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Design of Converters for Renewable Energy Generation

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ABSTRACT: The high gain DC-DC converter is preferred for the conversion of low voltage which is obtained from PV/ Renewable energy systems to high voltage with less voltage stress on controlled power switch. The sudden (step) change in input voltage is shown as the energy that is obtained from PV/ Renewable energy systems is not constant is varied throughout years. In this simulation the input voltage is varied from 10V to 20V.The implementation of a coupled inductor to improving the efficiency compared to the conventional DC-DC boost converter. This topology is designed and simulated in MATLAB / SIMULINK platform. the simulation is done for sudden change in load wattage (340W and 420W) and output voltage of the designed converter is kept nearly constant at 240V.

KEYWORDS: DC- DC converter, Duty cycle, Renewable, High voltage gain, MATLAB / SIMULINK, PI controller.

I. INTRODUCTION

PV Module voltage is very low (12V to 40V). For various household and industrial applications high output voltage is preferred which encourages the research on highgain,DC-DCstep-upconverter[1]-[2].Thus,ahighgain DC-DC converter is used to optimize this low voltage, for operating a high voltage device. Due to several advantages of non-isolated converters over isolated converters, later on is chosen mostly [3]. In the proposed converter topology, coupled inductor concept isintroduced in place of a conventional step-upconverter [4]. The boost converter is implemented which reduces problems like non-linearity of a transformer, voltage spike at switches, a larger size of inductor, higher cost etc. [5]. the simulation is done for the proposed converter without closed loop where the output voltage is lesser than the expected output voltage. Then the proposed converter is simulated with closed loop control mechanism which consists of PI controller. The control signal is then fed to Signal generator [PVM] which is considered as switching signal of the MOSFET (switching device).

It gives a controlled output voltage with better transient stability. The coupled inductor- based topology has also some limitations, the effect of which can be reduced by active or passive clamp network. The concept of a coupled inductor with intermediate capacitors is chosen for a high gain of the proposed dc-dc converter. The schematic diagram of this paper is shown below-

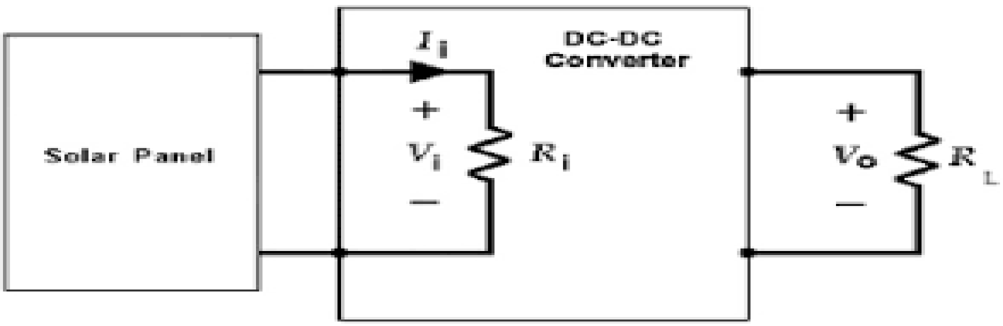

Figure 1. Schematic diagram of the work

II. PROPOSED WORK

The of conventional DC–DC boost converter a high output voltage gain can be achieved when the duty ratio is extremely high which causes sufferings from low voltage gain and high output voltage ripple. It results in several problems like

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high reverse recovery current across the rectifier diodes, turn-on and turn-off losses of switches, current stress in switching devices and leakage inductance energy across the active switches induces high voltage spikes, etc. To resolve such problems, the input-side inductor of the conventional DC-DC boost converter is replaced by a coupled inductor. [8] Here by changing conversion ratio(n), high gain in the output of the converter side is obtained while keeping the voltage stresses across the switches at a lower limit.[9]This topology also mitigates the recovery problems of a diode, active and passive switches. To reduce the ripple content of the output voltage (to the converter side) an L-C filter is designed. [10] Here PWM signal generator along with PI controller is used in control feedback path. It is necessary for the fluctuating behaviour of the input side, keeping in mind the variation of the input side voltage for PV and wind applications. In this proposed DC-DC high gain boost converter high voltage gain is obtained depending on the conversion ratio of the coupled inductor. Here the conversion ratio of the primary andsecondarycoilofthecoupledinductorisconsideredas1:7 (N1:N2). To limit the current with primary side coil of the coupled inductor, a current limiting inductor is used. Diodes and capacitors are connected in order to reduce voltage stress [12]. The output voltage ripple of the proposed converter is minimized by using an L-C filter[13]. The voltage gain of the proposed converter can be expressed as,

$V_0 / V_S = n/(1-D)$ (1)

Where 'n' is the turns ratio of the coupled inductor, D is the duty cycle of PWM signal, V0, Vs are output voltage and input voltage of the proposed boost converter.

