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Design and Implementation of ANFIS Controller Based Hybrid Energy Storage System in an Electric Vehicle Charging Station

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ABSTRACT: This project focuses on the design and implementation of an Adaptive Nero-Fuzzy Inference System (ANFIS) controller for an advanced electric vehicle (EV) charging station. The proposed system integrates various energy sources, including a solar photovoltaic (PV) array, grid connection, battery storage, super-capacitors, and a diesel generator set, to enhance the charging station's efficiency, reliability, and sustainability. The ANFIS controller is employed to manage the power flow among these energy sources dynamically, considering factors such as weather conditions, grid availability, and charging demand fluctuations. Through adaptive learning capabilities, the ANFIS controller optimizes the charging station's operation in real-time, maximizing renewable energy utilization, minimizing grid dependency, and ensuring uninterrupted EV charging services. The project aims to demonstrate the feasibility and effectiveness of ANTFS based control strategies in complex energy management systems, contributing to the advancement of sustainable transportation infrastructure. Experimental validation and performance evaluation will be conducted to assess the proposed ANFIS controller's robustness, accuracy, and practical applicability in real-world electric vehicle charging scenarios.and the total harmonic distortion is less than 3% as per IEEE standards

KEYWORDS: ANFIS controller, PV Array Grid, Super capacitors, EV charging station

I. INTRODUCTION

The enormous increment of load demand and simultaneous decrement of coal reserves forces the researchers to search for the alternative renewable energy sources industry growth increasing day by day in all the industry applications Electric vehicles are the best solution of for environmental pollution and oil reserves the charging of the electric vehicles are the thrust area where we concentrated even though many solutions are present we are proposing the solution with present technology, Here we are proposing ANFIS based controller for charging the battery from different sources of energy and its coordination.

As in the Era of modern generation the use and demand for the electric vehicles are more in order to meet the requirements of the vehicle charging the charging stations are established to meet the charging of the vehicles the charging station are designed in such a way to deliver uninterrupted output So the charging stations are implemented by using multiple sources like solar PV array, Diesel generator set battery and from the Grid. The performance characteristics of the station are controlled by using various controllers for the use of charging stations

To address these issues in the existing system, the PI controller was replaced with an ANFIS controller. This transition significantly improved system performance, particularly in maintaining high power quality. Additionally, a Hybrid Energy Storage System, comprising a super capacitor system alongside the battery system, was integrated into the EV charging station. This hybrid approach ensures a consistent and reliable high-power supply, enhancing the overall efficiency and effectiveness of the charging station.

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II. METHODOLOGY

In this project we have proposed a block diagram in which the electric vehicle charging station is been operated on various energy storage systems in which they are operated when the remaining are absent and the charging station is been controlled by the means of the advanced controller that is termed as ANFIS which is the combination of both ANN and Fuzzy logic controller.

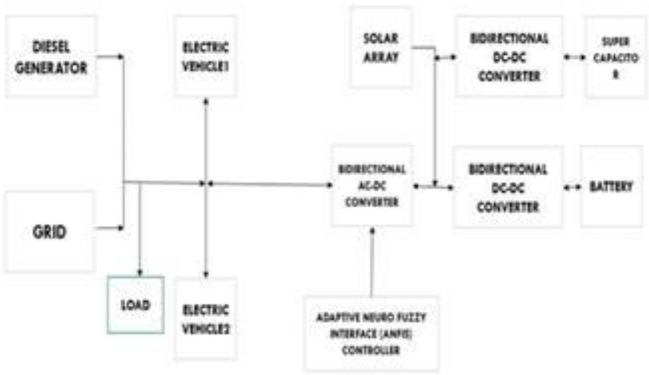

Fig 1: Block diagram of proposed system

Here this controller is designed for the control of the station in which the previous controller drawbacks are reduced

The proposed system consists of majorly 4 modes of operation using the ANFIS controller and super capacitor set they are

When diesel generator set is acting alone, when solar is acting alone, when grid and diesel generator set both are acting, when all sources are acting and the connected loads are unbalanced

The existing methods are having the disadvantages of slow response of the system and the position constant and the acceleration constant should be changed manually so it takes more time So to overcome this the system is designed in such a way that the combination of both the ANN and Fuzzy logic combination controller ANFIS controller is used

III. CONTROLLERS USED

MPPT CONTROLLER

An MPPT solar charge controller integrates an MPPT algorithm designed to optimize the flow of current from PV module to the battery. Maximum Power Point Tracking, functioning as a DC-to-DC converter, ensuring precise alignment between the PV module and the battery.

