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A Dual Control Regenerative Braking Strategy for Two-Wheeler Applications

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ABSTRACT: In this paper, bi-directional DC/DC buck-boost converter with dual controlstrategy during regenerative braking is used for a two-wheeler application. Proposed system combining of two source one as PV array and other as Battery which use to provide as input to bidirectional DC DCconverter .During the normal and Good Solar Irradiation Conditions the PV array generated maximum voltage therefore it play important role during motoring mode to supply power to motor but when Availability or less amount of solar irradiations output battery will supply power to motor . PV and battery not sufficient to provide power to motor some time. Theconverterwiththeproposedcontrolstrategy used in this work has made it possible to charge the battery even when the back emf ofthe machine is less than the battery voltage. A fuzzy logic control strategy is used to consider the non-linear factors like SOC, speed of the vehicle and the required brake force. This is done in order to make the system more reliable and realistic. The model is completely simulated in MATLAB/Simulink. By implementing the dual control strategy, the average power stored by the battery is increased and the vehicle comes to halt faster in comparison with the existing control strategy. To support the above claims, simulation results are presented to show the effectiveness of the proposed method

KEYWORDS*:* Braking, Bidirectional Converter, Fuzzy, SOC

I. INTRODUCTION

In today's world of dwindling resources and ever increasing prices, spending a lot on fuel has become a major part of the economic budget. Reducing fuel consumption can have a major impact on decreasing the capital spent on fuel. To achieve this, hybrid electric vehicles (HEV) and plug in hybrid electric vehicles (PHEV) [2] are an alternate solution. Installation of high energy battery packs and regenerative braking play an important role in improving the drive range [7] of the electric vehicles as well as improving the battery life.In order to extract the maximum electrical energy from the rotational mechanical energy, DC/DC converters with appropriate charging and discharging profile are required. Various topologies of DC/DC converters have been discussed in . However, regenerative braking [7], has to be carried out with the conventional frictional braking. In the braking process, there are two issues that are to be addressed. First is accurately applying the brakes which restrains the vehicle speed and maintains the vehicle's travelling course. And the second issue is to recover the braking energy to increase the energy efficiency of the battery. In practical scenario, factors like state of charge (SOC) of batteries, speed of the vehicle and driver's brake force requirements limit the effectiveness of electric braking. Thereby mechanical braking has to be incorporated along with regenerative braking. In literature, many works on regenerative braking and various algorithms for the control during the regenerative braking are proposed. The work proposed a method wherein vehicle's speed is taken into account and not the SOC. Authors in [4] have taken the SOC into account and computed the regenerative force. However, the above works have not stated any methods to utilize the regenerative power to charge the battery. Works carried out in [5] and [6] have used different topologies of bi-directional DC/DC converters to charge the battery. However, the converters used in the works do not address the issue that arises if the terminal voltage of the machine falls below the battery voltage during low speed of the vehicle. The back emf is neglected when the battery voltage is greater than the terminal voltage of the machine.In this paper, the focus is on the dual (voltage and current) control strategy which is used to extract the maximum possible energy during the regenerative braking and to ensure that the vehicle stops in an optimum time frame. In addition, fuzzy logic control is used to determine the battery charging current as its determining factors (SOC, vehicle speed and brake force requirement) have an uncertain relation with it. In addition, a cascaded bi-directional DC/DC buck-boost converter with a PMDC machine has been used. This is done to charge the battery even when the back emf of the PMDC machine is less than the battery voltage and at the same time have an effective braking while taking the safety issues and battery conditions into consideration. In this paper we have PV as parallel source to the battery

