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FFT Analysis on Closed Loop Control of Separately Excited DC Motor

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ABSTRACT: The power electronic converters are undeniable controllers in modern drive systems. DC drives are mostly used in applications where adjustable speed control, frequent starting, good speed regulation, braking and reversing is required. In this period of time, various industrial, agricultural, transport and domestic resources have validated the diverse application of electric drives. By selectively regulating the operation of electric drives the efficiency of the industry van be improved. The DC motor plays a significant role in modern industrial drives due to its higher performance, reliability and adjustable speed control. Below the rated speed, the speed control of SEDC is carried out by changing the armature voltage. In this paper a speed control methodology is used for varying the armature voltage by means of buck boost converter. Using Proportional-Integral controller, the fast correction is performed by the proportional term and the integral term makes the steady state zero in finite time. FFT analysis is also done in this paper. Simulation results are implemented to confirm the effectiveness of the proposed model.

KEYWORDS: Buck Boost Converter, PI Controller, Separately Excited Dc Motor, Rectifier, FFT analysis.

I.INTRODUCTION

In all engineering applications, we have to control electrical parameters such as speed, torque, voltage to achieve the required working. Some of the power converters are used to change the voltage level of the system. Power Electronics refers to the process of controlling the flow of current and voltage and converting it to a form that is suitable for user loads. The most desirable power electronic system is one whose efficiency and reliability is 100%. A fast Fourier transform (FFT) is an algorithm that computes the discrete Fourier transform (DFT) of a sequence, or its inverse (IDFT). Fourier analysis alter a signal from its original domain (often time or space) to its frequency domain and in reverse. Fast Fourier transforms are widely used for applications in engineering, music, science, and mathematics.

1.1 Buck boost Converter

The buck–boost converter is a type of DC-to-DC converter that has the output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a fly back converter using a single inductor instead of a transformer. It can produce a range of output voltages, ranging from much larger (in absolute magnitude) than the input voltage, down to almost zero. Figure 1 shows the schematic diagram of buck boost converter [1-2].

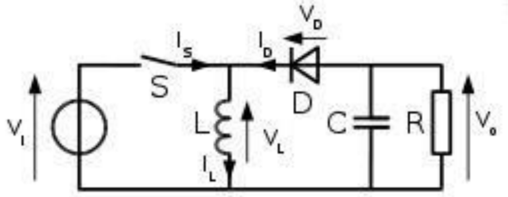

Fig 1.1a schematic diagram of buck boost converter

The basic principle of the inverting buck boost converter is shown in figure 1.1b

1. In the on state, the input source gets directly connected to the inductor (L). This results in store up of energy in L. Thus the capacitor powers the load.
2. In the off state, the inductor will be connected to the output load and capacitor, so the energy flow will be from L to C and R.

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Compared to the buck and boost converters, the characteristics of the inverting buck-boost converter are mainly:

- The polarity of input and output will be reverse in manner;
- The output voltage can vary continuously from 0 to -∞ (for an ideal converter). The output voltage ranges for a buck and boost converter are respectively v_i to 0 and v_i to ∞.

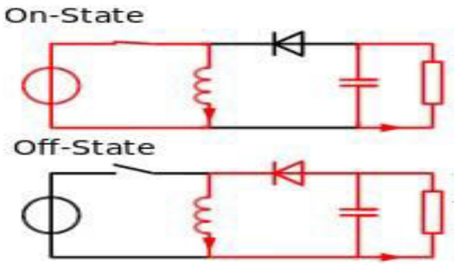

Fig 1.1b on state and off state

Let us analyse the **Buck Boost converter** in steady state operation for the mode Switch is ON, Diode is OFF using KVL.

$$\frac{diL}{dt} = \frac{\Delta iL}{\Delta t} = \frac{\Delta iL}{DT} = \frac{Vin}{L} \tag{1}$$

Since the switch is closed for a time T_{ON} = DT we can say that Δt = DT.