CONTROL ALGORITHM

The primary goal in charging station design is to efficiently utilize energy from the photovoltaic array to charge electric vehicles and maintain a consistent power supply for household appliances. As a result, the controller is intricately designed to support the charging station's functionality in islanded, grid-connected, and diesel generator set scenarios. A detailed control diagram illustrates the operational procedures of the charging station across these diverse modes.

A. Islanded Mode Control

When operating in islanded mode, the charging station utilizes power from both the PV array and a battery to meet its energy requirements. In this setup, the station produces a sinusoidal voltage (vc) at 230V with a frequency of 50 Hz. This generation process involves comparing the reference sinusoidal voltage (vc) with the sensed Point of Common Coupling (PCC) voltage (vc), resulting in the derivation of an error voltage (vce). The error voltage acts as the input to the Proportional Integral (PI) controller, which adjusts its output to regulate the system accordingly.

$$i_c^*(s) = i_c^*(s-1) + k_{ps}\{v_{ce}(s) - v_{ce}(s-1)\} + k_{is} v_{ce}(s) \quad (1)$$

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B. Grid or DG set Connected Mode

In the Voltage Source Converter (VSC) control strategy, whether power is supplied from the Distributed Generator (DG) or the grid to the Point of Common Coupling (PCC), the VSC is designed to maintain sinusoidal currents (ig) from the DG or grid (is), even if the total current (iL+ie1+ie2) deviates from sinusoidal patterns. This objective is accomplished through a control algorithm that evaluates the active (wp) and reactive (wq) components of the total current at the PCC, utilizing an adaptive control mechanism for precise estimation. Based on these calculated values (wp) and (wq), the VSC generates reference sinusoidal currents (ig) or (is) and generates switching pulses accordingly. Additionally, the control scheme includes voltage and frequency regulation for the Distributed Generator (DG). However, these control loops are inactive during grid connection to the system.

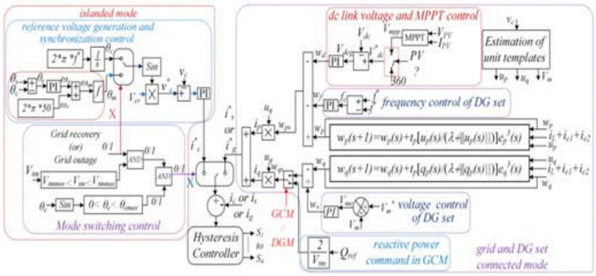

Fig 2a VSC control of charging station.

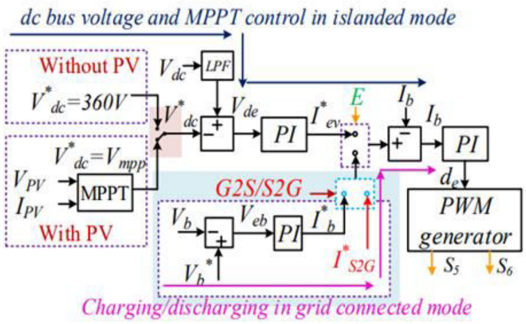

Fig 2b control of bidirectional DC converter

PROJECT DESCRIPTION

The overall project is been developed and designed in the MATLAB simulation and the results are been displayed in been form of continuous graphs the analysis is done by using the powerful digital signal analyzer which is called the FFT that stands for fast.

Fourier transform for the analysis of the graphs that are obtained by the system after simulation the simulation models and the structure of the ANN and Fuzzy logic controllers are shown and described below.

The ANN controller primarily consists of three distinct layers: the input layer, the hidden layer, and the output layer.

Based on the inputs that are given to both the controllers the output is been generated to control both the converters and charging station

Below is the illustration depicting the structure of both the ANN controller and the fuzzy system.

