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Intelligent Enhancement of Fault Identification in Electrical Grid through Distributed Software-Defined Internet of Things System

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ABSTRACT: We present a customized software-defined networking (SDN) based remote condition Internet of Things monitoring and failure prediction system. By combining an effective and real-time wireless communication architecture with the power grid, this method transitions to deploying the smart grid. Two stages are involved in the SDN implementation: the first involves installing a controller in each local zone, and the second involves installing the main controller between zones and connecting it to the core network. Additionally, we suggest installing a distribution transformer failure prediction system in the management plane to make periodic predictions based on real-time sensor input to our suggested cloud. This prediction system is based on an artificial neural network algorithm. Additionally, we suggest a local zone communication mechanism.

INDEX TERMS: Fault prediction, Long Range Internet of Things (LoRa-IoT), monitoring network, neural networks (NNs), sensors, smart grid, software-defined networks (SDNs).

I.OVERVIEW

GENERALLY, large amounts of power must be produced and delivered to residential and commercial buildings around the clock. The electrical system's power source and distribution network

Conventional electricity networks depend on human operators to oversee and track the system's performance, balance supply and demand, and guarantee consistent grid stability. The noticeably growing need for Conventional electricity networks depends on human operators to oversee and track the system's performance, balance supply and demand, and guarantee consistent grid stability. Control and monitoring mechanisms are adopted throughout the grid system to meet the significantly rising standards for quality power management. The typical lifespan of traditional distribution transformers (DTs) is 20 to 25 years; however, most of these transformers are nearing the end of their useful lives and are periodically a risk to the electrical grid system. The monitoring system is in place now.

II. LITERATURE REVIEW

For the development of the Indian economy power system safety is very important. To provide the safety and reliability of the transformer monitoring system is used. A transformer is an important asset of the electrical network and it needs extra care and concentration.

Sajidur Rahman. In 2017 he proposed THMS (Transformer Health Monitoring System) for monitoring the condition of the transformer in real time. So, an automatic monitoring system is needed to observe the condition of the transformer. This proposed system is embedded with the mobile to observe the load of the current, voltage level, oil temperature, and level of the oil. This system is integrated with the GSM (Global Service Mobile), microcontroller, and various sensors. The sensor data are collected and stored in the memory. The system checks the condition of the transformer using inbuilt instructions. If any abnormal conditions occur on the transformer the GSM component sent the message to the receivers' mobile phones contains the data about the abnormal condition. It is a wireless system to

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better monitor the transformer's condition. The developed system is embedded with the transformer and it sends the abnormal parameters to the cell phone using the GSM technique.
A transformer is a major component used in the electrical field. Measuring faults in the internal part of the transformer is a very tedious process.

P.G.Navamanikumar . In 2018 he proposed a new system to collect the information from the transformer and send the conditions to the users' mobile by using IoT and GSM concept. Mainly this system is used to monitor the temperature, current, and voltage level of the transformer. MQTT protocol is used to transfer the message to the concerned people. By using this system the authorized peoples are received an alert message before the transformer going to the fatal condition.

K. Santhiya. He implemented a new system to assess the current load, voltage level, oil level, and temperature of the transformer using an Arduino microcontroller and various sensors. This system is mounted at the transformer. System-generated output values are stored and processed by using system memory. The designed system was developed with an inbuilt function to verify the abnormal state of the transformer.

The main goal of the proposed system is to identify the abnormal condition of the transformer before any severe breakdown.

D.Sarathkumar. He proposed a system to obtain transformer data in real time with the help of the IoT technique. In real-time data is collected from the temperature sensor, current transformer, and potential transformer and transferred to the remote place. These collected analog values are transferred to the 8051 microcontrollers using ADC 0808. This data are directly sent to wifi part with TCP IP to committed IP that visualizes the information through the chart. The major benefit of this system is to observe the condition of the transformer automatically and real-time data updated on the webpage when the condition is abnormal.