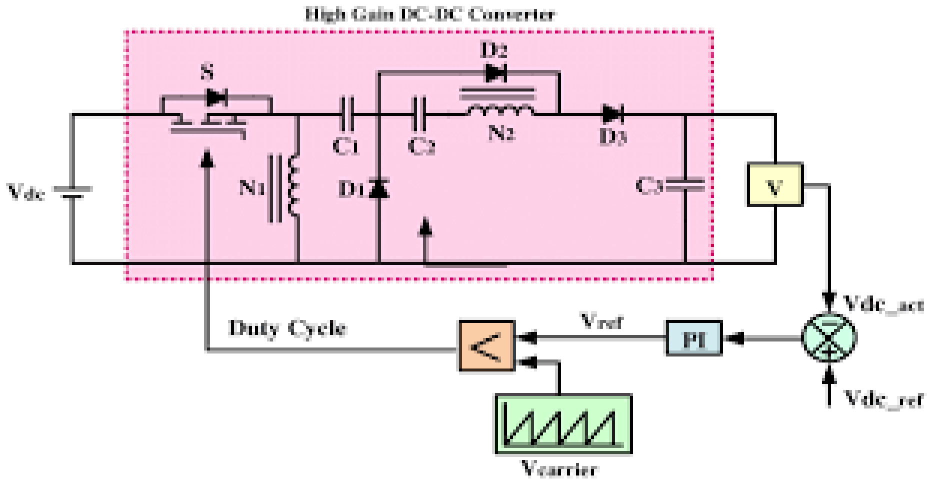

Figure 2. Closed loop model of the proposed high gain dc-dc converter

By gradually varying the turns ratio maintaining the duty cycle at a comparatively lower value of the coupled inductor, output voltage of the proposed boost converter is adjusted. In this proposed topology output voltage is will be higher and it will be about 20 times of input voltage. As this topology PV, wind application for a variation in the input voltage, the output voltage of the proposed converter is maintained nearly constant. Here, the MOSFET is used as a switching device, where the switching frequency is20kHz. In this feedback control loop, the output voltage of the high gain DC-DC converter is considered as a reference voltage. It is compared with a triangular pulse of the PWM signal generator which is treated as a carrier wave that signal is passed through PI controller which is fed back like a gate pulse to the MOSFET. Thus, the stability of the system is verified with variation in the input voltage to the converter.

III. CONVERTER CONFIGURATION

PV cell is replaced by a variable controlled DC voltage source. Depending on solarirradiation and temperature, the output voltage will be generated. Now this generated output voltage may vary from time to time throughout the day. For this reason, a controlled DCvoltagerangesbetween 10V to 26V is considered as the input to the high gain DC-DC boost converter.The variation of input is shown as it resembles practical energy sources which is obtained from renewable sources like solar/wind applications. In figure 3 output voltage of the high gain dc-dc converter is simulated at fixed duty cycle (D) of 0.6 which gives around 234 volts with the current limiting inductor. The output voltage is also varied due to changes in different loadconditions. But as per proposed converter specifications and from the application point of view output voltage must be nearly constant around 240 volts for a sustainable operating condition

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which can be fed into a single phase or three- phase inverter for industrial or household appliances. Thus, it is necessary to design a closed-loop mechanism to control the gate pulse of the switching devices (here, MOSFET) by varying the duty cycle.

