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An Overview of the Grounding System of the Power Substation

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ABSTRACT:The grounding system of the power substation is composed of the tower structure, the equipment shell, the equipment neutral point, the grounding network and the grounding rod. When the power system is abnormal, such as lightning strike voltage or equipment failure, the voltage generated by the fault current flowing through the grounding grid poses a threat to the equipment and maintenance personnel in the substation. In particular, there are four different voltages generated on the personnel – step voltage, touch voltage, touch voltage (metal-to metal), mesh voltage, etc.The above voltages are calculated according to the IEEE 81-2012 specification, and the cross-sectional areas of the grounding grid conductors and grounding rods are calculated according to the three-phase short-circuit fault current in the substation.This article only measures the grounding resistance of the power substation grounding grid and the tower structure according to the IEEE 81-2012 0.618-pole method, and provides data discrimination specifications.It should be concluded with the matters needing attention when measuring the grounding resistance and expanding the project in the substation.This paper reminds designers to consider the fault current of the three-phase short-circuit of the final target substation equipment as a relevant design basis when building a new power substation, and then calculate the specifications of the grounding grid conductors and grounding rods.

KEYWORDS: Three-phase short-circuits fault current, Power substation, IEEE 81-2012, Grounding grid, 0.618 pole method measurement..

I.INTRODUCTION

The power substation plays an important role in the conversion and transmission and distribution of voltage and current in the power system.Howeverthe grounding system is also very important. It needs to have a low impedance value and can immediately introduce the instantaneous high voltage caused by lightning strikes on the transmission line or the fault current caused by equipment abnormality, and immediately introduce it to the ground to avoid abnormal voltage or fault current. Scramble to expand its power system disturbances affecting the power supply. Therefore, this article outlines the precautions that maintenance personnel should pay attention to when they are in the usual grounding grid measurement, which ispatrolling in the substation.There are many measurement methods used in the industry today, and each has its own advantages and disadvantages. After reviewing each measurement method, this article only introduces the representative IEEE 81-2012 0.618-pole measurement method

II.LITERATURE REVIEW

References [1], [2] explain the basic principles and overview of grounding. The definition of grounding terms is divided into three types - electrical systems, electrical equipment and metal enclosures and the connection to the ground, all of which are connected to the earth. The grounding of the power system is very important, and most power failures are looped through the grounding system. In order to ensure the safety of equipment components and operators are necessary facilities. Reference [3] divides the processing of measurement results into three levels according to the IEEE 81-2012 standard specification: not required, necessary, and required, and introduces the measurement method. Reference [4] explains the equipment connection diagram in the power system substation, the description of each equipment name and the different specifications of the system voltage level. Reference [5] explains that the grounded grid is placed under the ground of the entire substation, which has a dual purpose: the operation of the grounding system is to transmit the fault current of the power system to the ground without affecting the operation of any equipment, And to ensure the safety of the personnel in the place and not to come into contact with excessive voltage step voltage or contact voltage may cause shock to personnel. Reference [6] describes an electronic recording system that captures the ground potential voltage rise (GPR) characteristics of the power system during a ground fault, and calculates the fault point of the ground system by measuring the change in impedance. Reference [7] describes the use of programming to provide an optimally designed grounding system for substations with high soil resistivity in the plot area. Hybrid grounding system for grounding electrolytic rods reinforced grounding materials and auxiliary conductors by chemical treatment. Reference [8] states that the grounding system value depends on the soil resistivity so that the

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touch and step voltage values change accordingly. Reference [9] states that the grounding system of the power substation must be designed according to the IEEE 80-2000 standards to avoid danger to equipment and personnel. The grounding system of the 150 kV voltage level substation is designed and calculated the voltage gradient of each equipment, the resistance value of the grounding system and the rise value of the grounding potential voltage.This article is written by compiling the above-mentioned literature and selecting the best and abandoning bad and the author's years of experience in serving Power Company.

III. POWER SUBSTATION EQUIPMENT

The equipment of the power substation is shown in Fig 1. There are two types of equipment on the ground and those below the ground.The equipment on the ground includes transmission towers, arresters, measuring transformers, current comparators, circuit breakers, air-break switches, circuit breakers, current comparators, measuring transformers, main transformer distribution terminal voltages, and there are barrier strings, overhead ground wires, iron structure, cement foundation, gravel, etc., and each equipment has a ground wire (including the neutral point of the main transformer).The equipment below the ground has a grounding grid and a grounding rod.The ground point of anyequipment is must to connect thepower grid below the ground with the ground wire, and then connect the ground rod to form a power grounding system.

