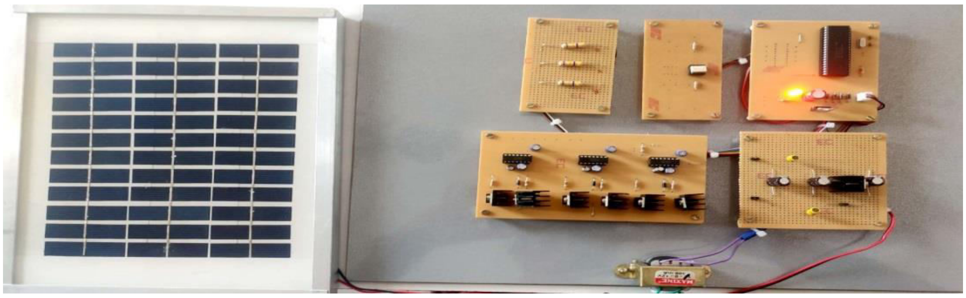

Fig 6.1 Hardware

Maximum Power Point Tracking (MPPT) method for a grid-tied Z-Source Inverter (ZSI) that interfaces Photovoltaic (PV) sources to the grid. The proposed MPPT method maximizes the energy harvest by guaranteed convergence to Maximum Power Point (MPP) under dynamic weather condition from the PV panels by the ZSI as a Power Electronics Interface (PEI) using the proposed MPPT algorithm.

The main hindrance for the penetration and reach of solar PV systems is their low efficiency and high capital cost. In this thesis, we examine a schematic to extract maximum obtainable solar power from a PV module and use the energy for a DC application. This project investigates in detail the concept of Maximum Power Point Tracking (MPPT) which significantly increases the efficiency of the solar photovoltaic system. Solar energy can be utilized in two major ways. Firstly, the captured heat can be used as solar thermal energy, with applications in space heating. Another alternative is the conversion of incident solar radiation to electrical energy, which is the most usable form of energy

VII. HARDWARE RESULT

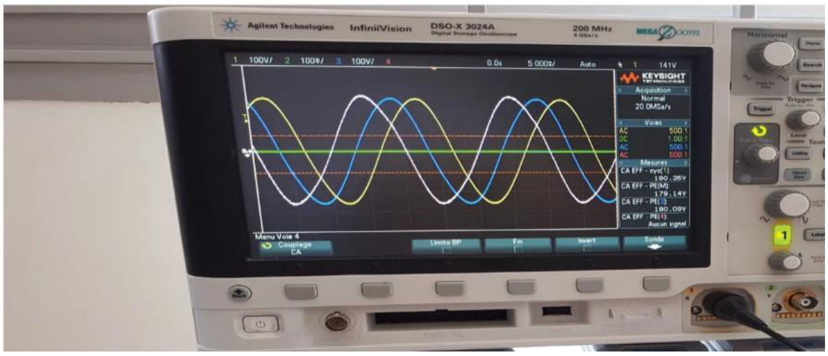

Fig 7.1 Hardware Result

The output of the three phase load is shown in the CRO. The proposed method uses the concept of Model Predictive Control (MPC) in conjunction with Extreme Seeking (ES) optimization to track the true maximum power point and can operate without knowledge of the PV panel parameters or ambient condition. To gain maximum voltage forms the Z-source inverter with the help of fuzzy controller.

VIII. CONCLUSION

A single stage PEI based on impedance source inverter for PV applications with the capability to converge to true MPP operation, A new discrete-in-time ES based predictive MPPT algorithm is proposed for PV power harvesting systems using ZSI. The mathematical proof of convergence of the proposed method was provided to guarantee its effectiveness for tracking the MPP, Several experimental results were provided to validate the operation of the proposed method. The

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results demonstrate the proposed controller features: converges to true MPP with average tracking efficiency of 98.8% in steady state PV ambient condition, fast dynamic response to change in ambient condition of PV module.