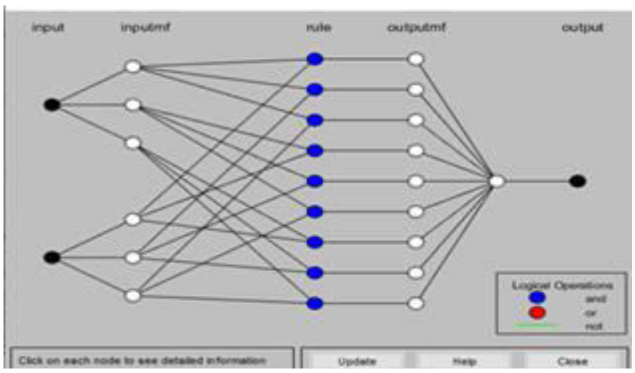

Fig 3: The structure of the ANN controller

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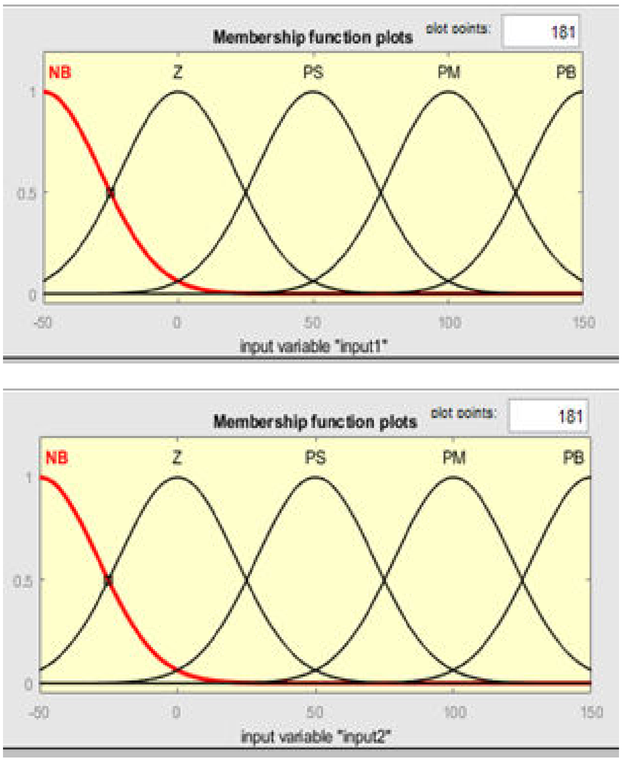

Fig 4: The inputs and outputs of the fuzzy controller   for the signals from the system

IV. SIMULATION MODELS AND WAVEFORMS OF SYSTEM

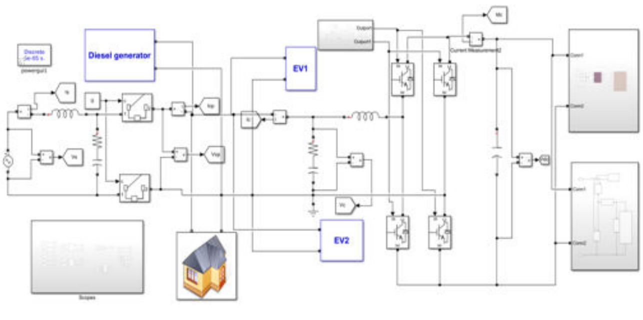

Fig 5: Simulation model when DG is acting alone

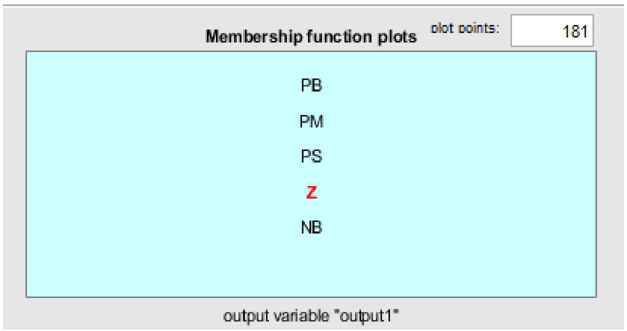

Fig 6: Simulation model when solar panel is acting alone

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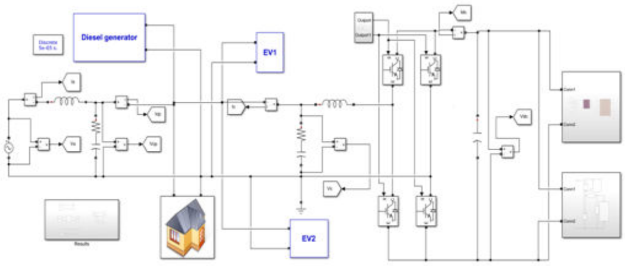