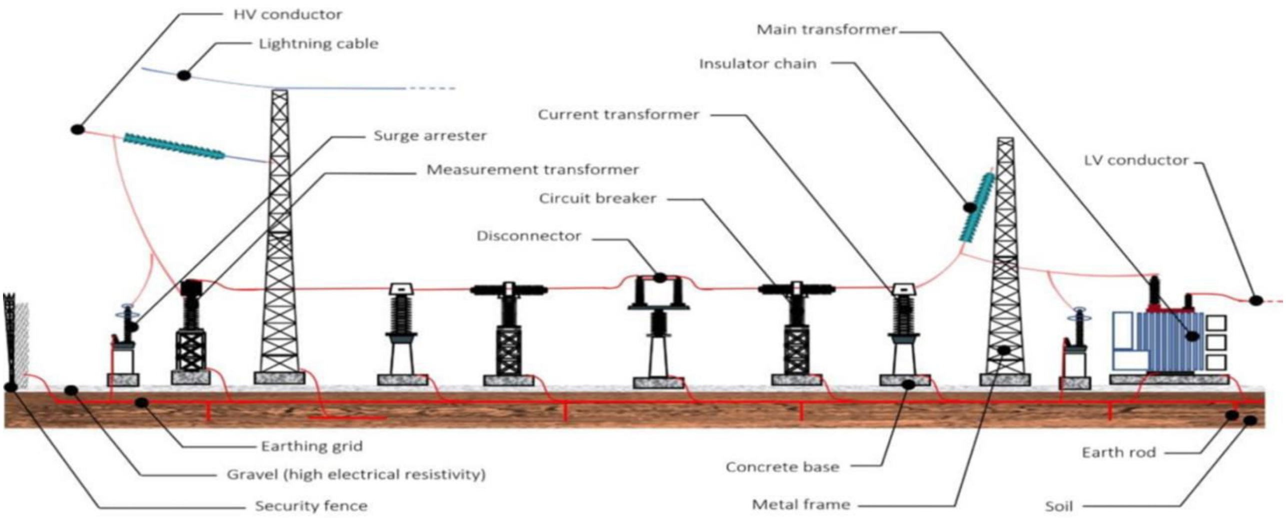

Fig. 1 power substation equipment [4]

3.1 Underground equipment

The equipment under the ground of the power substation includes grounding grids and grounding rods.Its function is to introduce the high voltage of the overhead ground wire of the transmission line into the ground when it is struck by lightning. The other is to quickly introduce the fault current into the ground when the equipment fails, so as to ensure the safety of equipment and personnel and avoid the expansion of fault points.These devices must be planned in detail when building the plant. As for the wire diameter of the grounding grid wire and the size of the grounding rod section, it is based on the formula (1) in the IEEE 81-2012 specification and its parameters:$I''K_1$ (relative to ground short-circuit current (A)),t_s (fault time (s)), $\Delta\theta$(maximum allowable temperature rise (°C)) calculation. [2]

$$S[mm^2] = \frac{I''K_1}{13} \times \sqrt{t_s \times \Delta\theta} \quad (1)$$

3.2 Equipment on the ground

The iron structure and equipment on the ground of the power substation, including the neutral point, must be connected to the grounding grid to form a grounding system, which will immediately introduce the fault current to the ground when the equipment is abnormal.At the same time, the maintenance personnel in the substation patrol the switchyard or touch the equipment, and the grounding grid in the substation generates potential voltage by the fault current.The types of potential voltage are divided into four types - contact voltage (iron structure to iron structure) (E_{mm}[V]), step voltage (E_s[V]), contact voltage (E_t[V]), grounding grid voltage (E_m[V]), ground rod end voltage(E_{trrd}[V]), etc.,Of course, the contact voltage (iron tower to iron tower) is equal to the grounded grid voltage, as shown in Figure 2. The data generated by the respective potential voltages above are derived from IEEE 81-2012. The relevant formulas and symbol descriptions are shown in Table 1.