$$(\Delta i_L)_{closed} = \left(\frac{V_{in}}{L}\right) DT \tag{2}$$

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{(1-D)T} = \frac{V_o}{L} \tag{3}$$

When Switch is OFF& Diode is ON using KVL.
Since the switch is open for a time

$$T_{OFF} = T - T_{ON} = T - DT = (1-D)T$$

we can say that Δt = (1-D)T

$$(\Delta i_L)_{open} = \left(\frac{V_o}{L}\right)(1-D)T \tag{4}$$

It is already established that the net change of the inductor current over any one complete cycle is zero.

$$\left(\frac{V_o}{L}\right)(1-D)T + \left(\frac{V_{in}}{L}\right) DT = 0$$

$$\frac{V_o}{V_{in}} = \frac{-D}{1-D} \tag{5}$$

We know that D varies between 0 and 1. If D>0.5, the output voltage is larger than the input; and if D<0.5, the output voltage is smaller than the input. But if D = 0.5 the output voltage is equal to the input voltage. A Buck-boost converter offers a more efficient solution with fewer, smaller external components. They are able to both step up and step down voltages using this minimal number of components while also offering a lower operating duty cycle and higher efficiency across a wide range of input and output voltages. Buck boost converters are also a lot less expensive when compared to other converters [3]

1.2 Separately Excited DC Motor

Like other DC motors, SEDC motors also have stators and rotors. Stator infers the part to the part which consists of field winding. It is also the stationary part of the motor. Stators infers to the part which consist of field winding. It is also the stationary part of the motor. The rotor is the rotating part of the motor. It consists of the armature coils or

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windings. Separately excited dc motor has field coils similar to that of shunt wound dc motor. The name suggests the construction of this type of motor. In other motors the armature and field windings are energized from a single source and no separate excitation has to be provided. But, in the separately excited DC motor, separate supply should be provided for the excitation of both armature and field winding. Figure below shows the separately excited dc motor [6].

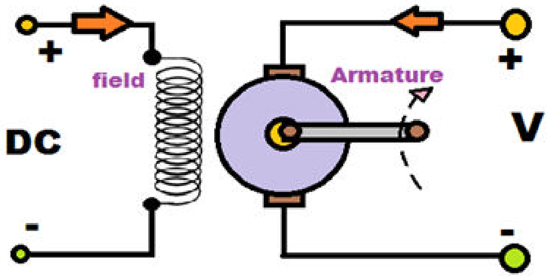

Fig 1.2 separately excited dc motor

For the field circuit, $V_f = I_f R_f$ (6)

The back emf, $E_g = K_v \omega I_f$ (7)

The armature circuit, $V_a = I_a R_a + E_g = I_{aRa} + K_v \omega I_f$ (8)

For normal operation, the developed torque must be equal to the load torque plus the friction and inertia,

i.e. $$T_d = J * \frac{d\omega}{dt} + B\omega + T_L \quad (9)$$

The torque developed by the motor is:

$$T_d = K_t i_f i_a \quad (10)$$

Where

($K_t = K_v$) is torque constant in V/A-rad/sec

B: viscous friction constant, (Nm/rad/s)

TL: load torque (Nm)

J: inertia of the motor (Kgm^2)

II.RESULT AND DISCUSSION

The closed loop and open control of buck boost converter has been simulated in MATLAB – SIMULINK and compared with that of a three phase rectifier.

TABLE 1 SIMULATION PARAMETERS

Armature voltage	230 Volt
Rotor Speed	1500 rpm
Armature current	8.3 Amp
power	2 hp
Field Voltage	300 Volt
Field Resistance	200 Ohm
Armature Resistance	2.581 Ohm
Inductance of Motor	0.028 Henry
Moment of Inertia	0.02215 kgm2
Viscous Friction Coefficient	0.002953Nms

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2.1 Simulation results of system with three phase rectifier

Figure 2.1.1 depicts the pulses generated and output voltage under no load condition in open loop system. Figure 2.1.2 illustrates the corresponding motor characteristics under no load condition. We have conducted FFT analysis and obtained a THD value of 18.74% in open loop (Figure 2.1.3).