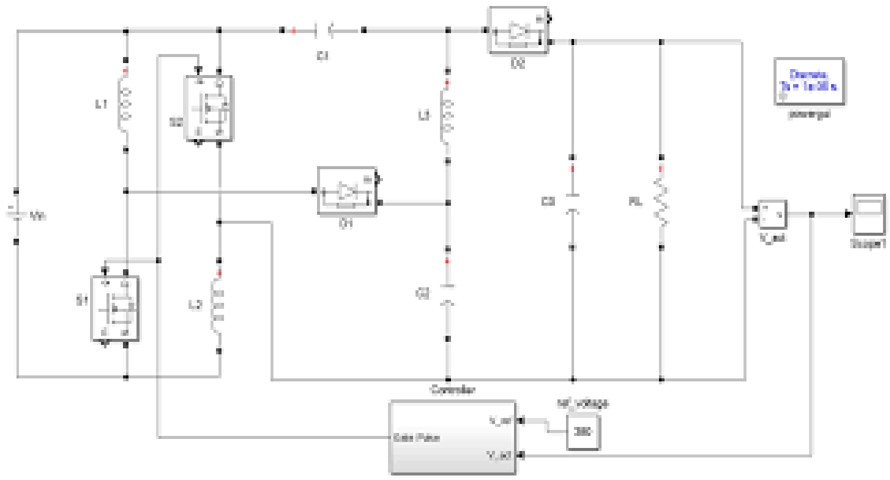

Figure 3. SIMULINK model of high gain dc-dc converter without closed loop

The output voltage is also varied due to changes in different load conditions. But as per proposed converter specifications and from the application point of view output voltage must be nearly constant around 240 volts for a sustainable operating condition which can be fed into a single phase or three- phase inverter for industrial or household appliances. Thus, it is necessary to design a closed-loop mechanism to control the gate pulse of the switching devices (here, MOSFET) by varying the duty cycle.Here MOSFET is selected as a switching device in the proposed converter due to some of its property like high switching frequency, bi-directional, low cost etc.
Output voltage expression of the proposed converter: - V0 = {n/(1-D)} *Vs (2)
Here, Switching frequency (F) = 20 KHz. (Converter) Time period (T) = 1/F = 1/20 kHz = 50 µsDuty cycle (D) = Ton / (Ton + Toff)
= Ton / T = (30 µs / 50 µs) = 0.6
n (Turns ratio of the coupled inductor) = N2 / N1 = 8 We know, L = (µ0 * µr * N2* A)/l (3)
Here, L =Inductance,
N = No. of turns of coupled inductor coil, A = Cross-sectional area,
l = Length,
µ0 =permeability of the material,
µr = permeability of air. From equation (3),