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$$E_s[V] = (1000 + 6 \times C_s \times \rho_s) \times \frac{0.116}{\sqrt{t_s}} \quad (2)$$

$$E_t[V] = (1000 + 1.5 \times C_s \times \rho_s) \times \frac{0.116}{\sqrt{t_s}} \quad (3)$$

$$E_m[V] = R_w \times I_f - (I_f \times S_f) \times S_f \quad (4)$$

$$GPR[V] = (R_W + R_g) \times I_f \times S_f \quad (5)$$

$$I_b[A] = \frac{0.116}{\sqrt{t_s}} \quad (6)$$

$$R_g[\Omega] = \frac{\rho}{4} \times \sqrt{\frac{\pi}{A}} + \frac{\rho}{l_T} \quad (7)$$

$$C_s = 1 - \frac{0.09 \times \left(1 - \frac{\rho}{\rho_s}\right)}{2h_s + 0.09} \quad (8)$$

Table 1 Explanation of formula symbols

Cs	Calculation formula of derating coefficient of grounding power grid conductor surface
ts	Fault current duration time
ρs	Surface material resistivity [Ω.m]
ρ	Earth resistivity below surface material [Ω.m]
hs	Thickness of surface material [m]
A	Area occupied by ground grid [m2]
l_T	Total buried length of conductors including ground rod [m]
I_b	Human body allowable conductive current
I_f	Fault current
S_f	Split factor
R_w	Ground grid resistance
R_g	Ground rod resistance

Note: If no protective surface layer is used, Cs =1 and ρs = ρ

Taking an example of equipment failure, when the system fault current is 7000A, the fault current flowing through the grounding system is 4200A. The grounding resistance is the grounding grid resistance plus the grounding rod resistance totaling 1.07Ω. The ground voltage (GPR) is calculated as 4500V according to formula (5), and the body current is calculated as 164mA according to formula (6). The grounding grid voltage is the grounding grid resistance (about 0.1Ω) multiplied by 2800A (7000A-4200A) and calculated as 280V due to the splitting factor. As for the contact voltage and the step voltage generated by people traveling in the switch field, they need to be calculated according to the relevant data in formula (3) and formula (2). In short, the ground grid voltage $E_m[V]$is equal to $E_{mm}[V]$ that is greater than the step-to-step voltage$E_s[V]$ and $E_s[V]$isgreater than the touch voltage$E_t[V]$.

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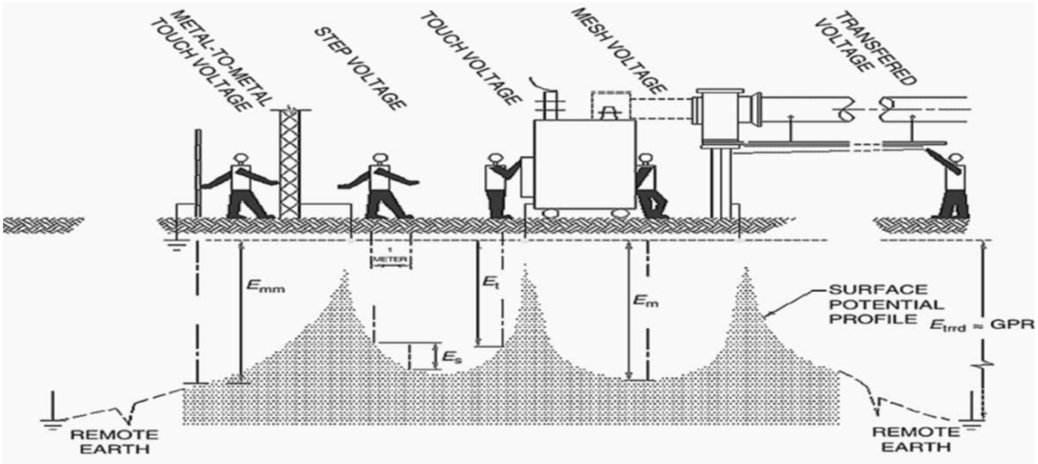

Fig. 2 Schematic diagram of voltage distribution of grounding grid [4]

3.3 Difference between grounding grid and grounding rod

Before distinguishing between the grounding grid and the grounding rod, the location of any equipment is shown in Fig 3 for easy understanding and explanation: The so-called grid voltage is called the potential difference between the lead from the iron structure grounding wire to the grounding grid wire. As for the voltage of the ground rod, it is from the wire of the iron structure to the grounding grid and then to the ground rod, and the voltage generated at the end of the ground rod is called.