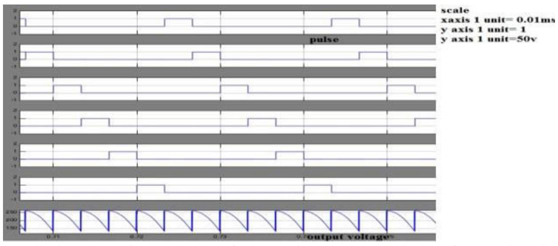

Fig 2.1.1 open loop pulse generation and output voltage in no load condition

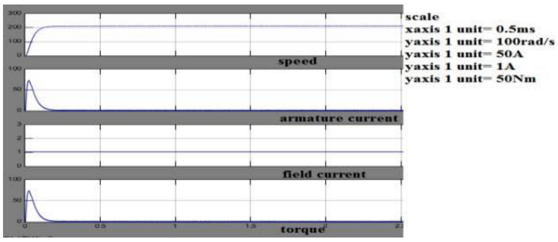

Fig 2.1.2 open loop motor characteristics under no load condition

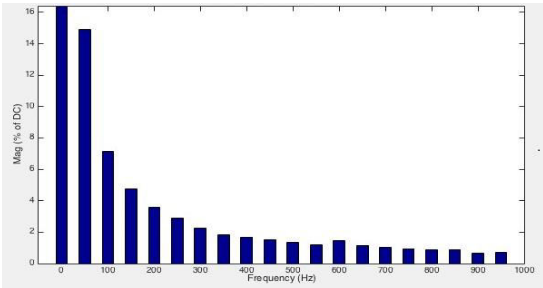

Fig2.1.3 FFT analysis on open loop control of rectifier in no load condition

Figure 2.1.4 depicts the input voltage and current under loaded condition in open loop system. Figure 2.1.5 illustrates the corresponding motor characteristics when a load of 5Nm is applied. We have conducted FFT analysis and obtained a THD value of 16.03% in open loop (Figure 2.1.6).

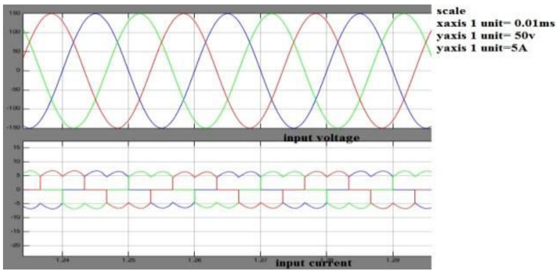

Fig 2.1.4 Input voltage and current of open loop control of SEDC using rectifier in loaded condition

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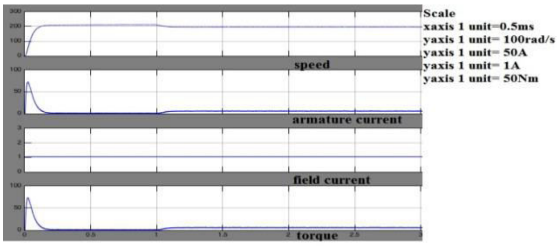

Fig 2.1.5 Motor characteristics when a load T_L=5Nm is applied

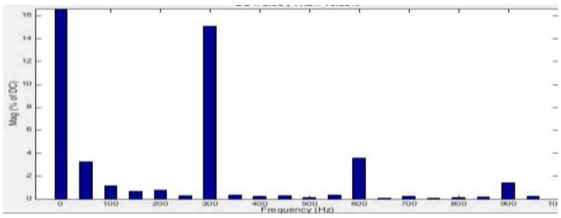

Fig 2.1.6 FFT analysis of open loop control of SEDC using rectifier in loaded condition

Figure 2.1.7 shows the motor characteristics of closed loop control of SEDC under no load condition. Figure 12.1.8 illustrates the FFT analysis conducted and obtained a THD value of 16.87%.

