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Integration of Microgrid with Utility Grid Using ANFIS Controlled Converter

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ABSTRACTAs a low-pollution and high-efficiency power-generation system, microgrid has been widely favoured in recent years. In the developed countries, it has gradually become a new way to solve many problems in the traditional power system. According to the different of the bus, microgrid can be classified as the AC microgrid and the DC microgrid. The master-slave control, peer-to-peer control, hierarchical control, and multi-agent control have been analyzed in the application of the AC microgrid.DC microgrid has become a research hotspot because of the lower line loss and the higher efficiency of energy transmission. According to the limitation of traditional control strategy for DC bus voltage, an energy management based on local information and coordination control was proposed, which effectively solved the deviation problem. However, the DC bus voltage has a large fluctuation during mode switching in the simulation. The battery life was affected because of the frequent charging and discharging.

KEYWORDS:DC Microgrid, MPPT Control, Utility grid, ANFIS Control, Fuzzy-PI Controller.

I.INTRODUCTION

As a low-pollution and high-efficiency power-generation system, microgrid has been widely favoured in recent years. In the developed countries, it has gradually become a new way to solve many problems in the traditional power system [1, 2]. According to the different of the bus, microgrid can be classified as the AC microgrid and the DC microgrid. The master-slave control, peer-topeer control, hierarchical control, and multi-agent control have been analysed in the application of the AC microgrid [3–5]. It does not need considering frequency and phase in the DC microgrid. Compared with the AC microgrid, DC microgrid has become a research hotspot because of the lower line loss and the higher efficiency of energy transmission. Some DC power system have been established to research-related issues, such as 10 kW DC power distribution system in Tokyo Institute of Technology in 2004 [6], DC microgrid system to provide power for different loads in Virginia Polytechnic Institute and State University in 2010 [7], DC power supply system and microgrid research centre in Myongji University [8]. At the same time, the technology about DC microgrid has also been continuously renovated and broken through in China. Some universities and research institutes have set up their exemplary platform. Rich achievement has been got. The researches of DC microgrid mainly include system modelling, topology selection, control strategy, operation optimising, system detection, fault diagnosis, technical standards, economic benefits etc. [9]. In [10], the hierarchical coordinated control strategy based on the bus voltage was adopted. Here, the droop control was employed to distribute energy equally among distributed power sources. A strategy of power derated for non-essential load was putforward when the system is necessary to keep DC bus voltage stability. According to the limitation of traditional control strategy for DC bus voltage, an energy management based on local information and coordination control was proposed, which effectively solved the deviation problem [11].
However, the DC bus voltage has a large fluctuation during mode switching in the simulation. The battery life was affected because of the frequent charging and discharging. Here, in order to realise the coordinated control of DC microgrid system, an energy management system was designed. The variable step incremental conductance method was taken to realise maximum power point tracking (MPPT). The adaptive fuzzy-PI controller was designed based on the traditional voltage and current double closed-loop control system, which improved the robustness of the system.

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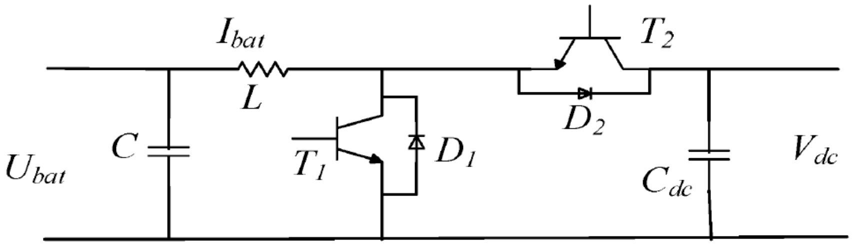