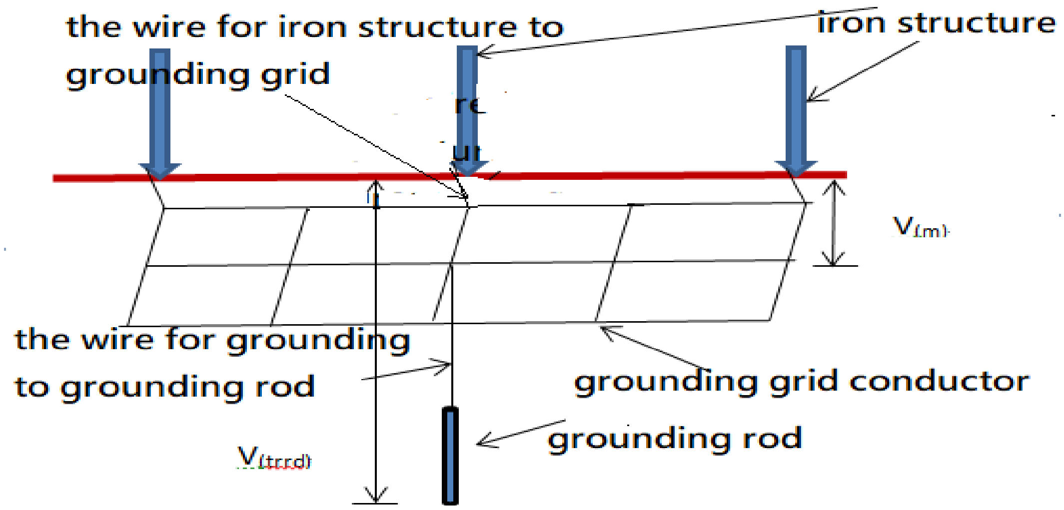

Fig. 3 Schematic diagram of grounding grid and grounding rod

3.4 Grounded grid measurement

After understanding the function of the equipment of under the ground, it is necessary to measure the resistance value regularly every year to avoid the resistance value becoming larger due to the expansion of the substation and the disconnection of the conductor connected to the ground network or the deterioration of the contact point. It will affect the ability to divert the fault current and endanger the safety of personnel and equipment. There are many types of grounding grid resistance measurement methods. This article only introduces the grid method in the substation based on the IEEE 81-2012 0.618 measurement method. As shown in Fig 4, the D distance is 120 meters, and the X distance is 45.84 meters. As for the qualified data value (Rt) of the measurement standard and the precautions for strain maintenance, it is shown in Table 2.

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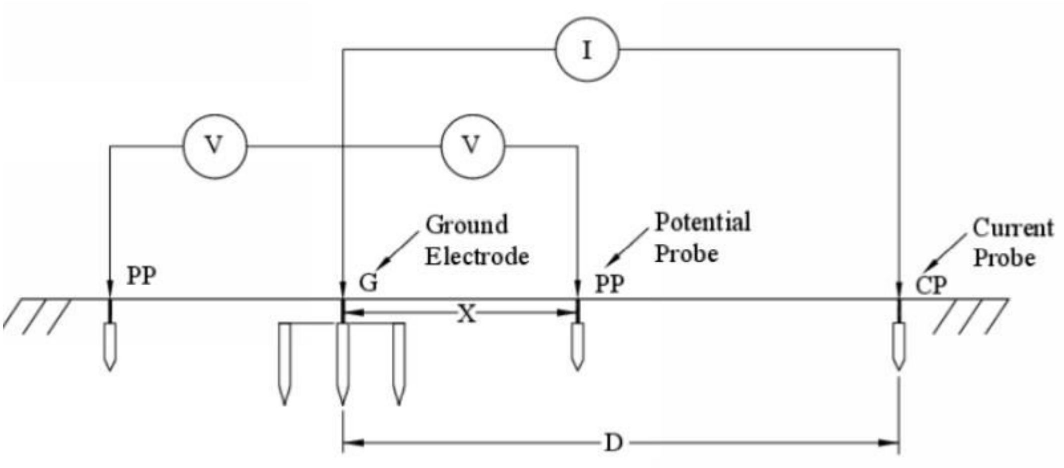