III. STRUCTURE OF THE PROPOSED SYSTEM

Real-virtualized hardware components that operate on a Linux server make up our suggested GMN. The OpenFlow vSwitch (2.9.2) forwarding engines and two SDN controllers with fail-over capabilities comprise the pure SDN architecture of the core network data center. We have been using Ubuntu Server (14.04.5) with four-port Intel Ethernet NIC cards as our operating system platform. Mininet was put into use by us. and Floodlight Controller as SDN devices, which we later built and adjusted to meet the specifications of our suggested network architecture and enable grid network connectivity. The matching statement in the forwarding table determines how traffic is forwarded. If a match is found, the packet is forwarded to the next device; if no match is found, an inquiry message is sent to Floodlight, the SDN controller, asking for instructions on what to do with the packet. In response, the SDN controller either installs new rules or suggests dropping the packet. Since they offer a vital and accurate status update of the project, the wireless sensor nodes are regarded as one of the most important components the arrangement.

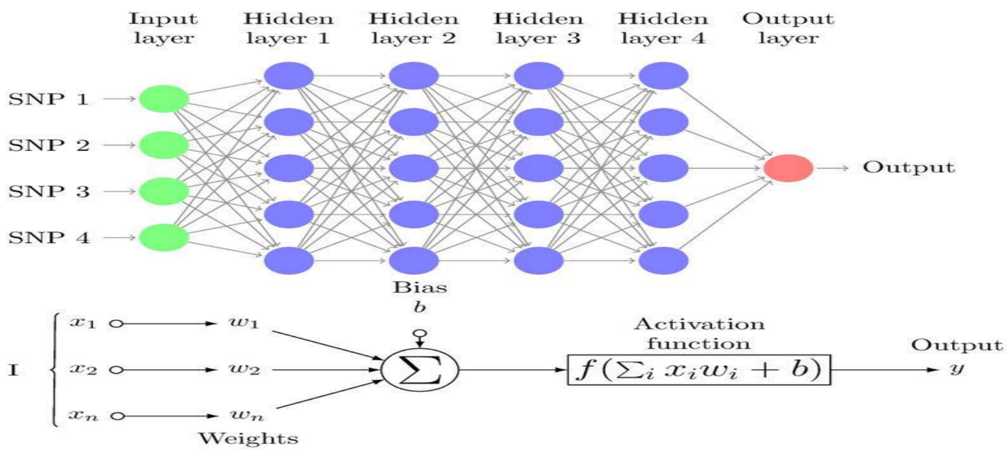

Fig. 1. Multilayer perceptron architecture diagram

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We suggest using a range of sensor-equipped LoRa RF communication devices to enable multi-feature sensor readings. The SDN concept served as the foundation for our wireless network design, with the sink node serving as the gateway SDN controller and the other nodes serving as OpenFlow forwarding engines. The first is a temperature sensor mounted on the transformer's outside tank shell. Its output is an analog signal that is supplied to a microcontroller—like an Arduino Uno—so it can convert analog data to digital data. as SDN devices, which we later built and adjusted to meet the specifications of our suggested network architecture and enable grid network connectivity. The matching statement in the forwarding table determines how traffic is forwarded.

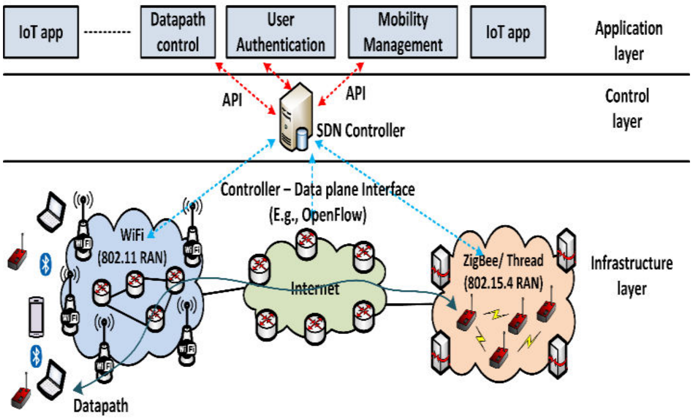

Fig. 2. Proposed architecture block diagram.

The packet is forwarded to the following device if a match is found; otherwise, an inquiry message is sent to the SDN controller (floodlight) asking for advice on what to do with the packet.

