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Control Strategies of Solar PV Array Integrated UPQC for Power Quality Improvement - A Review

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ABSTRACT: Power quality has become more important in utility systems and in industry. The quality of energy tends to have a direct economic impact on customers and suppliers. Nowadays, standards and regulations are imposed to maintain the power quality parameters at the point of common coupling (PCC). Growing consumer demands lead to power quality issues. Many customers can experience severe technical and economic impacts due to power quality issues such as voltage drop, swell, harmonics, and long voltage interruptions. Therefore, there is a need to implement innovative and cost-effective compensation technologies. The compensation methodology applied using high-speed electronic devices is an effective solution to energy quality problems. A dedicated power device such as a Photovoltaic Unified Power Quality Conditioner (PV-UPQC) is one of the most versatile devices with the outstanding ability to improve voltage and current quality at the installation point in distribution and industrial power systems. This paper was mainly discussed about the complete review of the PV-UPQC system with current control strategies. The PV-UPQC system control strategy includes two parts, namely serial control and shunt control.

KEYWORDS: Unified power quality conditioner (UPQC),Power quality, solar PV system, Maximum power point tracking, THD, active power filter

I. INTRODUCTION

In recent years, energy quality has become more important in utility systems and industries. The quality of power tends to have a direct economic impact on customers and suppliers. Nowadays, standards and regulations are imposed to maintain power quality parameters at the common coupling point (PCC). Increasing consumer demands lead to energy quality problems. Many customers can experience severe technical and economic impacts due to power quality problems such as voltage sags, surges, harmonics and outages. Such phenomena appear more frequently in the power system due to non-linear loads. Optimal power quality is required for both technical and economic reasons. Therefore, implementations of innovative and cost-effective compensation techniques are needed. The compensation methodology implemented using high-speed power electronic devices is an effective solution to power quality problems. Dispersion Generation (DG) is becoming popular in the distribution system, due to the huge availability of the renewable energy source. It will provide large active power to customers in remote areas and assist in load sharing along with utility system. One of the favorable DGs is that of photovoltaic systems (PV) and is increasingly used to exploit the enormous resource of the sun and will play a key role in the future sustainable energy system. They offer consumers the ability to generate electricity cleanly and reliably. However, PV can have a negative impact on existing power systems, such as: B. Voltage fluctuations and harmonics. The photovoltaic arrays are integrated into the DC and AC distribution systems with the help of power electronic circuits. The DC boost converter is used to convert the DC output voltage of the PV array into the voltage level in the intermediate circuit. The advantages of this converter are simple configuration and high efficiency. The scope of the PV-UPQC is to compensate for long voltage interruptions, voltage drops, voltage fluctuations and harmonics. The PV-UPQC system has the excellent ability to improve the quality of voltage and current in PCC, and it will be a highly effective solution to most of the power quality problems. The most important and critical problems with the power quality are voltage dips, voltage spikes, harmonics and long voltage interruptions of the power supply. Customers need to be supplied with good quality power and not suffer from power quality issues. Custom Power (CP) devices provide an integrated solution to the

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current problems faced by customers and power distributors. The PV-UPQC system uses a photovoltaic energy source and offers an effective solution to the problems of voltage drops, swellings, harmonics and long voltage interruptions. The unified power quality conditioner is an effective product for improving the power distribution network. It is a combination of a shunt and a series active power filter. Here a shunt active power filter is used to compensate for the harmonics of the load current and to make the source current completely sinusoidal and free of harmonics and distortion.