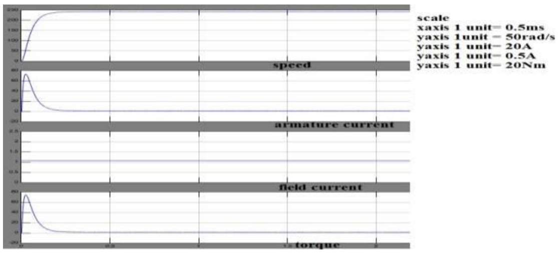

Fig 2.1.7 Motor characteristics of closed loop control of SEDC using rectifier in no load condition

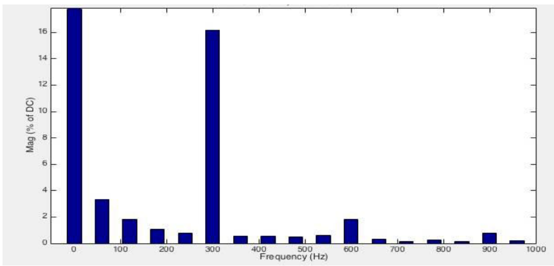

Fig 2.1.8 FFT analysis of closed loop control of SEDC using rectifier in no load condition

Figure 2.1.9 shows motor characteristics of closed loop control of closed loop control of SEDC using rectifier when a load of 5Nm is applied. We have conducted FFT analysis and obtained a THD value of 15.79% (Fig 2.1.10).

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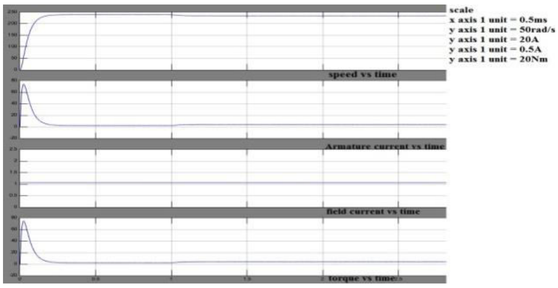

Fig 2.1.9 Motor characteristics of closed loop control of SEDC using rectifier when T_L= 5Nm is applied

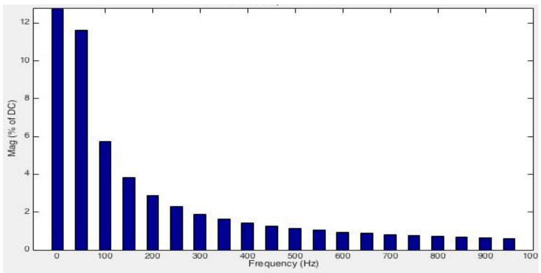

Fig 2.1.10 FFT analysis of closed loop control of SEDC using rectifier under loaded condition

2.2. *Simulation results of system with buck boost converter*

The simulation block diagram of proposed system is shown in Fig.2.2. The actual reference speed will be decided by the applied load at that instant and the controller will response to adjust its speed for specific application of the motor. The speed difference between the actual and reference speed results the speed error. Figure 2.2.1 shows motor characteristics of the open loop control of SEDC using buck boost converter in no load condition. Figure 2.2.2 depicts the FFT analysis of torque of the motor in no load condition and the THD is found to be 18.20%.