TABLE I

CONDITION SI

Status Index (%)	Condition
100<SI<90	very good
80<SI<70	good
70<SI<65	yellow alert (require investigation)
SI<60	system critical (fail)

TABLE II

INVESTIGATED TRANSFORMER SPECIFICATION

Parameter	Description
Rated voltage(max)	11kVA
Rated voltage (low)	433v-250v
Load current (max)	3.3A
Load current (high)	84A
Connection	Delta
No. of phases	3
Frequency	50 c/s
Noise level	50db
Operating average temperature	35-40 Deg.C

The SDN controller then reacts, suggesting that the packet be dropped or applying additional rules.

Fig. 2 shows the suggested architecture's block diagram. The forwarding plane in the diagram stands in for the OpenFlow engines of the wireless network and the core. The control plane, which represents the platforms for data steering and route management, is the next layer. For data security and dependability, a secure connection is created

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between the main SDN and sink SDN controllers. Moreover, the defect prediction network in the top layer, known as the management layer, is continuously trained with new events every hour and serves as a representation of the storage and real-time sensing platform. The backpropagation model is employed to carry out the retraining. After applying our developed suggested DTFP algorithm, we discovered that the suggested model achieves effective fault prediction accuracy.

We use the status index (SI) component of the DT, which is thought to be a potent instrument for determining the overall operational health state, to track the overall status of the DT system. In a logistic regression model, the SI for multivariable inputs can be written as follows:

$$SI\ (\%) = \frac{1}{1 + e^{-\sum_{i=1}^{n}(\alpha x_i)}} \times 100 \qquad (3)$$

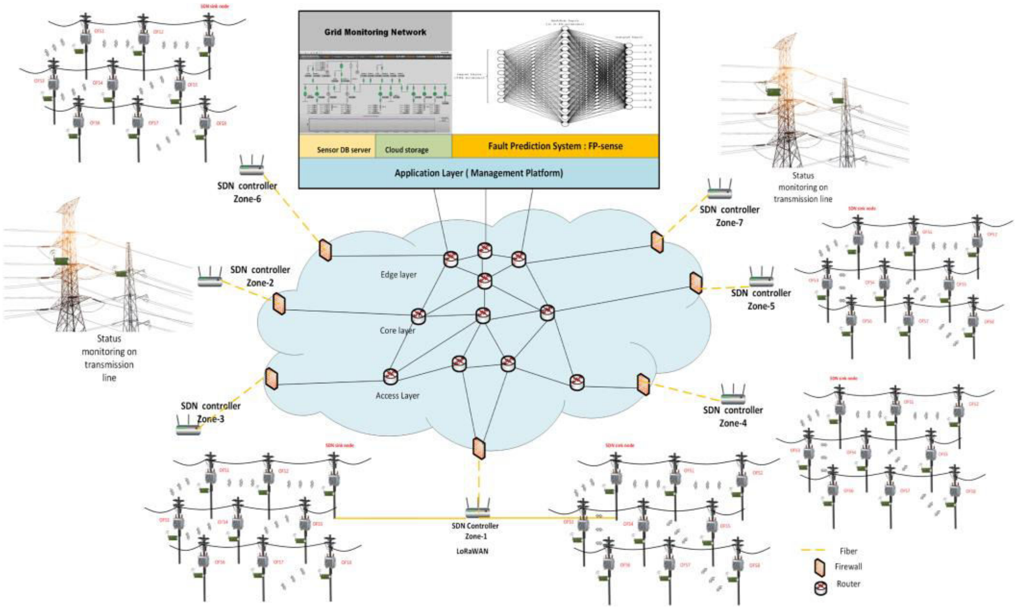

Fig.3 GMN proposed architecture platform.

where α, which spans from 1 to 10, denotes the weight effect of each sensor variable. According to Table I, we may categorize the DT health status's SI index.

As shown in Fig. 4, the SDN-sense algorithm governs the suggested communication algorithm between the IoT nodes. Table II describes the DT that is under investigation.