Fig 7: Simulation model when dg and grid both are action

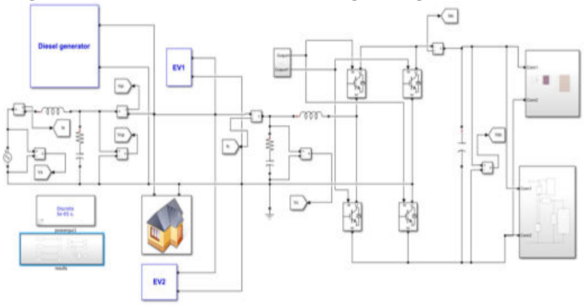
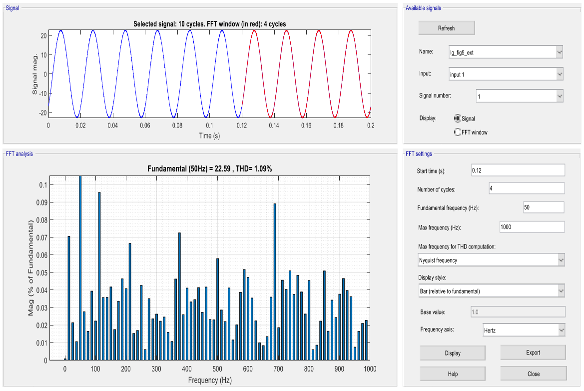
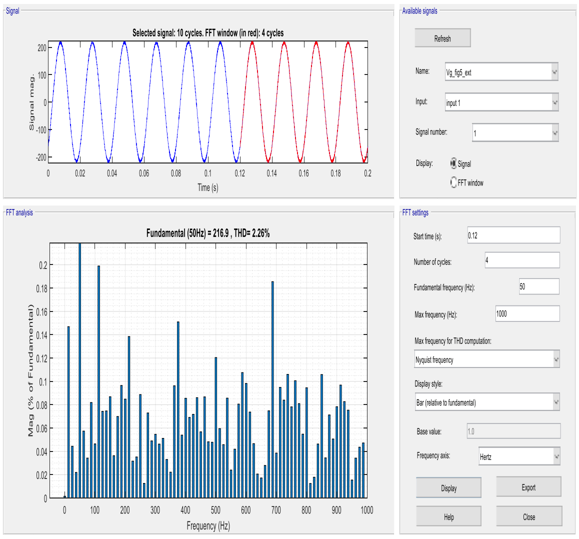


Fig 8 when all sources are active but with unbalanced loading

ANALYSIS OF RESPECTIVE RESULTS



Generator Current



Generator Voltage

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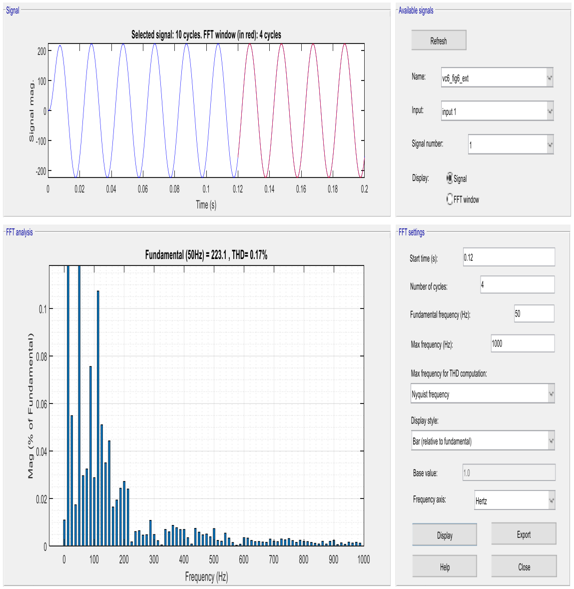
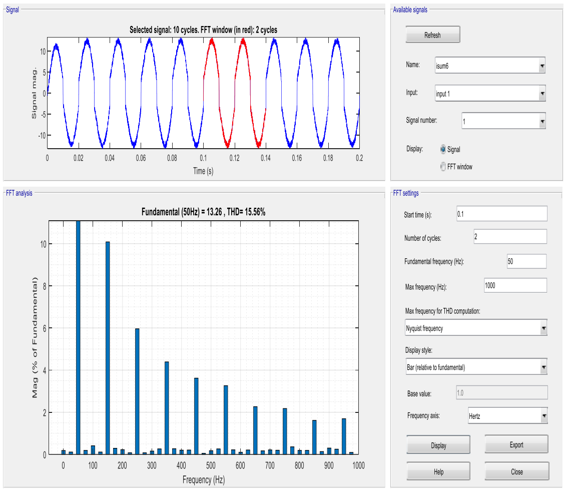
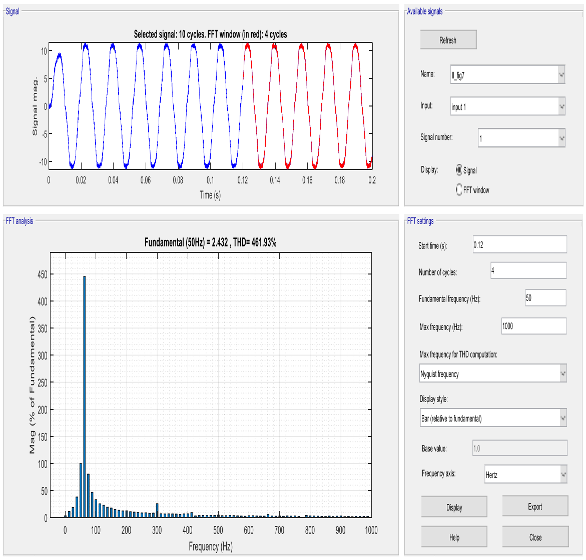