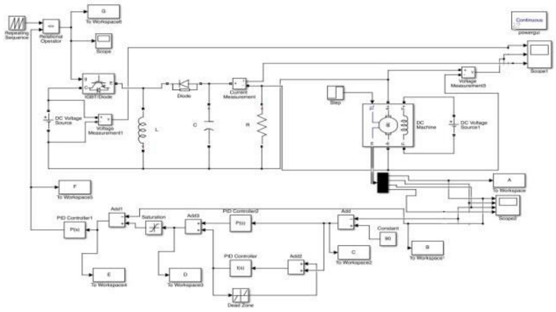

Fig2.2 Simulation block of the proposed schematic

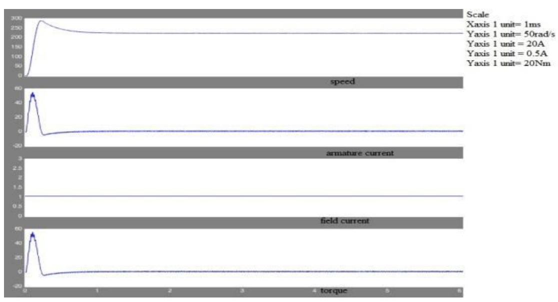

Fig 2.2.1 Motor characteristics of open loop control of SEDC using buckboost converter in no load condition

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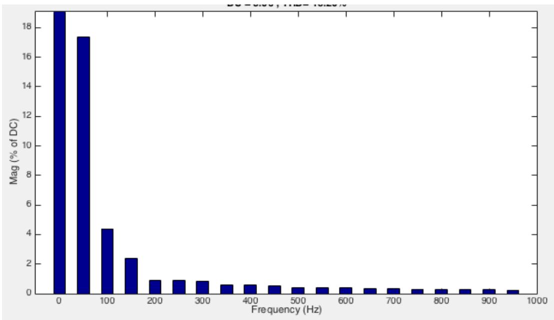

Fig 2.2.2 FFT analysis of open loop buckboost controlled SEDC in no load condition

Figure 2.2.3 shows motor characteristics of the open loop control of SEDC using buckboost converter when a load of 5Nm is applied. Figure 2.2.4 shows the FFT analysis of the motor in loaded conditions and the THD is found to be 16.95%.

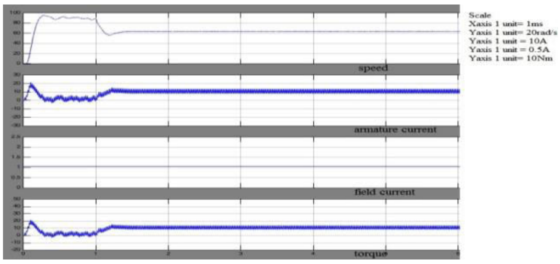

Fig 2.2.3 Motor characteristics of open loop control of SEDC using buckboost converter when T_L= 5Nm

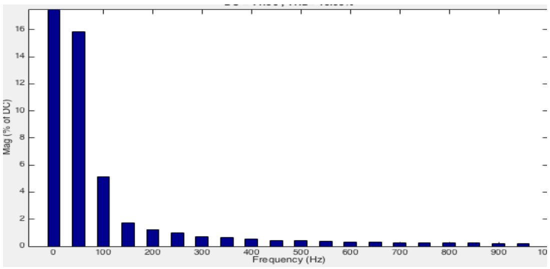

Fig 2.2.4 FFT analysis of open loop buckboost controlled SEDC when T_L= 5Nm

Figure 2.2.5 shows the motor characteristics of closed loop control of SEDC using buckboost converter under no load condition. On analysing the FFT on the torque curve, the THD is found to be 16.16%(figure 2.2.6).

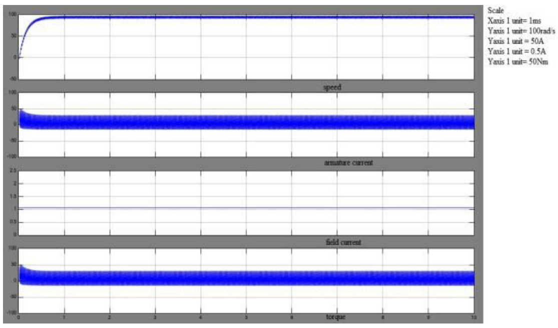

Fig 2.2.5 Motor characteristics of closed loop control of SEDC when T_L= 5Nm under no load condition