Fig1: control strategies of bidirectional DC/DC converter

II. CONTROL SYSTEM

2.1 Energy management system This paper focuses on the independent DC microgrid with photovoltaic and energy-storage systems, and its structure is shown in Fig. 1. In DC microgrid, the balance of the system energy corresponds to the DC bus voltage stability. That is: Pc = Ppv + Pb + Pg − Pload (1) Ppv + Pb + Pg − Pload = CVdcdVdc dt (2) where Pc is the charging power of the DC bus capacitor, W; Ppv is the photovoltaic output power, W; Pb is the battery power, W; Pg is the transmission power between microgrid and power grid, W; Pload is the power demand of the load, W; C is the bus capacity, F; Vdc is the DC bus voltage, V. Since this paper studies the independent DC microgrid, the transmission power between microgrid and power grid Pg should be zero. The strategy to keep DC bus voltage steady determined the stability of the DC microgrid system. Here, the coordinated control strategy based on energy management system was adopted to control the DC bus voltage. The coordinated control strategy of energy management is designed as shown in Fig. 2

2.2 Control structure of the interface In the microgrid, the output voltage and the current variation of the distributed generator were determined by the control strategy of the interface converter and had no direct correlation with the distributed generator [12]. As illustrated in Fig. 1, the photovoltaic and the battery are connected to the microgrid by unidirectional DC/DC and bidirectional DC/DC, respectively. The control structure of the interface is shown in Fig. 3. The battery gets bidirectional energy flow with the DC microgrid through the Buck-Boost transformation. The photovoltaic is controlled to supply energy by the DC/DC boost circuit. Here, the battery is selected as the voltage stabilising unit of the DC microgrid system. There is a relationship between the battery and the DC bus voltage during the Buck-Boost transformation. (1) Buck mode: ΔiL + = Vdc − Ubat L d1T (3) ΔiL − = − Ubat L (1 − d1)T (4) ΔiL + = ΔiL − (5) According to the formula (3)–(5), get the following equation: Ubat = d1Vdc (6) (2) Boost mode: Vdc = Ubat 1 − d2 (7) where Ubat is the voltage of battery, V; ΔiL + is the charged current of the inductor, A; ΔiL − is the discharged current of the inductor, A; T is the switching period, S; L is the inductor on the side of the battery, mH; d1 and d2 are duty cycle, %.

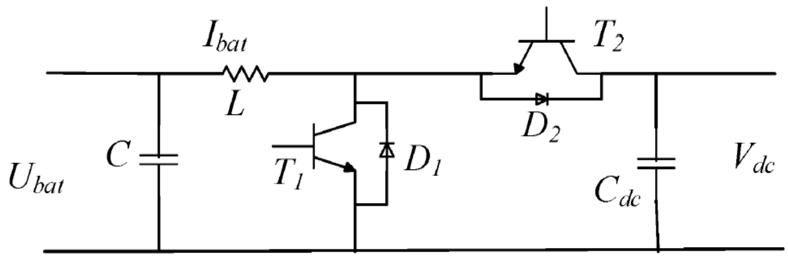

Fig 2.2 under directional DC/DC Converter

2.3 Correlation between microgrid & regular power network:

The deviations between ordinary power network and Microgrid are:

The yield abilities of creating power by micro sources are significantly smaller when contrasted with a regular power plant that can deliver.Microgrid establishments are normally nearer to the client stack which prompts low misfortune in transmission lines. Microgrids are in this manner exceptionally productive as far as voltage supply and recurrence profile instead of concentrated power plant with transmission and appropriation arrange is shown in fig