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II. PROPOSED MEHODOLOGY

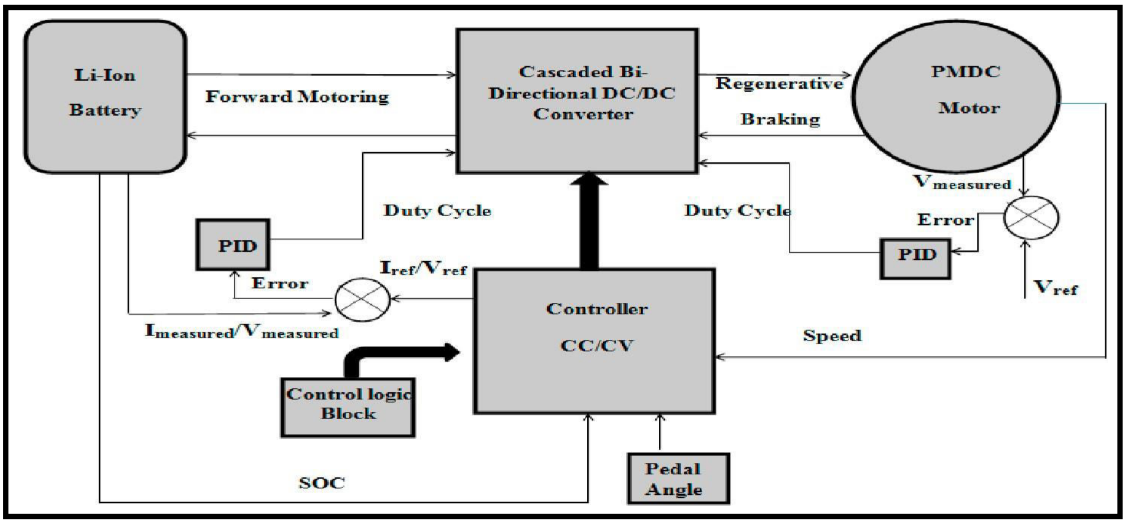

Fig-2 Proposed system

Figure.2. shows the overall configuration of the electric vehicle system, with the dual controlstrategy we propose. Different parts of this block diagram are simulated on MATLAB/Simulink.Thevarious componentsinclude:

i. Li-ion battery
ii. Permanent Magnet DC motor
iii. Cascaded bidirectional buck-boost dc-dc converter
iv. Fuzzy logic reference current generator
v. Control logic block

Mode 1: Boost Operation – Battery to DC Bus during motoring operation (Primary Boost Mode)

Switches S3, S4 are off, S1 is on and S2 is in PWM switching mode. The battery voltage is stepped up to the level of the terminal voltage of the PMDC machine. The converter operates in this mode when the PMDC machine is running as a motor. [1]

Mode 2: Buck operation - DC bus to battery during the regenerative braking.

Switch S1 is on, S2 and S4 are off and S3 is in PWM switching mode. The PMDC's terminal voltage is stepped down to the level of battery voltage during the braking operation. The converter

operates in this mode when the PMDC machine is operating as a generator and the generated voltage is greater than the battery voltage. [1]

Mode3: Boost operation - DC bus to battery during the regenerative braking (Secondary Boost mode)

The terminal voltage of the PMDC is stepped up to the level of battery voltage. This situation occurs when the generated battery voltage is less than the battery voltage. During this mode S1 and S2 are off, S3 is on, S4 is in PWM switching mode. [1]

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In the above Fig.2, there are blocks of subsystems representing the CC/VC blocks for each mode. In the next section, the modelling and explanation of each of these blocks is mentioned