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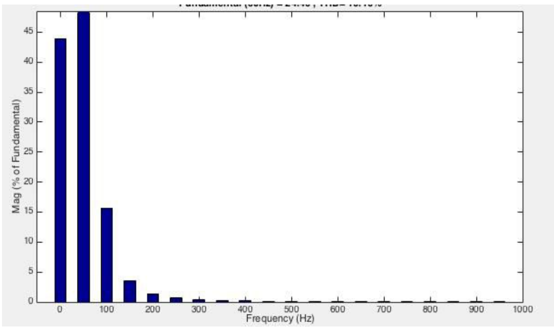

Fig 2.2.6 FFT analysis on Close loop control of SEDC on no load

Figure 2.2.7 shows motor characteristics of the closed loop control of SEDC using buckboost converter when a load of 3Nm is applied. Figure 2.2.8 shows the FFT analysis of the motor in loaded conditions and the THD is found to be 15.31%.

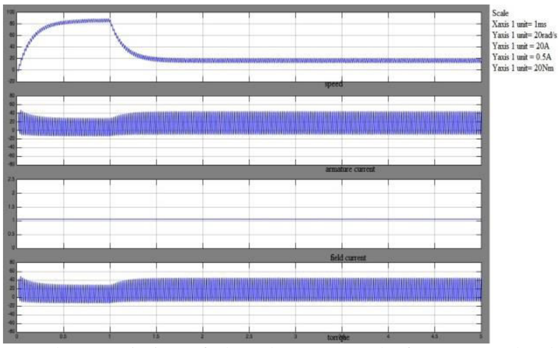

Fig 2.2.7 Motor characteristics of close loop control of SEDC on loaded condition

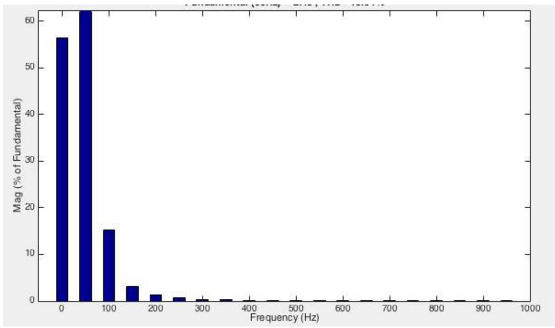

Fig 2.2.8 FFT analysis on Close loop control of SEDC on a load T_L=3Nm

III. CONCLUSION

This paper presents the validation of speed control of DC motor by utilizing the Buck boost converter as the controlling device. In the initial phase, the requirement of a PI controller is studied on a simplified open loop model for speed control of DC motor. This controller in closed loop mode has able to regulate the speed of the motor by varying its armature voltage. Later on, a generalized study of modelling of separately excited dc motor is performed and an anti-windup circuit has been incorporated to achieve error less reference for the PWM circuit. The MATLAB simulation are performed and found accurate control of output speed. By changing the duty cycle of the pulse, average voltage level is also changed and hence the speed. The table 2 below shows a comparison between the values obtained in FFT analysis on torque in open loop and closed loop speed control of separately excited DC motor under loaded and no load conditions while using a three phase rectifier and a buck boost converter. After analyzing THD, closed loop speed control of Separately Excited DC Motor using buck boost seems to be more effective than that of a three phase rectifier

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as the THD of closed loop control of Separately Excited DC Motor using buck boost seems to be less. It is easy to implement and is low cost. It also gives smooth speed control of DC motor.