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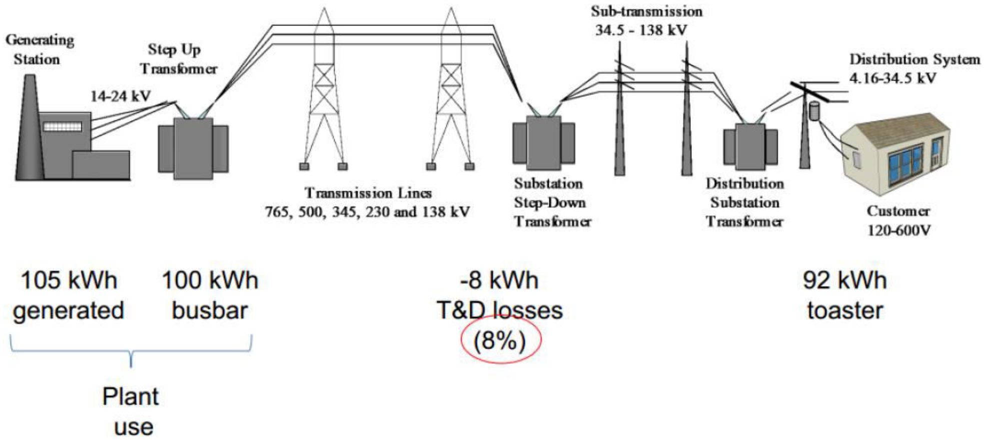

Fig 2.3 General architecture of centralized electric power

It is more reasonable in Microgrid to mine energy to remote regions where it is nearly not appropriate for the national lattice.The procedure of customary power network reclamation is cumbersome. It requires a quick intercession, generally physically and progressively while with a Microgrid technique the whole rebuilding procedure is simple in light of the set number of controllable factors.

III. SELF-ADAPTIVE FUZZY-PI CONTROLLER

Self-adaptive fuzzy-PI controller In the double closed-loop control strategy, the traditional PI controller had a low adaptation to the non-linear system, and it could be improved by the intelligent algorithm. Fuzzy control was a kind of intelligent control method based on the fuzzy set theory, the fuzzy linguistic variable, and the fuzzy logic inference. It had the characteristics such as the simple algorithm, the good adaptability, and easy realisation. Fuzzy control strategy could handle the time-varying and non-linear system whose accurate model was difficult to establish, and it had been widely used in the designing of the controller [14, 15]. Here, the self-adaptive fuzzyPI controller was designed to improve the traditional double closed-loop PI control strategy. The schematic diagram of the improved strategy is shown in Fig. 6. The voltage error and the error rate are used as the input of the fuzzy controller. The variation of the proportional coefficient and the integral coefficient is used as the output. There is the discrete form of fuzzy PI control. That is: $u(k) = Ku(k) \times e(k) + Tu(k) \times \sum i = 0\ k\ e(i)$ (13) $Ku\ (k + 1) = Ku\ (k) + \Delta Ku$ (14) $Tu\ (k + 1) = Tu\ (k) + \triangle Tu$ (15) where $Ku\ (k + 1)$ is the proportional coefficient at time $k + 1$; $Tu\ (k + 1)$ is the integral coefficient at time $k + 1$; ΔKu is the variations of the proportional coefficient; ΔTu is the variations of the integral coefficient; $u(k)$ is the reference current at time k. The theory domain of error and error rate are set as [6, −6]. Define the fuzzy subset of the two output variables as NB, NM, NS, ZO, PS, PM, PB . This paper chooses the Trapezoid as membership function. According to the fuzzy domain and the basic domain, the quantisation factor can be calculated. That is: $ke = 6 - (- 6)\ 1 - (- 1) = 6$ (16) $kec = 6 - (- 6)\ 1 - (- 1) = 6$ (17) where ke is the quantisation factor of the error; kec is the quantisation factor of the error rate. In this paper, the fuzzy rules of self-adaptive fuzzy-PI controller are designed according to the following principles: (1) When the absolute value of the error is large, the proportional coefficient should be increase in order to remove the deviation and improve the response speed. (2) When the absolute value of the error is small, the proportional coefficient should be reduced to avoid the oscillation caused by the overshoot. (3) When the absolute value of the error is very small, the proportional coefficient should be continually decreased in order to eliminating static error, overcoming the large overshoot and keeping the system stable as soon as possible. (4) When the error and the error rate have the same sign, the controlled variable will change towards the direction of the reference value. The proportional coefficient should be reduced and the integral coefficient should be slightly added. (5) When the error and the error rate have the different sign, the controlled variable will change towards the direction of the reference value. In order to accelerate the dynamic process, the proportional coefficient should be increased and the integral coefficient should be reduced. The error and the error rate get their membership g.