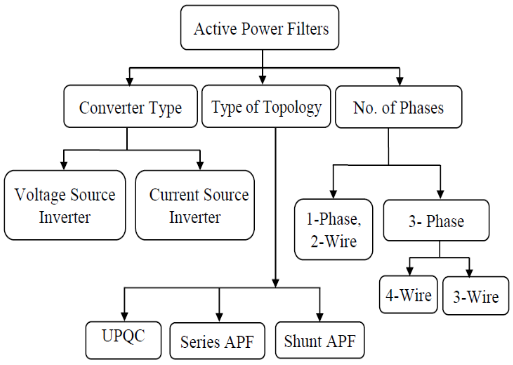

Figure 1Classifications of Active Power Filters

There are two types of filters: active and passive filters. Passive filters are the combination of capacitor, inductor and resistor usedearlier to compensate harmonics and voltage distortion of the system quality.But due to many drawbacks such as larger size, resonance problem, effect of source impedance on performance, and fixed compensation characteristics, they are not currently used. There are two types of filters available, active and passive filters. Passive filters are the combination of capacitor, inductor and resistor previously used to compensate for harmonics and voltage distortion for system quality. But due to many drawbacks such as larger size, resonance problem, effect of source impedance on performance, and fixed compensation characteristics, they are not currently used. Subsequently, the use of power electronic devices which act as a non-linear load is the cause of the degradation of the poor quality of the power supply. This leads to a number of problems in distribution systems such as higher power losses, voltage sags and swells, harmonics, displacement factor, and bad distortion. Recent growth in modern communications, digital electronics, and control systems has dramatically improved the use of a number of sensitive loads that require an ideal sinusoidal supply voltage for their proper operation. Therefore, it is necessary to include compensation for the above problem. So, the unified power quality conditioner is a combination of back-to-back connected shunt and APF in series through a common DC link voltage. These two filters work differently to overcome the problem of power quality. Injecting UPQC into a power electronic device has its own advantages and disadvantages. This device has the ability to compensate for quality issues after said issues and it is the most powerful electronic device for high loads. In addition, it is very sensitive to line voltage and load current disturbances which help reduce energy loss in systems with healthier safety operation.

II. SYSTEM CONFIGURATION AND DESIGN

The construction of the PV-BESS-UPQC is shown in Figure 1. The three-phase system is designed for the PV-BESS-UPQC model. The PV-BESS-UPQC consists of a series APF compensator and a shunt linked to a DC-link split capacitor. Battery and photoelectric array are connected parallel to DC connection. The PV is connected through a boost converter to DC-link. Furthermore, BESS is interconnected through a DC-link Buck-Boost converter. The series compensator works like a controlled voltage source method and mitigates supply voltage slack, swell, outage and voltage consistency. On the other hand, the shunt compensator attenuates the load current harmonics. Both series and APF shunt compensators are connected by connecting inductors.

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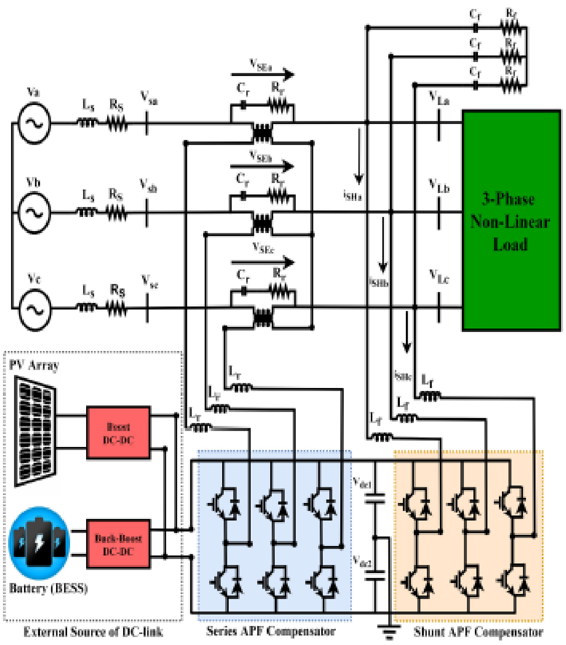

Figure 2.UPQC system configuration.

Due to the switching action of the converter harmonics are generated and, therefore, the ripple filter is used to filter harmonics. The series compensator uses a series injection transformer to feed voltage into the network. In this work, a three-phase non-linear load is used. The PV-BESS-UPQC design procedure starts with accurately measuring the PV array, split capacitor, DC link reference voltage, etc. The design of the shunt compensator follows the way that, in addition to mitigating current harmonics, it controls the peak power output from the photovoltaic field. Since the PV generator is directly connected to the DC link UPQC, the PV generator is constructed in such a way that the voltage of the maximum power point (MPP) is equivalent to the reference voltage of the DC link. Under nominal conditions, the nominal value of the photovoltaic field ensures that the active power of the load is supplied by the photovoltaic field and that the power is supplied to the grid and charging BESS also from the photovoltaic field. Furthermore, the BESS is designed in such a way that when the PV field generates less power than the load demand of the DC link, the BESS provides insufficient power equivalent to the decrease in the DC link voltage. Furthermore, when there is no power produced by the photovoltaic field, the BESS will provide the total load request.