	Open Loop Control		Close Loop Control	
	No load	Load	No load	Load
Rectifier	18.74%	16.03%	16.87%	15.79%
Buck boost	18.20%	16.95%	16.16%	15.31%

Table 3 Comparison of THD values obtained

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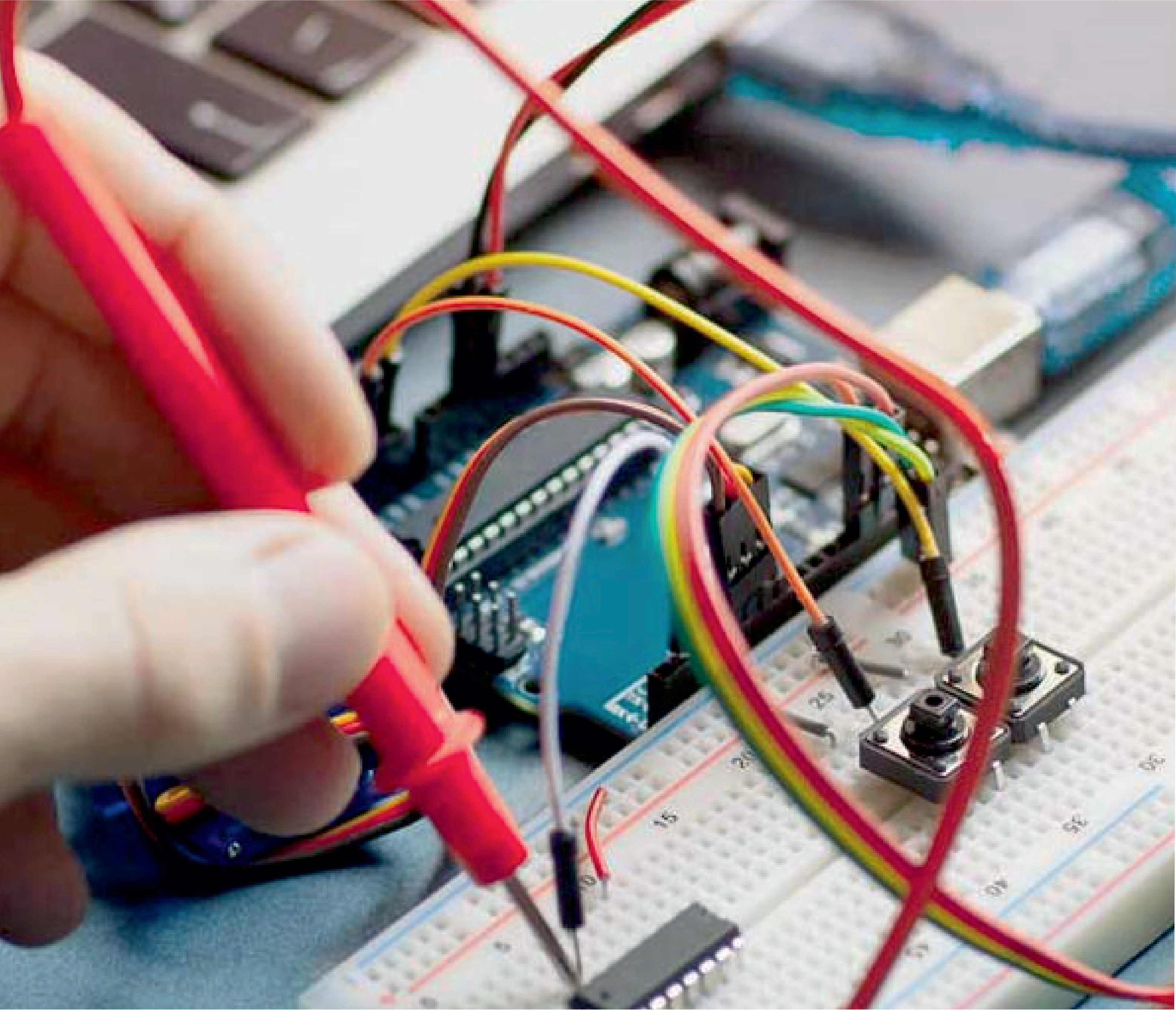

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