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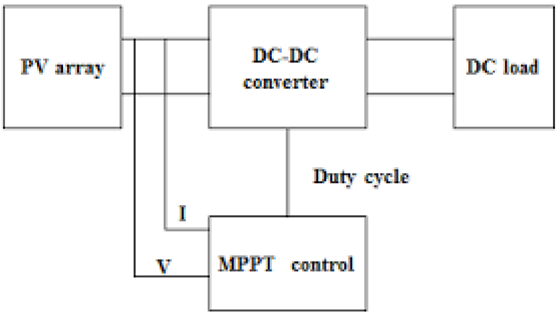

Fig 3: Schematic diagram of PV system

3.1 PV array:

PV exhibit is comprised of individual photovoltaic cells associated together. The measure of daylight based power conveyed by a singular photovoltaic board or module isn't adequate for normal use. Most create produce standard PV sheets with a yield voltage of 12V or 24V. PV cells are associated in arrangement to build the voltage esteems and are associated in corresponding to expand current qualities [12].

Sunlight-based PV establishments will in general be costly when contrasted and customary non-renewable energy source power generation, however, advantage from having no related fuel cost. In any case, to augment the profit from speculation, it is imperative to augment the measure of power created by the PV framework.

3.2 Working of PV cell:

The working of a PV cell relies upon the basic standard of the photoelectric effect. The photoelectric effect can be described as a marvel in which an electron gets darted away from the conduction band as a result of the osmosis of sunlight of a particular recurrence by the matter (metallic or non-metallic solids, liquids, or gases). Thusly, in a photovoltaic cell, when light strikes its surface, some piece of the sun-based energy is up to speed in the semiconductor material. Whenever retained virility is higher prominent than the bandgap virility of the semiconductor, the electron from the valence band leaps to the conduction band. By this, sets of opening electrons are made in the edified region of the semiconductor. The electrons thusly made in the conduction base.

Directions by the movement of electric field mount in the PV cells. These race away electrons set up current and can be illustrate for outside use by a partner a metal plate on the top and lower part of the PV cell. This stream and the voltage (made because of its implied electric fields) produce vital power.

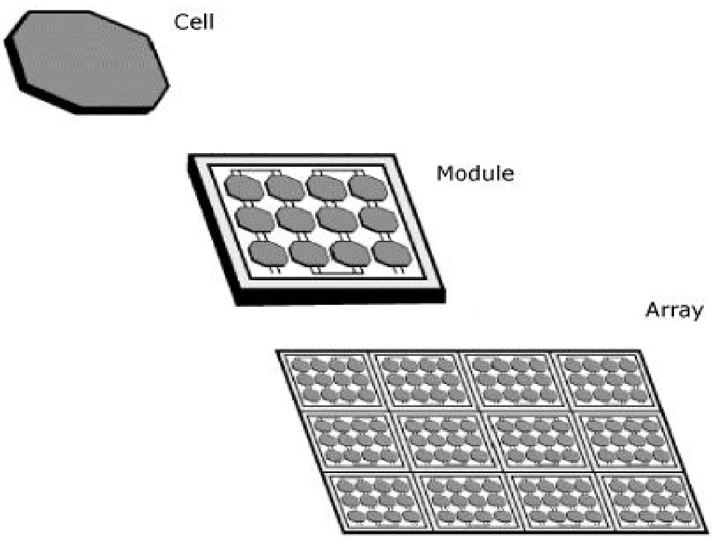

Fig3.2: PV array

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3.3 Maximum Power Point Tracker:

To utilize the greatest power catalyzed by the PV cells, the power revamping equipment must be furnished with a maximum power point tracker (MPPT). It is a utensil that remnants the voltage at where the greatest force is used congruously.