III. SIMULATION AND RESULT

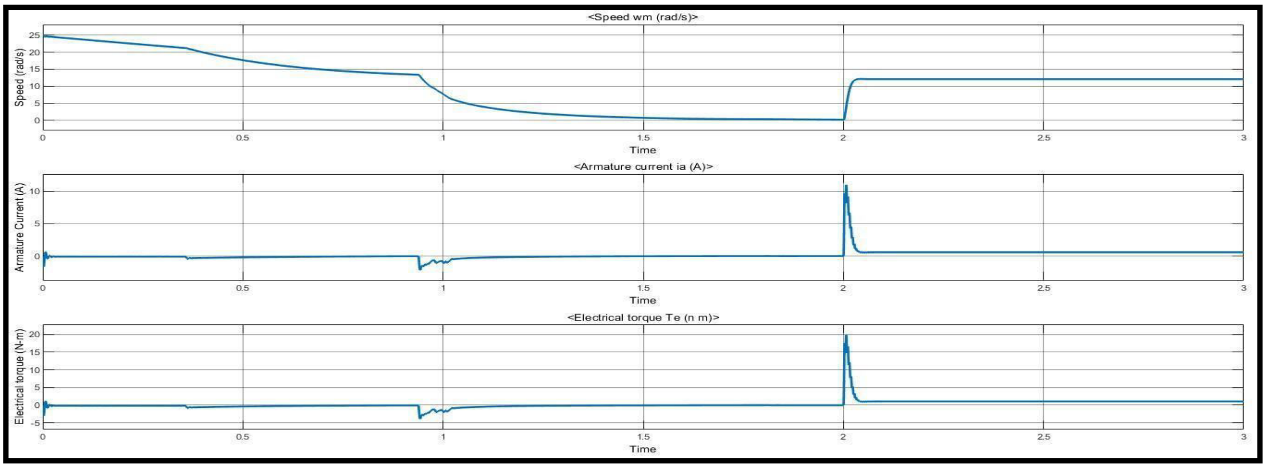

Fig.3 Proposed simulation

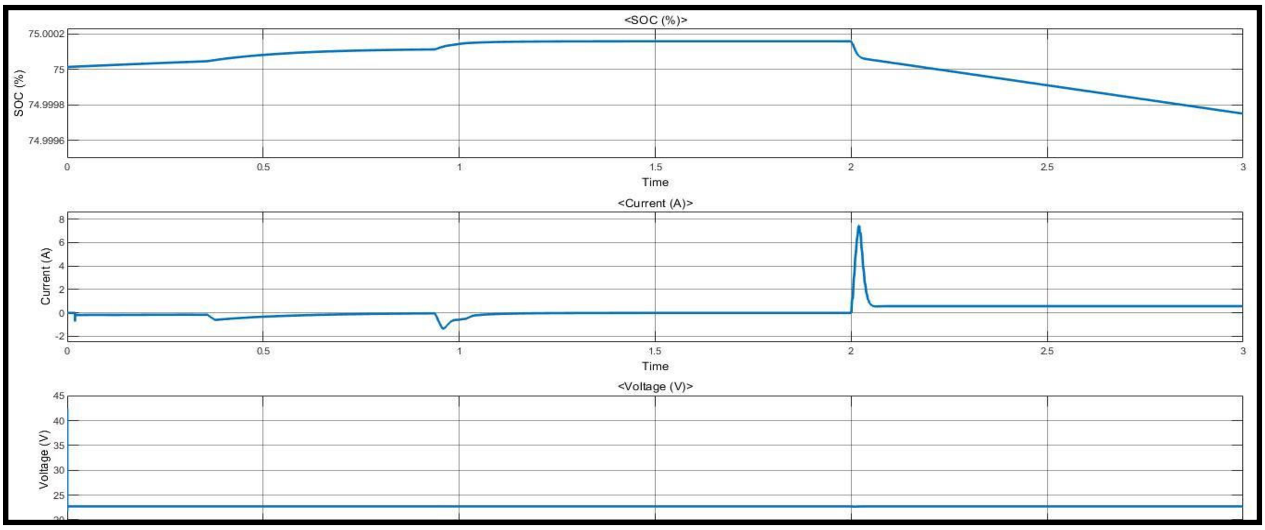

Fig.4BatteryOutput SOC, current,Voltage

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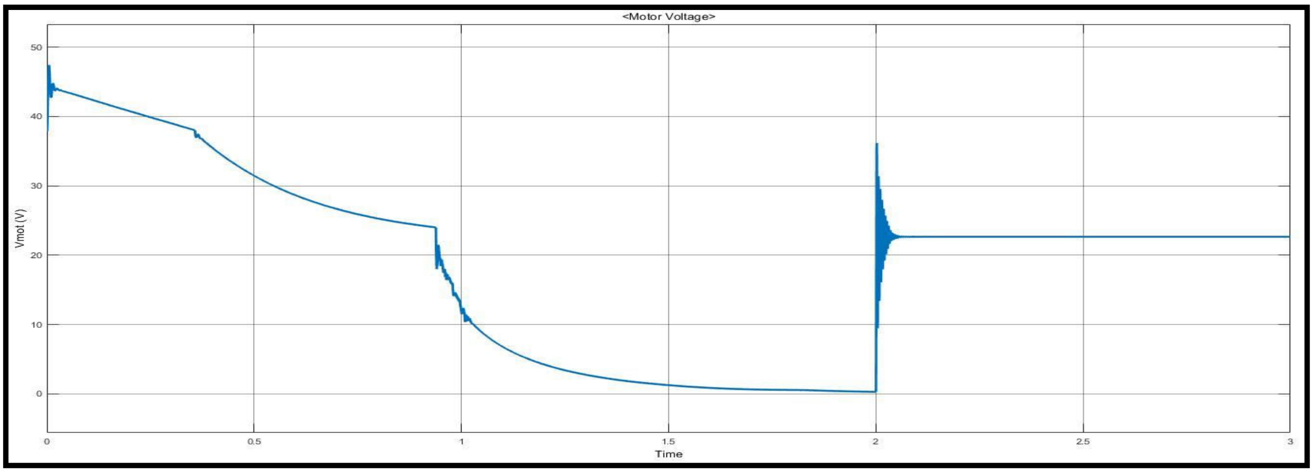

Fig 5. motor speed, Armature current, Electromagnetic torque

above simulations show the braking process occurring from t = 0 to 2.
At t = 2, a positive load torque is applied to show the transition from braking to motoring mode.

Fig 4 (a) shows the SOC of the battery which is initially at 75%. As the battery gets chargedduring thebraking process theSOC ofthe battery rises. After t =2 the SOCstarts to drop again asthe motor now operates in forward motoring mode.

Fig 4 (b) shows the battery current. When the brakes are applied the motor acts as a generator(reversemotoring mode) and the current flows from the motor to the battery.
From t =0 to 2 the magnitude of the current is negative indicating that the current is flowing intothe battery. After that, the current becomes positive as the motor now draws current from thebattery for forward motoring. The sharp peak observed at t =2 is an indicator of the high startingcurrent of the motor.

Fig 4(c) shows the battery voltage whichremains moreor less constant throughout.

Fig 5 (a) shows the speed of the vehicle which is 25 m/s initially at the instant when the brakesareappliedandreduces tozerowhenthevehiclecomestohaltatt=2.Afterthatthevehiclespeedrises again