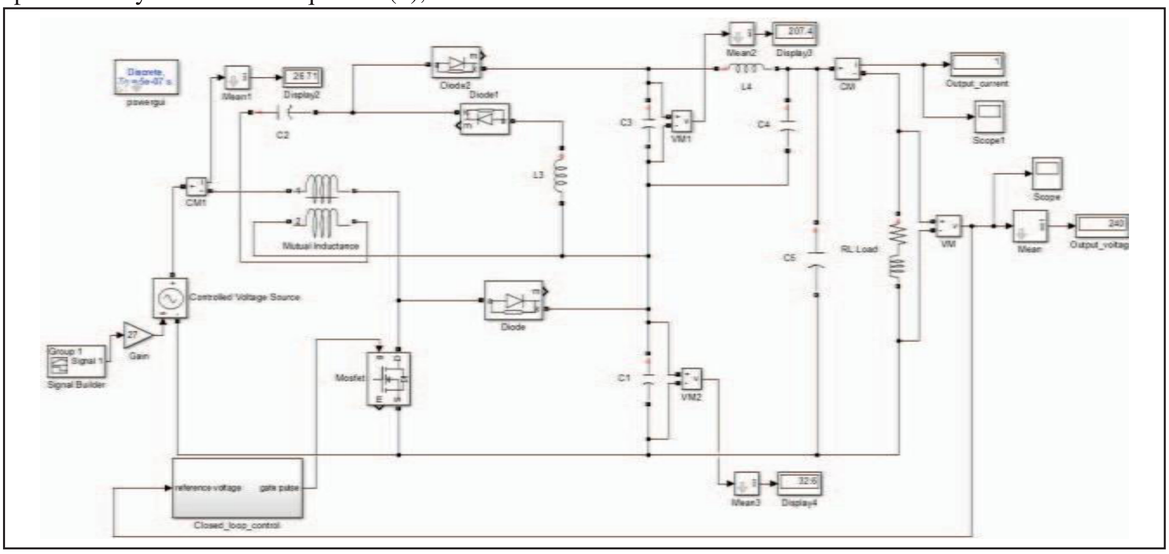

Figure 4. Closed loop circuit of the proposed converter

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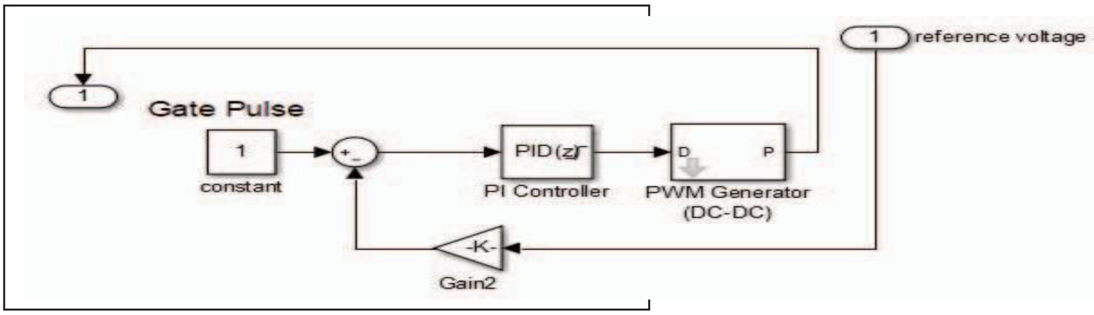

Figure 5. Closed loop control circuit of the proposed converter

L2 / L1 = (N2/N1)2 (4), L1 is calculated from

Vs= L1 * (dIL1/dt) (5) And from Eq. (4),L2 = (N2 / N1)2 *L1

Our desired output voltage is obtained by using a controlled feedback path.

IV. SIMULATION RESULT

Parameters	Values
Input Voltage	9V – 21V
SwitchingFrequency	20KHz
Inductor(L1)	15uH
Inductor(L2)	960uH
Duty cycle (D)	0.6
Load (R-L)	240ohms, 120mH

TABLE I. INPUT OF THE CONVERTER

In the first stage the primary coil of the coupled inductor(L1) is charged with the source voltage when the switch is closed. At the same point of time the secondary coil of the coupled inductor(L2) is also charged along with capacitor(C2). In the Second stage the switch is opened circuited and the source voltage as well as the coupled inductor is supplied to the load. From the volt-sec balance, the output voltage expression of the proposed converter is obtained.

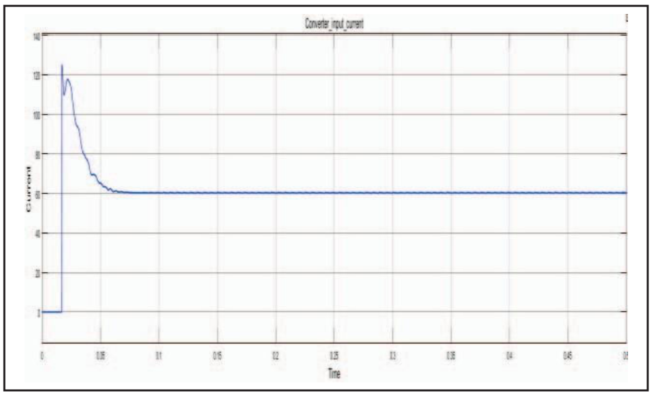

Figure 6. Input current waveform without current limiting inductor

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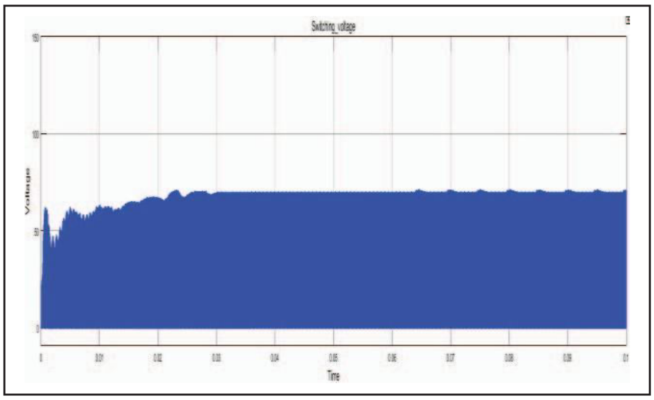

Figure 7. Voltage across the switching device

V. CONCLUSION

The output voltage obtained from proposed converter can be fed directly to inverter before it is finally applied to the electrical load for various AC appliances. Closed loop control scheme helps to achieve a nearly constant output voltage from the proposed converter end which is also required to attain better efficiency. From the performance comparison with the existing converter topologies maximum efficiency is compared here. At full load condition,

Efficiency (%) = (Output power / input Power) * 100 (6)
The output power (P0) = V0*I0 (7)
P0 = (240 * 1) W= 240 W
The input power (Pin) = Vin* Iin (8)
= (12 * 21.1) W= 253 W
Efficiency (%) = (240 / 253) * 100 = = 94.8 %.