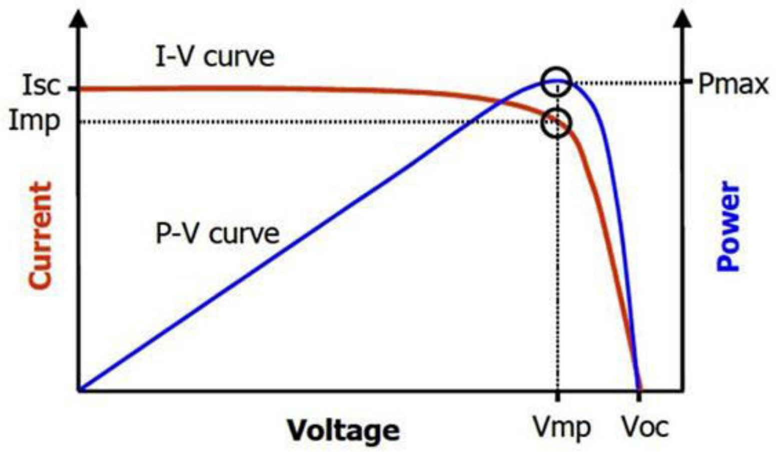

Fig 3.3: V-I characteristics of PV cell

The above curve show, the V-I curve of the PV array from short circuit to open circuit. The power from PV module is the aftereffect of voltage (V) and current (I). At both no-load and short circuit conditions, the force is zero. Eventually in the center (around the knee point) the passed-on power is for the most part phenomenal. The cell current is dependent on the extent of light force (irradiance) falling on the PV cell and the cell's temperature. As the intensity reduces then force diminishes, just as the pinnacle direct moves to one side. So, likewise as the temperature of the phone grows, the force yield cuts down and the limit PowerPoint again moves the left. The MPPT is intended to ceaselessly follow and change the voltage to produce the most force regardless of what season of day or climate conditions [14].

3.4 Equivalent circuit diagram of PV cell:

The equivalent circuit of PV cell comprises a current source with a diode in equal. The ideal sources are unrealistic. Along these lines, shunt and series resistors are added.

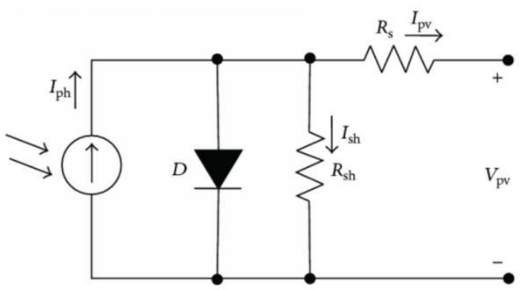

Fig 3.4: Equivalent circuit diagram of PV cell

IV. CONCLUSION

In this project, the microgrid is integrated with utility grids to meet the excessive load demand. By integrating the microgrid with utility grid the continuity of the supply is maintained and the reliability of the system is also increased. While integrating the grids the system may experience lots of fluctuations. To decrease these fluctuations and to integrate the grids ANFIS controller is used. ANFIS controller not only integrates the grids but also increases the system stability by decreasing the fluctuations.

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Variable step incremental method is adopted to convert the voltages of the into DC bus voltage. The variable step incremental method compares the parameters with referenced parameters to generate gating pulses.

Energy management system is adopted to maintain the stability of the DC bus system. The energy management system charges and discharges to avoid the voltage rising and voltage drooping conditions.

All the results of The ANFIS based integration of microgrid with utility grid is carried out in MATLAB/simulink environment. Simulation results have verified the effectiveness of the design methodology. It significantly enhances the power system stability. ANFIS controller effectively reduced the fluctuations and increased the system stability.