Table 1 Comparison of various Custom Power Devices:

S.No.	Factors	DSTATCOM	DVR	UPQC
1	Rating	low rating	high rating	higher ratings are available
2	Speed of operation	Less than DVR	Fast	Faster
3	Compensation Method	Shunt Compensation	Series Compensation	Both series & shunt
4	Active /reactive Power	Reactive	Active/ Reactive	Both
5	Harmonics	Less	Very less	Lesser

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6	Problems addressed	Sag/ Swell	Sag/ Swell/ Harmonics	Sag/ Swell/ Harmonics/ Flicker/ Transients/ unbalance in 3 phase system
7	Cost	Nominal	High	Higher

III.CONTROL STRATEGIES

The control strategy plays the most important role in any system based on power electronics. It is the control strategy that determines the behaviour and desired operation of a particular system. The effectiveness of a UPQC system depends exclusively on its control algorithm. The UPQC control strategy determines the reference signals (current and voltage) and thus decides on the switching times of the inverter switches so that the desired output can be achieved. Various control strategies / techniques that have been successfully applied to UPQC systems are available in the existing document.

a)P-Q-R Instantaneous Power Theory

This method provides an analysis and control algorithm for a three-phase four-wire Unified Power Quality Conditioner (UPQC) based on the p-q-r instantaneous power theory. The p-q-r theory transforms a three-phase four-wire voltage space vector into a single voltage and the corresponding currents into a p-axis component of active power based on des and two imaginary power components, q-axis and r-axis. If there are harmonics and there is a negative sequence in the voltage, the calculated reference current is not sinusoidal. In this method, an extra component of the q-axis is used to add to the original current compensation strategy based on the p-q-r theory to maintain a distorted sinusoidal low voltage current waveform. With the p-q-r theory, a control block model of a power integration feedback is used to keep the mean power at zero. Analysis of the effect of sampling and quantization error on storage voltage detection, minimization of active loop power and power loss in UPQC system, and consideration of source-side power flow can be complete in future work.

b)Switching Control Method

In this method, six single phase H-bridge inverters are used in the UPQC s tr u ctor connected to a common DC storage capacitor. Of these six inverters, three of them are used for series voltage insertion and the other three are used for shunt current injection. The UPQC current and voltage references are generated based on the Fourier series extraction of the components of the fundamental sequence using a half-cycle (moving) average. They also provide a switching controller scheme based on a linear quadratic regulator that follows a reference using the proposed compensator. This method is suitable for both utilities and customers with sensitive loads. From the utility point of view, it can make the drawn current balanced sinusoidal. To do this, the voltage at the common coupling point must be of a similar nature and therefore the operation of the UPQC is ideal from both points of view.

c)Direct Detection Method

A number of methods are proposed where the instantaneous active and passive forces are computed directly from a-b-c phase voltages and line currents. It eliminates the need for complex X-format conversion, thus reducing calculation size and improving detection speed. However, this method requires a low-pass filter such as X-transform. The exact sinusoidal waveform is stored in memory (EPROM). The microcomputer system reads the voltage values sequentially from the EPROM and compares them with the measured waveform and instantly gives the reference values. This method does not require calculation of the active current or component voltage so that the delay in the compensator response is avoided

d)Synchronous 'D-Q' Reference Base Theory

This algorithm is based on Parks' transformation in which three-phase voltage and current signals are transformed in a rotating frame synchronously. The active and reactive components of the system are represented respectively by the direct and square component. In this approach, the fundamental quantities become quantities d-q which can be easily separated by filtering. Some kind of PLL synchronization system should be used to implement the synchronous reference frame. The system is very stable as the controller mainly deals with the d-q quantities. The calculation is

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instantaneous but incurs delays in filtering the quantities d-q. This method is applicable only for three-phase systems. The modified synchronous reference system, called the "instantaneous id-iq method", is also proposed. This method is similar to the synchronous reference system method, except that the transformation angle is obtained from the X components of the voltage. The referential speed is no longer constant but varies instantaneously according to the waveform of the three-phase voltage system. In this method, no synchronization circuit is required.

e)Control Algorithm Based On Wavelet Transform

This control algorithm is used to control the UPQC in order to achieve the optimum performance for reducing current harmonics and compensating for voltage drop. The practicality of using wavelet as a good current noise extraction tool for the shunt portion of UPQC and the way it could be used to detect the voltage reduction and generate a control signal to drive the series filters to drive the Raise tension to a tolerable level.