The maximum efficiency existing converter is 94.5% [3]. In this proposed topology efficiency is approximately 95% whereas the switching peak input current is minimized from 125A to 57A. For low voltage (9V) the input current of the converter is 27A and for testing purpose 12V (nominal input voltage) is chosen, the input current is 21.5A. The voltage stress across the switch is also reduced by using current limiting inductor. Output voltage obtained such that application of transformer is not needed to boost up the output power and reduce the cost and bulkiness of the system before applying to the load.

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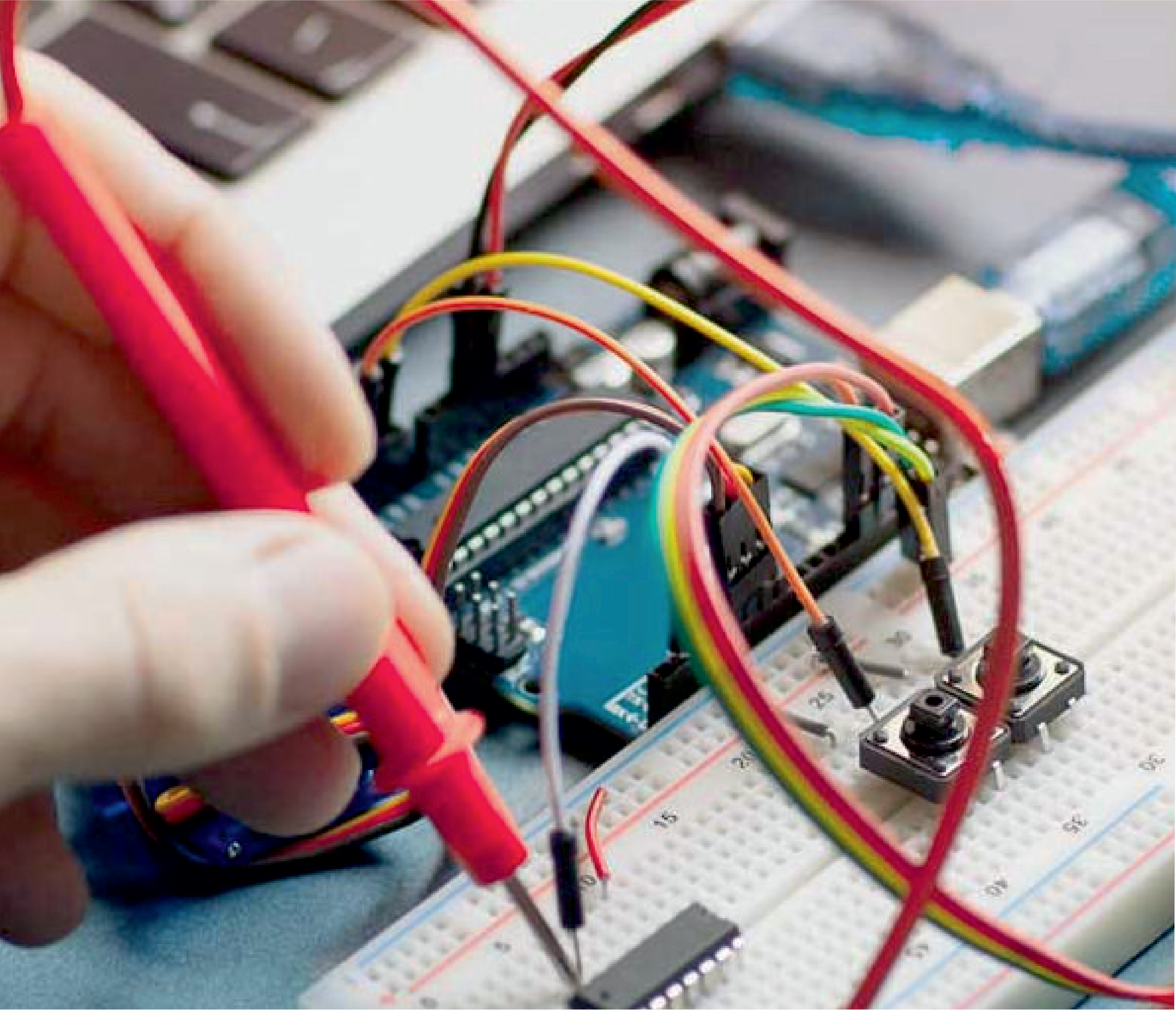

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