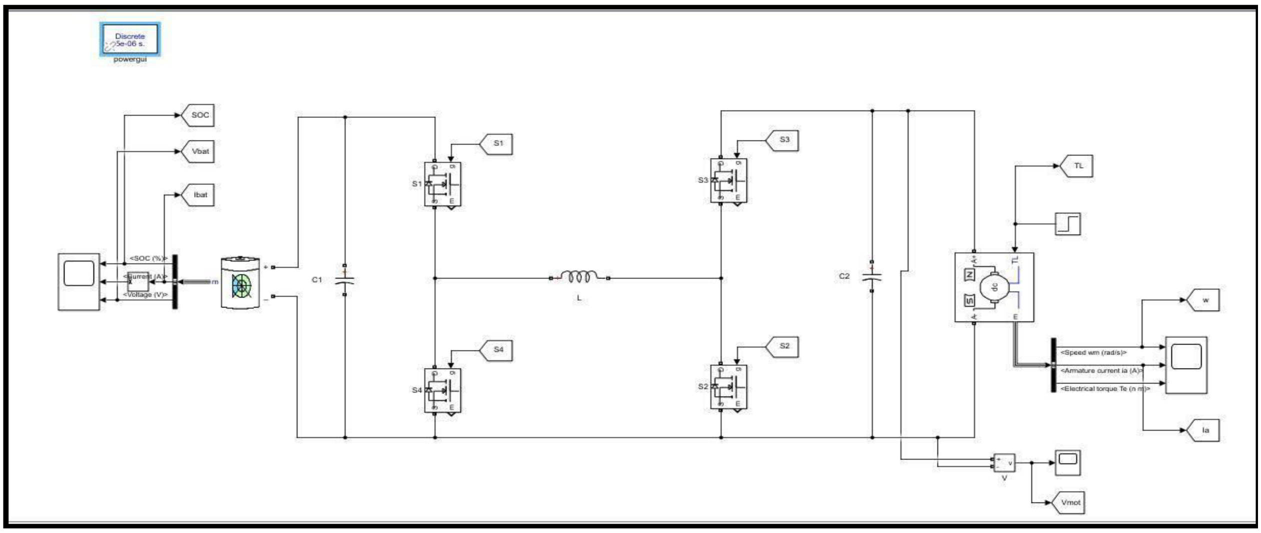

Fig:6 Motor Terminal Voltage

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Fig 5 (b) shows the armature current which has a negative value indicating flow of current from motor to battery until it becomes zero at t = 2. The current magnitude becomes positive after t = 2 as the motor transitions to forward motoring mode. The sharp peak observed at t =2 is an indicative of the starting current of the motor.

Fig 5 (c) shows the motor electrical torque. As the torque is proportional to armature current the torque curve follows the armature current curve, only differing in magnitude.

Fig 6 shows the motor terminal voltage. Initially its value is close to the rated terminal voltage of the motor. During the braking process the motor terminal voltage keeps dropping until the vehicle comes to halt. It rises again as the motor transitions to forward motoring.

1. When Vmot >= Vmot (rated)

   Converter operates in Mode 2 CC control, i.e. the motor voltage is stepped down and fed to the battery while deploying CC control as the initial charging current is of significant value.

2. When Vbat < Vmot < Vmot (rated)

   Converter operates in Mode 2 VC control, i.e. the control method is shifted from CC to CV

3. When Vmot < = Vbat, Ia is not zero

Converter operates in Mode 3 CC control

1. When Vmot < = Vbat, Ia = zero Converter operates in Mode 3 CV control

IV. CONCLUSION

Modelling And Analysis Of Dual Control Strategy For Two-Wheeler Electric Vehicle" suggests, through the course of this project we have thoroughly studied the proposed control strategy for two-wheeler electric vehicles. We have done so by:

i. Understanding the concept of regenerative braking in electric vehicles and why this is particularly useful but difficult for two-wheeler EVs.
ii. Understanding how the dual control strategy as well as our chosen components can help extract maximum energy and stop the vehicle safely in a limited time frame, irrespective of speed.
iii. Performing modelling of different components comprising the regenerative braking system of the vehicle as per the proposed control strategy. This helped us understand the merits of each component and their contribution to making the process as efficient as possible. The modelling performed on MATLAB/Simulink.
iv. Developing a compact Simulink model combining the different components and subsystems as it would be in a realistic system.
v. Developing a control logic algorithm for operating the circuit in different modes according to the speed of the vehicle and whether it is in motoring or regenerative braking mode.
vi. Studying outputs obtained for executing the braking system in a limited time frame and understanding the transition from motoring to regenerative braking with current control and voltage control performed accordingly.
vii. Use renewable source of energy (PV) in parallel with battery which help to maintain continuity of supply.
viii. Overall parameter of battery ad motor observed and analyzed using MATLAB which will be better using Proposed Methodology.