Fig. 4 IEEE 81-2012 0.618 measurement method

Table 2 Measurement standard qualified data

show	Rt<0.1Ω	0.1<Rt<1Ω	Rt>1Ω	disconnection
conclusion	good connection	problem connecting	bad connection	disconnection
dealing	unnecessary	when necessary	necessary	necessary

In order to describe clearly, a practical example is given to illustrate the connection method between the detection instrument and the detection lead-wire and the ground wire between the iron structure and the iron structure to the grounding grid for reference, as shown in Fig 5.

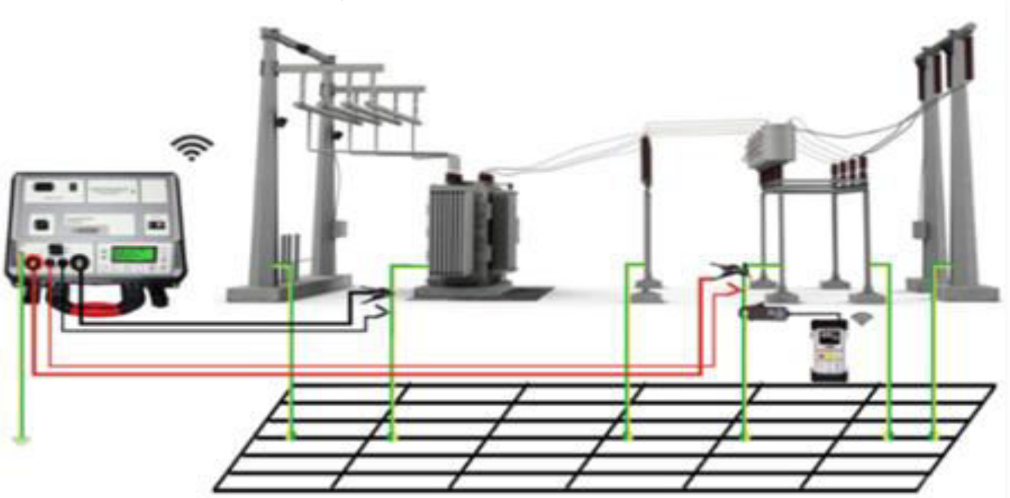

Fig. 5 Practical measurement diagram [5]

IV. DISCUSSION

The grounding system of the power substation plays an important role in the power system. It involves factors such as the short-circuit capacity value of any equipment in the substation, the duration of the fault current and the elimination of the fault point, so as to shorten the disturbance time of the power system.However, the grounding system of the substation is invisible underground equipment, and it is difficult to find the weaknesses of the equipment during daily inspections. It is only necessary to measure regularly every year. If the measurement method and data are incorrectly obtained and there is no immediate treatment, the protection system will not work properly operation and affect the normal power supply. It is convenient to understand that the functions of the grounding system of the integrated power substation are as follows:

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- Provide a neutral ground connection for equipment such as generators, transformers, capacitors, and reactors.
- Provide the fault current path of transmission equipment ground fault, overhead ground wire lightning strike, lightning arrester, circuit breaker, transformer and other equipment due to poor ground insulation.
- Due to the flow of ground current, limit the voltage difference between the metal and iron structure of the substation equipment and the ground voltage rise (GPR); they can be dangerous to equipment and personnel.
- Make sure the relay is functioning properly, and immediately clear the point of failure.
- Improve the reliability and availability of power systems.
- Grounding of electrical equipment is allowed during maintenance.

V.CONCLUSION

The generation of the above-mentioned related voltages, such as contact voltage (iron structure to iron structure) ($E_{mm}[V]$), step voltage ($E_s[V]$), touch voltage ($E_t[V]$) , the grounding grid voltage ($E_m[V]$), the grounding rod end voltage ($E_{trrd}[V]$), etc., the fault current needs to flow through the grounding system in the event of a grounding accident in the power system. The author has a deep understanding of the importance of the grounding system of the substation because of many years of service in the power company as substation equipment maintenance, design, and system electromechanical accident cause analysis. Therefore, every time the equipment in the station is expanded, many relevant change parameters must be taken into consideration together to ensure the normal operation of the protection relay system. In addition, the removal or connection of any existing grounding wires must be handled according to standard operating procedures to ensure the safety of the operators.