IV. ANALYSIS AND EXPERIMENTAL RESULTS

The full smart grid architecture-based SDN that has been suggested is explained in It is evident that multipath routing links controlled by SDN make up the core network, which is symbolized by the cloud and allows forwarding engines to perform their assigned functions. Moreover, a meshwork of OpenFlow switches and SDN relays sensor data to the primary SDN controller, which is situated at the cloud's edge, connecting each designated zone. Our experimental testing cloud is built on a virtualized environment, which is represented by virtual computers. Mininet and Floodlight Controller are used to implement the SDN controller. The Open vSwitch engines were preconfigured and set to install the rules. As illustrated in Fig. 4, the wireless node communication is based on our suggested algorithm, SDN-sense. Furthermore, the design shown in Fig. 5 summarizes the overall architecture that is being suggested, which incorporates the fault prediction system, the SDN wireless mesh network, and the cloud-based core network. The SDN architecture is viewed as a directed graph G = (SW, L), in which L denotes a collection of RF lines and SW denotes all of the OpenFlow switches (SDN to be in case of failure). The open flow (OF) switches and SDN are configured and modified

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by our case study. An application programmable interface (API) in Python can be used to access the SDN and retrieve data for additional modification. The number of rules that exist in a particular OF node can be represented as follows:

$$R_k = \sum_{1}^{n} \Delta_{k,t} \quad (1)$$

where $\Delta_{k,t}$ represents the rule per OF node with t as an indication for subrule. k is the subscript of total rules. The total matching delay that may occur in the OpenFlow table can be denoted as follows:

$$\varphi_{match\text{-}delay} = \sum_{1}^{N} R_k \times \sigma_{q\text{-factor}} \quad (2)$$

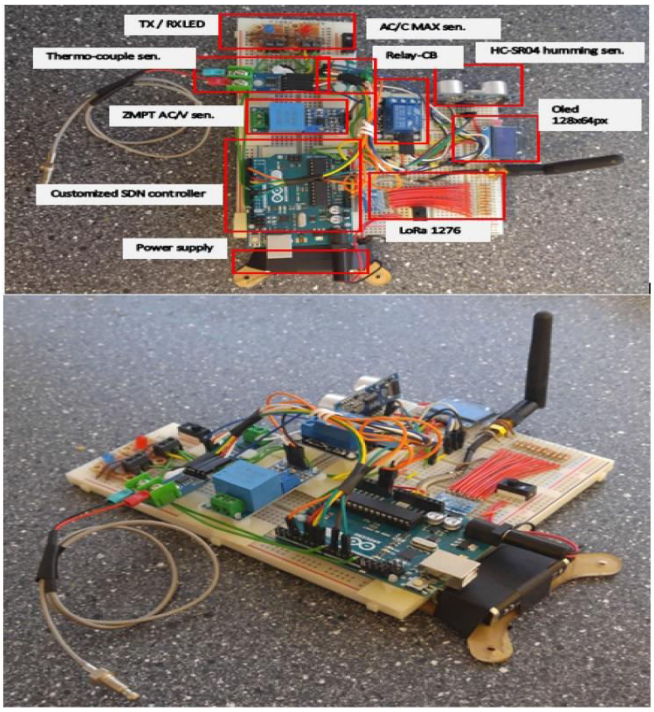

Fig.4. Proposed OpenFlow IOT sensor platform

Where $\sigma_{q\text{-factor}}$ is the queueing delay for processing flow that can affect the total processing capacity of the OF node significantly. Although the power consumption of the SDN sink node is not high, it is worth mentioning it as it may affect the lifetime of the node sensor, and designing an efficient power management node can result in efficient power consumption and longevity of the operating node.

The power consumption of the SDN sink and main SDN node can be expressed in (6) and (7)

$$P_{sink_{total}} = \sum_{1}^{n} \theta_{temp} + \sum_{1}^{n} \theta_{oil} + \sum_{1}^{n} \theta_{temp} \quad \text{Lora} \quad (3)$$

where θ represents the inbound traffic power consumption of a specific sensor

$$PSDN_{main} = \sum_{1}^{n} \lambda_{clust_1} + \sum_{1}^{n} \lambda_{clust_2} + \sum_{1}^{n} \lambda_{clust_3} \quad (4)$$

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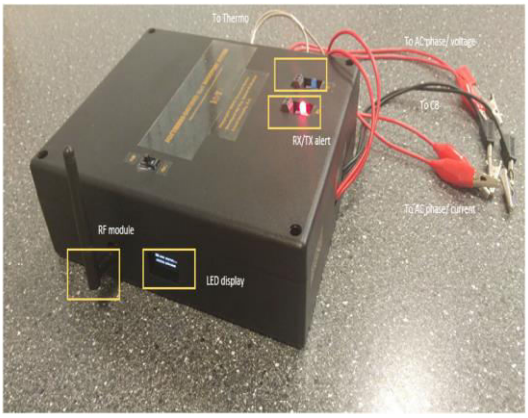

Fig.5. Completed suggested sensor platform while it is operating.