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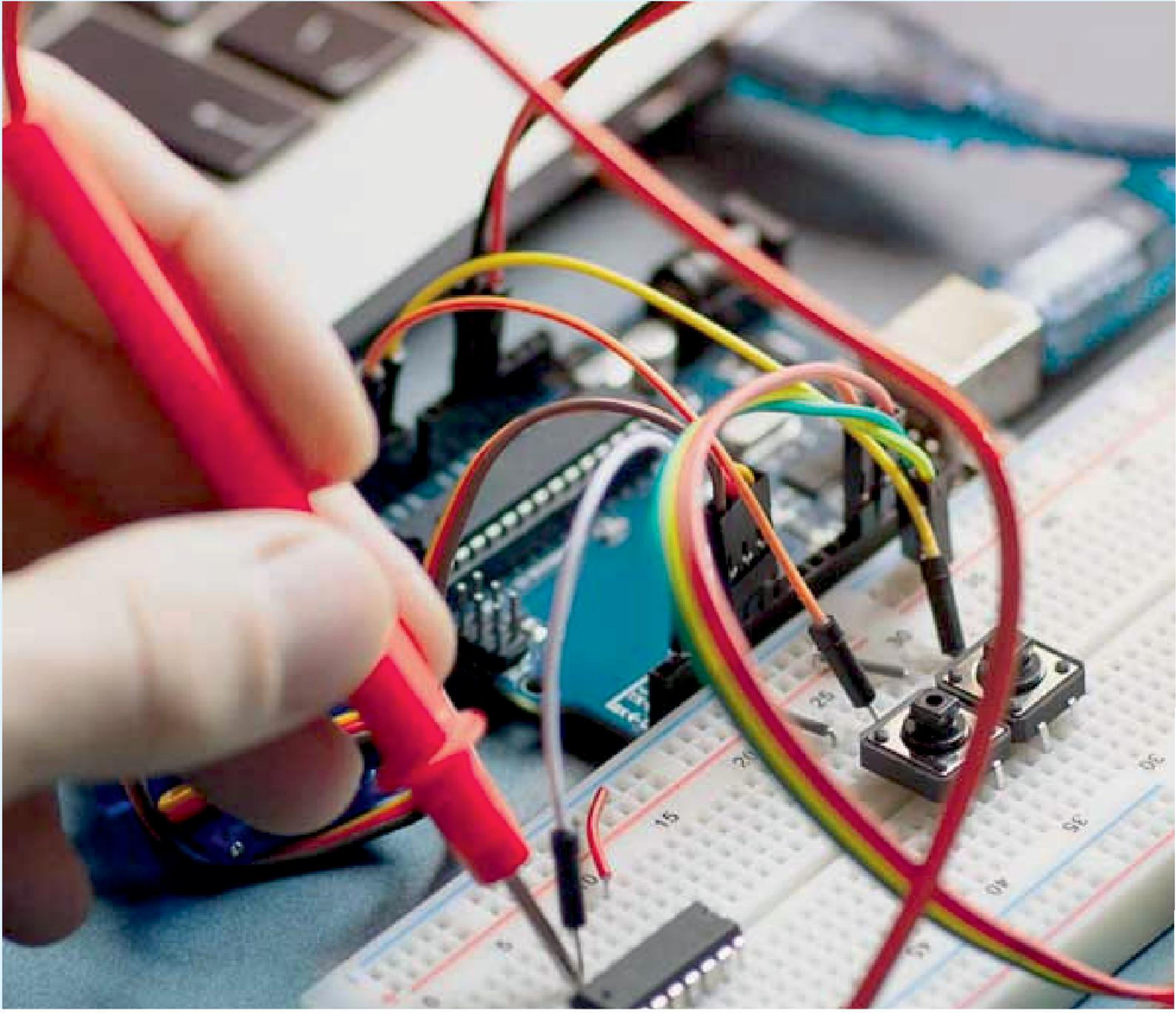

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