f)Control Method Based On H8

This method is based on the h8 standard adaptive system control used to design the optional H8 power quality controller. By analyzing the radical reasons for the coupling effect between the UPQC series unit and the bypass unit, a simple and practical coordinated control strategy for the UPQC series unit and the bypass unit has been obtained by introducing the link corrective voltage corresponding directly to the UPQC series unit and bypass unit respectively and by the appropriate PWM mode, in addition, the coupling effect between your series unit and the bypass unit is completely eliminated. Therefore, the complex degree of the entire UPQC control system is greatly simplified. Combined with a waveform tracking control method based on the h8 model matching technology on power quality, coordinated control between the UPQC series unit and the bypass unit is implemented through this strategy. . Experimental results indicate that the method can eliminate steady-state phase shift and amplitude attenuation of the series unit voltage tracking compensation and shunt unit current tracking compensation for UPQC. Finally, UPQC high-quality unified multi-function control is achieved. Through the application of a UPQC, the distribution network will become an ideal pure energy source with high reliability and premium quality for the energy customer and those customers with a pollution source will become qualified customers for the distribution system.

g)Hysteresis Control Algorithm

In this control strategy, unit vector models are generated using PLL from three-phase voltages measured at the PCC. It generates the phase angle for the reference currents. The PLL output with an appropriate phase shift is used to generate three phase unit sinusoidal reference source currents. The current magnitude of the reference source is decided by the output of the PI controller. The PI controller compares the measured intermediate circuit voltage with the reference value and its output is a measure of the fundamental source current needed to charge the capacitor. The measured source currents are compared to their reference values and the switching pulses for the APF shunt are generated using the ends of the unit's hysteresis controller. The triangular carrier is compared to the voltage modulation signal so as to obtain the APF shunt firing pulses.

h)Fuzzy Logic Controller Based UPQC

L.A. Zadeh presented the first paper on fuzzy group theory in 1965. Since then, a new language has been developed to describe the ambiguous properties of reality, which are sometimes difficult to describe using traditional methods. Fuzzy group theory has been used widely in the control region with some applications to a direct current to direct current conversion system. A simple fuzzy logic control is created by a set of rules based on human knowledge of the system's behavior. The Mat lab / Simulink simulation model is designed to study the dynamic behavior of the DC to DC converter and the performance of the proposed controllers. Moreover, fog logic controller design can provide both small signal and large signal dynamic performance desired at the same time, which is not possible with linear control technology. Hence, the Fuzzy Logic Controller was the potential ability to improve the durability of DC to DC converters. Fuzzy logic controller is better at improving power quality by reducing voltage drop and overall harmonic distortion when compared to conventional PI controller. To enable this, a structured approach to establishing ambiguous organism functions is implemented using an ant colony optimization technique for optimized fuzzy logic control.

i)ANNcontrol Based UPQC

Unified Power Quality Conditioner (UPQC) has been used convincingly to alleviate most power quality issues. Conventional control schemes such as synchronous reference fame (SRF) and control based on P-Q theory involve transformations from abc to dq. Therefore, they involve complex calculations and require DSP / FPGAs which are expensive. The use of artificial intelligent control schemes reduces the size of the control system and the complexity of

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its operation. The ANN controller reduces the cost and complexity of the system. The performance of the controller is analyzed under various conditions such as supply voltage and load current harmonics, load imbalances, voltage drop and rise. It is clearly seen that the UPQC based on a three-level converter with the proposed ANN controller successfully alleviates the power quality problems related to voltages and currents, thus improving the power factor of the system. The flow of active and reactive power is also verified in this study and it is observed that after compensation, UPQC based on a three-level converter with the proposed ANN controller provides the required reactive power to the load causing supply currents. sinusoidal. The hysteresis current controller and SPWM for three-level shunt and series converters effectively compensate for current harmonics, unbalanced currents to supply and voltage harmonics, voltage drop and voltage rise to the load. The ANN controller reduces math operations and the use of DSPs and FPGAs, thereby reducing the cost and complexity of the system. The ANN controller can be implemented in a microcontroller due to its small memory size. Finally it is concluded that, in view of converters, three-level diode clamped UPQC has least %THD in voltage and current. In view of controllers, ANN controller has superior performance over SRF controller.

j)ANFIS Controller-Based UPQC

UPQC is a combination of function simulated in DSTATCOM as well as DVR. The chain transformer does payoff in cases, when supply voltage harmonics and voltage imbalances occur. ANFIS is among the best applications in the field of building control, restorative analysis, etc., which can be used to control the various parameters of real-time systems. UPQC function based on the control method which has the ability to reduce voltage deceleration and voltage amplification. At this time, the methods have been investigated in UPQC, such as the ANFIS controller. This method uses UPQC based on ANFIS control method using a voltage source transformer to reduce voltage slack and voltage amplification and increase the PQ of the power system. The ANFIS control unit-based UPQC design, matching properties and mathematical models were examined using the voltage slip and voltage amplification control method, and the fully shortened PQ problems in the ANFIS control method are better than those associated with ANN and FLC.