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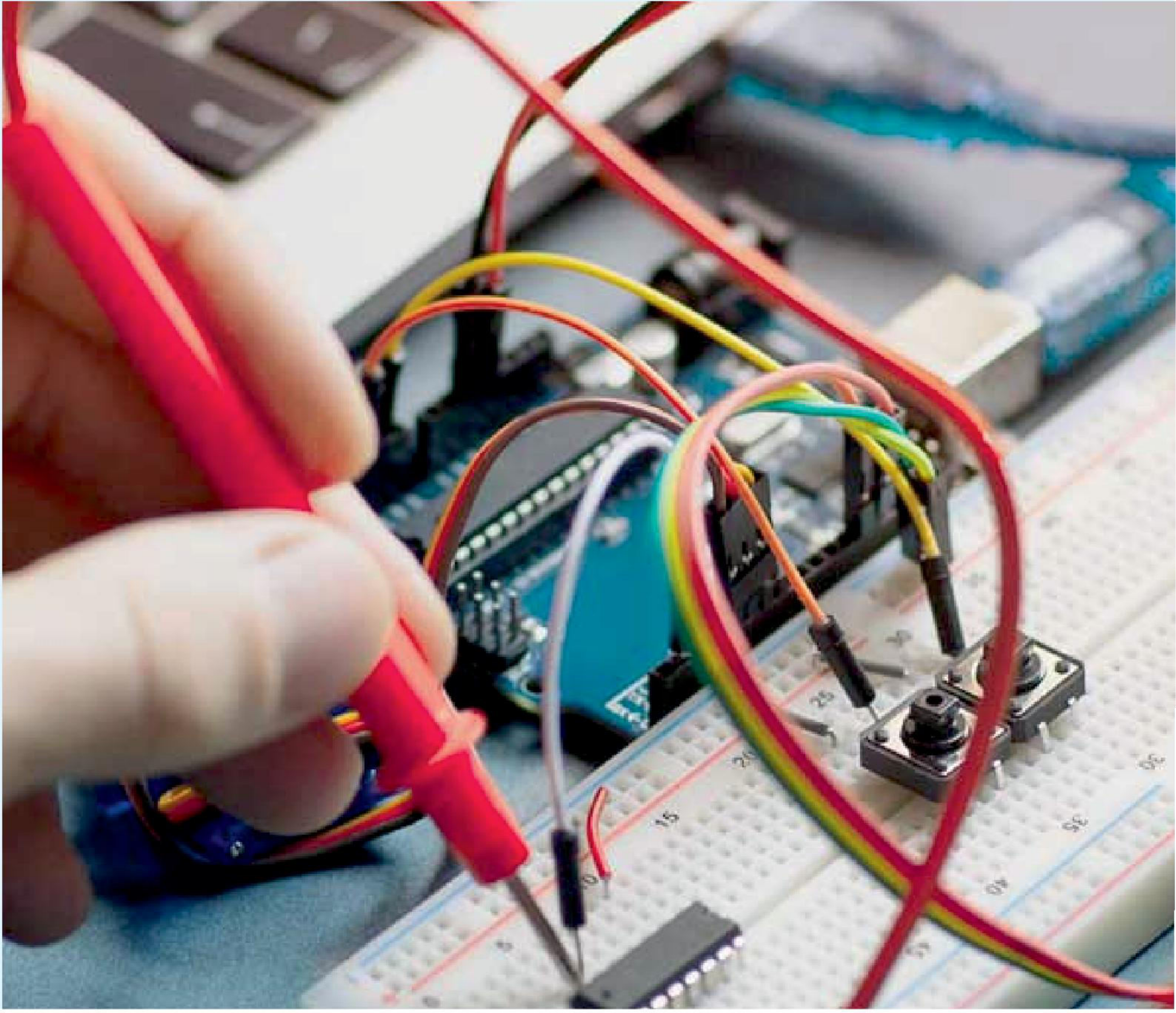

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