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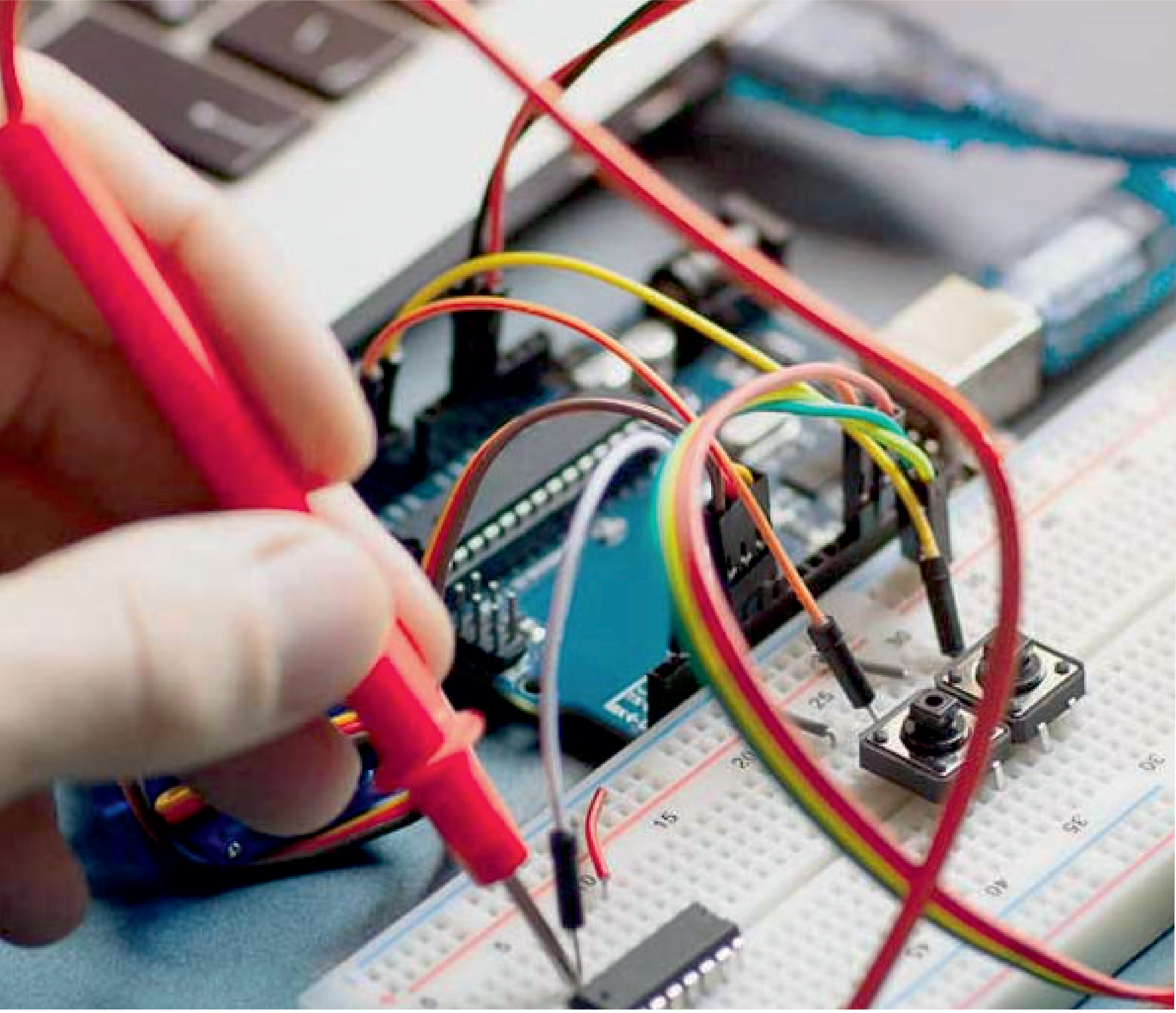

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