Capacitor Voltage



Sum of Currents



Load Current

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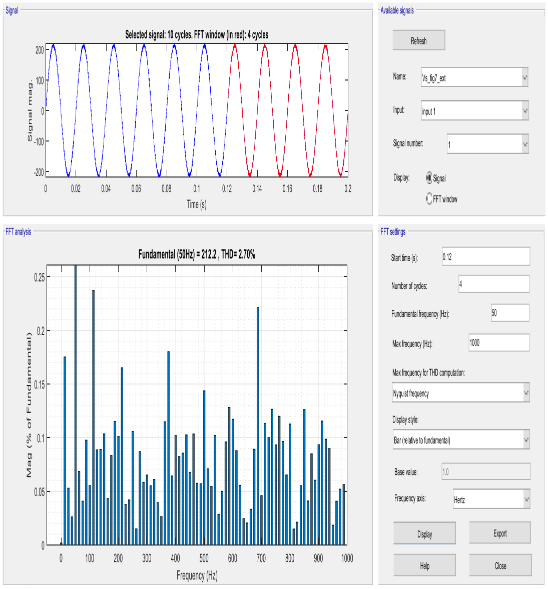
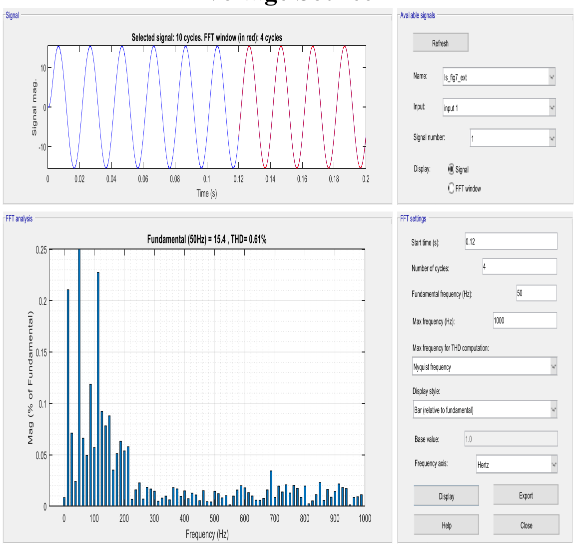


Voltage Source



Current Source

THDs Comparison between PI Controller and ANFIS Controller

Parameter	Using PI Controller	Using ANFIS Controller
Generator Current	2.53	1.09
Generator Voltage	4.97	2.26
Capacitor Voltage	2.03	0.15
Sum of Currents	15.6	15.57
Load Current	26.76	26.26
Current Source	1.67	0.62
Voltage Source	4.63	2.78

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III. CONCLUSION

The creation and implementation of an Adaptive Neuro-Fuzzy Inference System (ANFIS) controller within an integrated solar PV array, grid, and diesel generator set connected hybrid energy storage system (ESS) for an electric vehicle charging station project signify a substantial advancement. Extensive testing and analysis have highlighted the ANFIS controller's ability to optimize energy management within the hybrid ESS effectively. This system demonstrates remarkable adaptability, efficiently directing power flow from various sources to ensure dependable charging infrastructure for electric vehicles. Beyond merely enhancing the sustainability of electric vehicle charging stations, this innovation plays a vital role in maintaining grid stability by intelligently managing power demands and maximizing renewable energy utilization. Furthermore, the integration of ANFIS technology underscores the potential for further advancements in smart energy management systems, paving the way for a more sustainable and resilient infrastructure for future electric transportation networks.