IV. CONCLUSION

Most of the proposed or practiced control strategies for power quality conditioners have been reviewed with regards to performance and implementation. This work reveals that there has been a significant increase in interest in UPQC and associated control methods. This could be attributed to the availability of suitable power switching devices at an affordable price, as well as the generation of low-cost fast processing devices (microcontroller and DSP). Each technique has its advantages and disadvantages.

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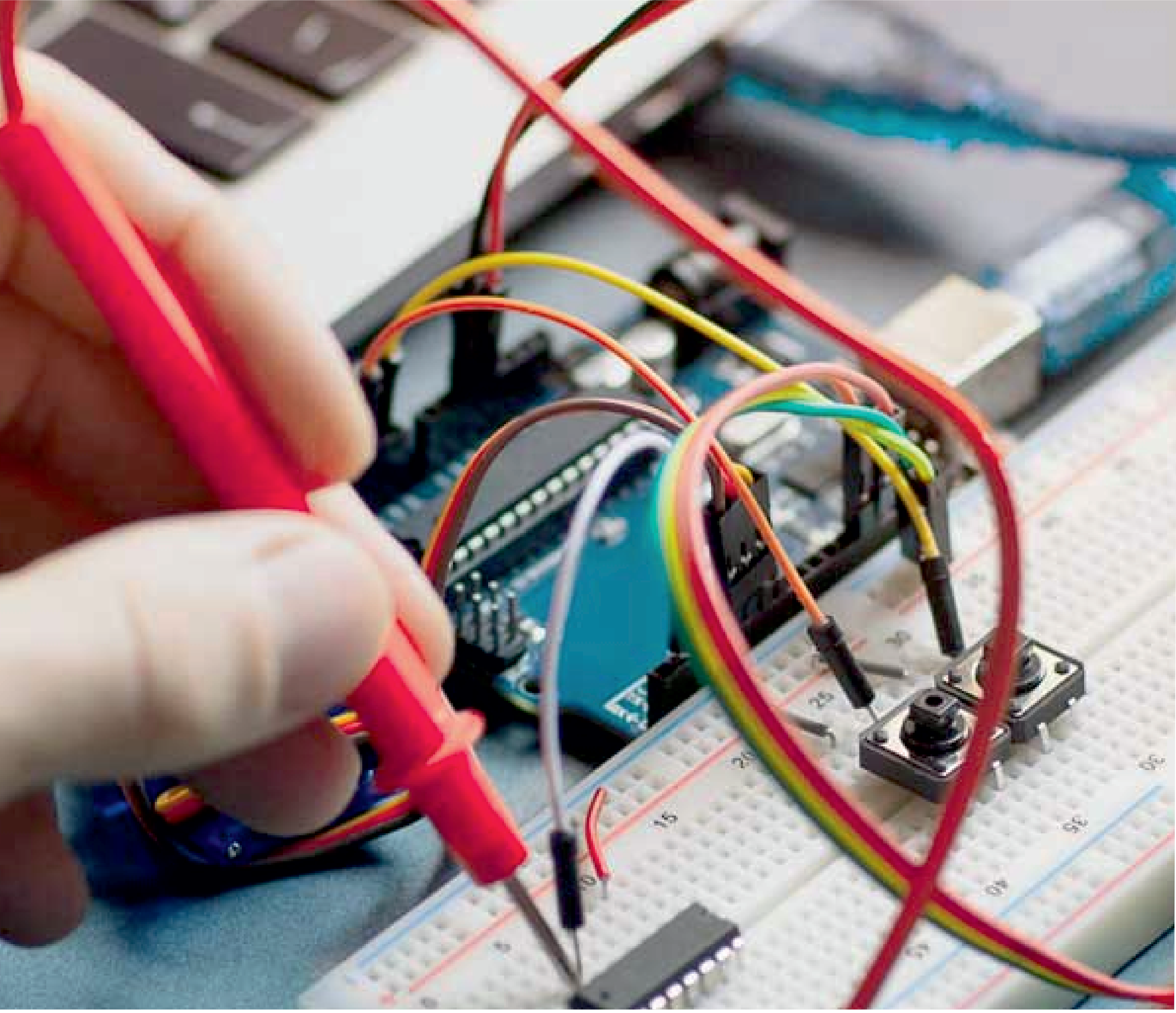

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