V. DEPLOYMENT AND IMPLEMENTATION OF HARDWARE

The suggested sensor hardware that can be installed in a residential transformer zone is shown in this section. Using off-the-shelf IoT gear that has been programmed using the SDN implementation approach, the system is constructed. The Arduino board, which is configured to act as a microcontroller board with SDN capability, makes up the hardware unit of the sensor. Five primary sensors make up the suggested hardware: a temperature sensor, an oil level sensor, an action sensor, a humming noise sensor, and a V-in sensor.

Fig.6. DT samples from the electrical grid maintenance location in Baghdad are flawed.

Because of the heterogeneity of communication in such an environment, the sensor nodes based on the OpenFlow platform connect with the sink SDN node over a long-range communication network by implementing the LoRa network. The main gateway, or SDN, is in charge of gathering all sensor data to be sent to the data center for aggregation and controlling communication with all sink nodes. The data will be supplied to the prediction systems once processed and stored to generate a failure prediction based on real-time sensor data. The prediction can assist in locating potential future D-Transformer failures, rerouting electricity, and isolating malfunctioning D-Transformers for maintenance.

While depicts the virtualized data center implementation running on a Linux server, Fig. 6 displays the suggested SDN IoT hardware prototype with the components indicated. The server is a representation of the main network, which effectively manages power consumption through network function virtualization. We demonstrate how our suggested SDN sink sensor might be deployed over home transformers. For sensor data processing, the sink node uses LoRa RF

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communication to connect to the SDN master node and eventually to the cloud network. The IoT-based sensor node is designed to sense the amount of incoming data from each sensor and implement actions accordingly. Our testbed is equipped with a wide range of sensors, including temperature, oil level, AC voltage, and AC sensors. In the event of a high alert, the circuit breaker will be turned off based on these facts. These data will also be supplied to the prediction system for statistical analysis based on historical data and real-time data.

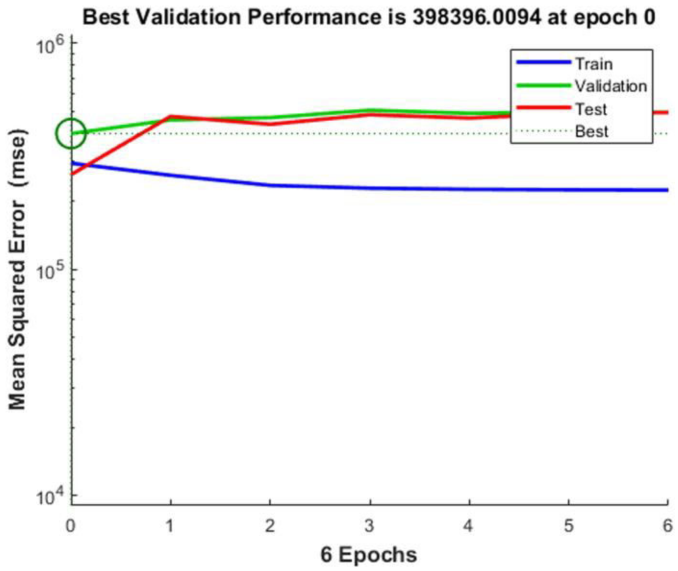

Fig.7.Objective function error rate

VI. SUMMARY

To address issues with demand and outages, the current electrical grid system has to be updated with new engineering implementations. It also needs to adjust to the new grid requirements to lower maintenance costs. To give solutions for the electrical grid, this article suggests a revolutionary SDN IoT sensor platform to monitor the electrical characteristics in DTs. We talked about the shortcomings in the current electrical grid and emphasized the efficiency of our proposed prediction system as well as our proposed system. To verify the suggested prototype, experimental testing was applied to an application case. IoT hardware controllers and sensors were used in the hardware's construction. The controller can function as a sink or a standard node and be configured as a bespoke SDN controller. The trial platform can additionally be connected to a circuit breaker so that any high alarm threshold—such as overload, high voltage, etc.—can be intelligently managed sum up, the suggested system is regarded as an affordable installation with real-time management that can offer a comprehensive picture of the DT status and get rid of any potential future distribution line failures or out.