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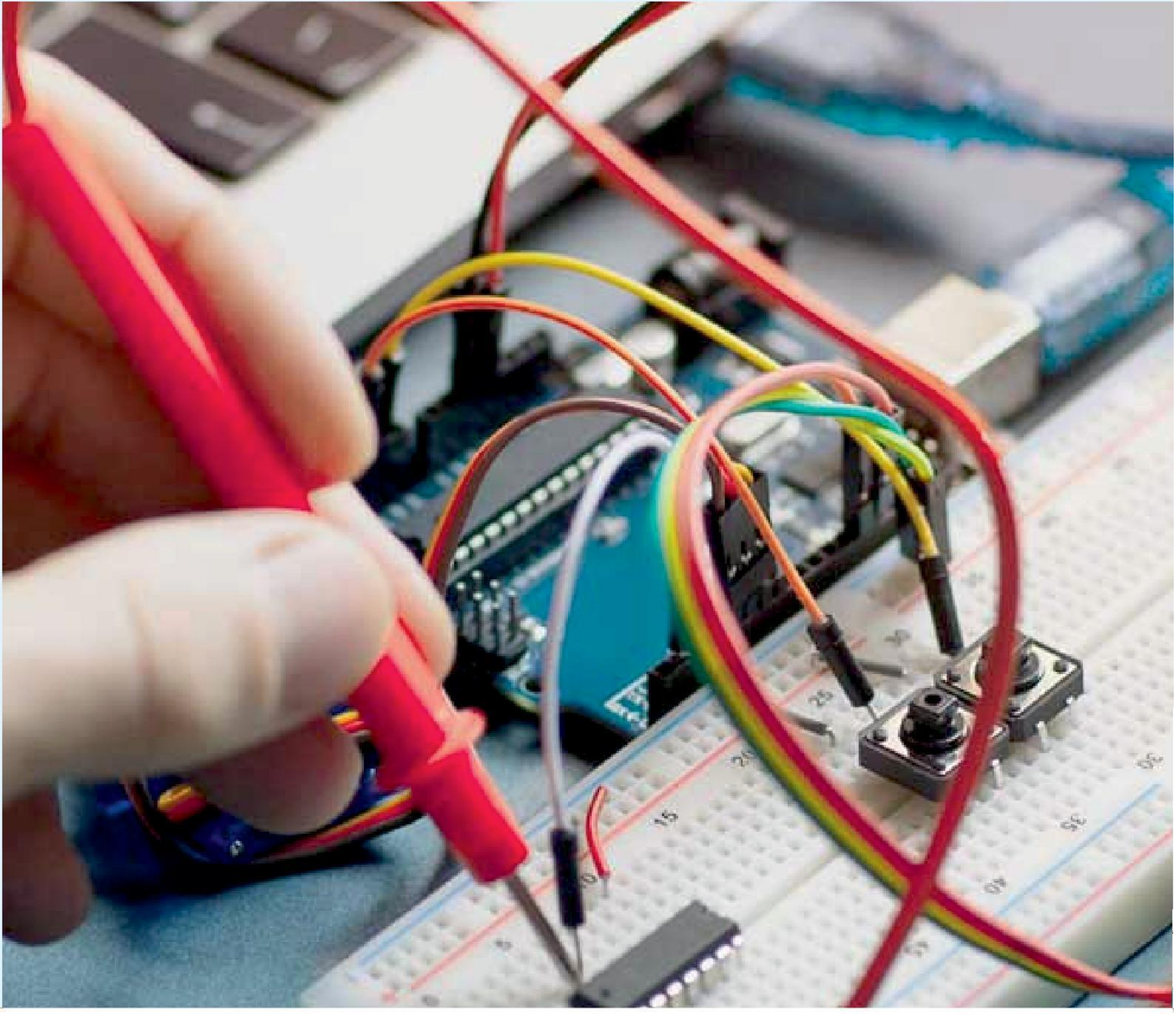

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