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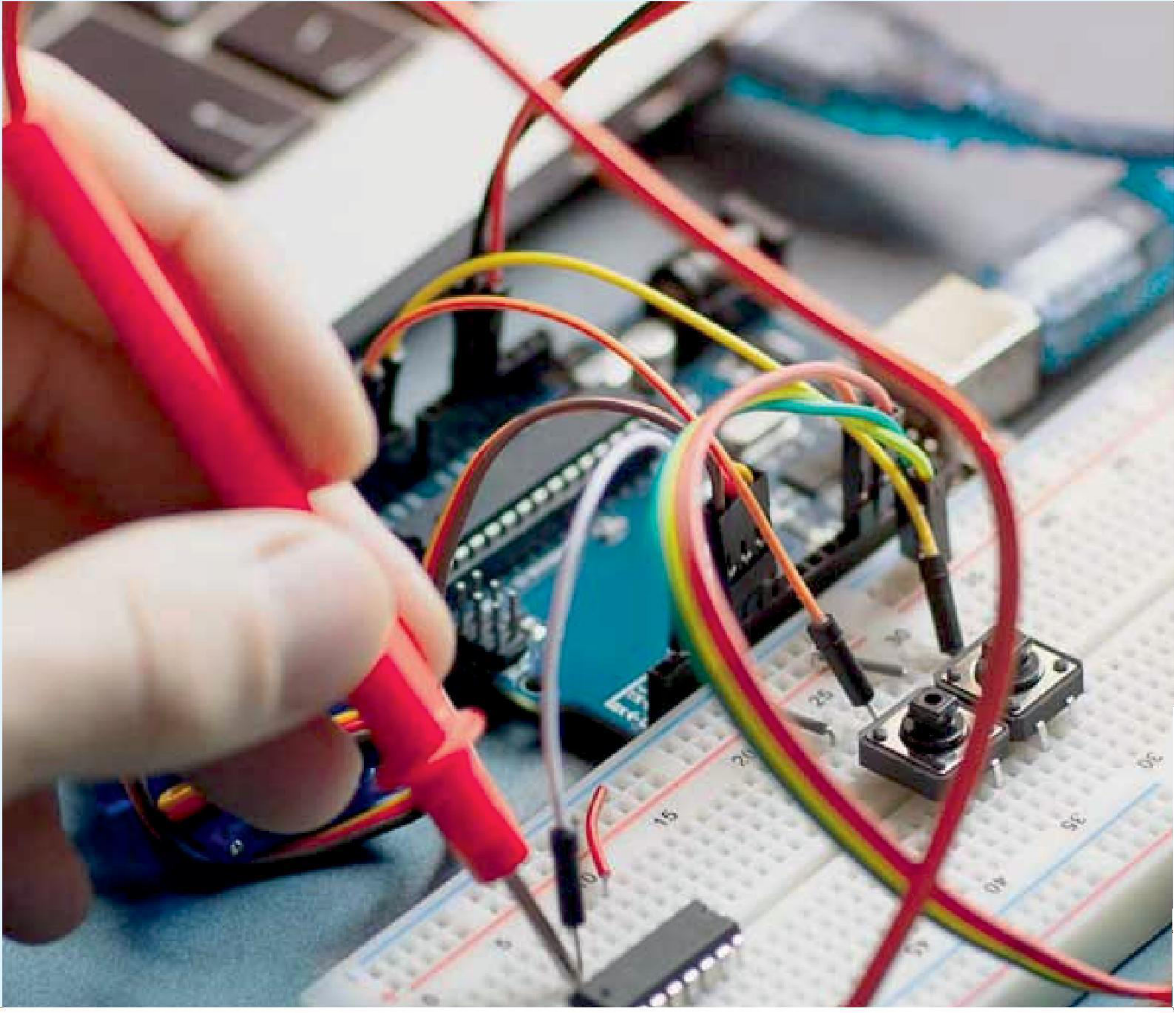

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