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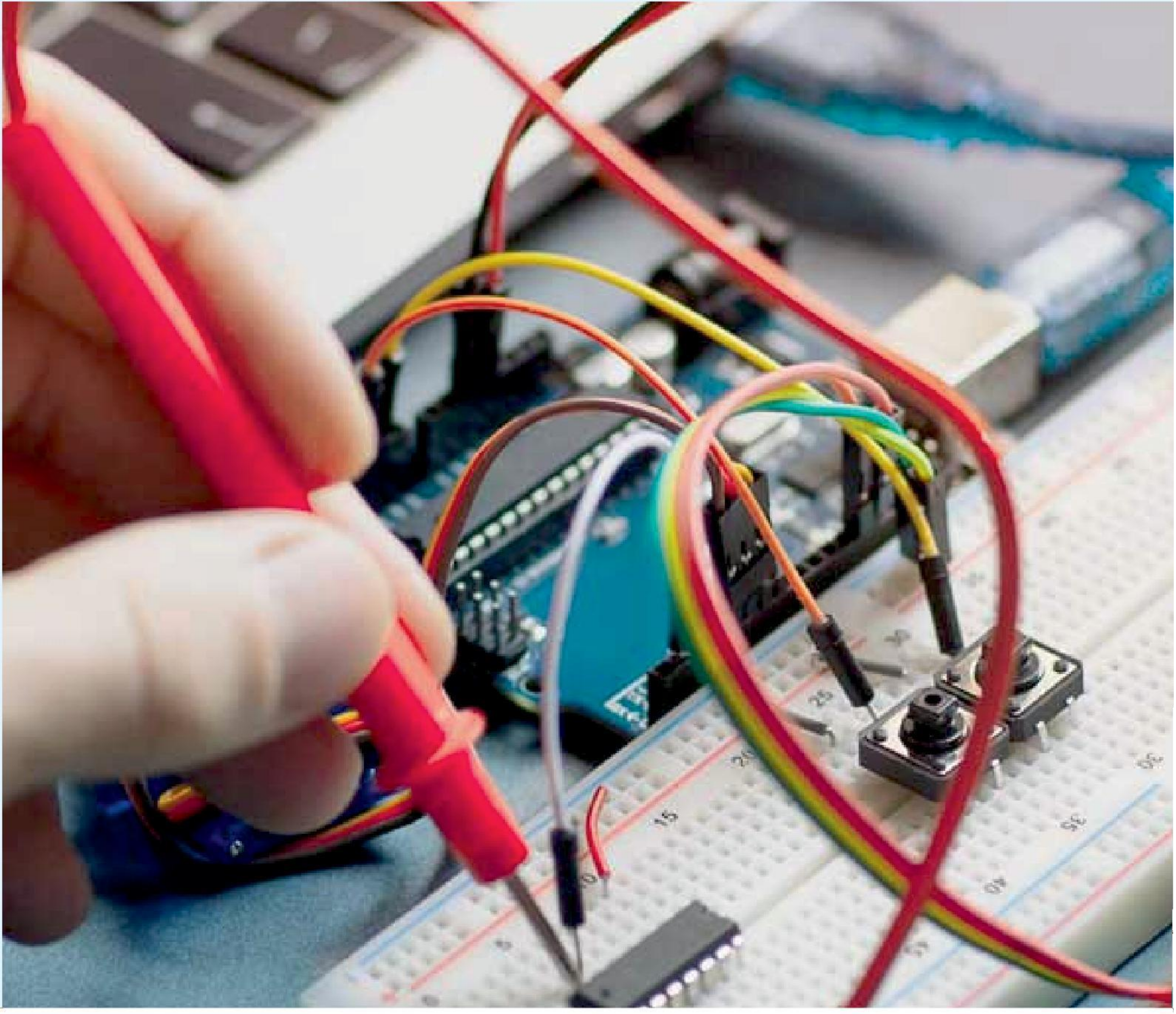

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