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Controlling a Hybrid Wind Solar Microgrid for Rural Electrification.

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ABSTRACT: A wind-solar micro grid (MG) is investigated to work in isolated and remote areas where abundance of renewable sources i.e. wind, solar, hydro etc. are available. The constant speed wind generation is achieved with permanent magnet synchronous generator (PMSG) and solar panels are used to generate DC power from the sun light. A boost converter is utilized to fetch this solar power to loads and the battery bank using incremental conductance (INC) approach. This battery bank is paralleled at the DC bus of the VSI (Voltage Source Inverter). The normalized sign least mean fourth (NSLMF) control is applied to provide power quality solutions like harmonic suppression, voltage regulation, the reactive power compensation and power balance etc. This study aims at reviewing the advances made towards the utilization of micro grid control systems incorporating PV-Wind generation units with emphasis on the applicable micro grid control strategies and principles. Based on the review conducted, it was noted that every control strategy has its merits, demerits, level of efficiency and cost. Further, to address the control challenges of the PV-Wind hybrid generation system, A MATLAB-Simulink model is developed to demonstrate the performance of the micro grid.

KEYWORDS: Wind- Solar MG, PMSG, Solar Panel, NSLMF, Power Quality.

I. INTRODUCTION

An increased demand of electrical energy and shrinkage of conventional resources (coal, natural gas & oils etc.) have given new dimensions to renewable energy research and their utilization in urban and rural areas. The remote areas where the grid is not accessible but the renewable sources like hydro, wind, solar are in abundance can be exploited to generate electricity in the form of distributed generation systems and microgrids [1, 2]. Renewable energy conversion into the electrical energy has become possible with the development and advancement in area of power electronics [3]. Price rate of the conventional sources are increasing day by day and to get relief from such expensive energy consumption [4], the renewable based micro grids can be a good replacement, as now the renewable energy has become affordable due to the reduction in cost. The wind and solar powers can be the good choices as they are in their advance stage of development and Governments are also promoting them under various schemes. The constant speed wind turbines are used to extract electrical power, which deliver power to the loads at constant frequency. Their control becomes simple and number of converters is reduced as MPPT and speed control are not required which are the common for variable speed wind turbines [5, 6]. Therefore, such system becomes cost effective and their installation cost is also reduced. For constant speed wind generation, PMSGs are used as they are maintenance free and have good thermal capacity as slip rings are absent. In absence of the rotor windings the field losses are reduced and the weight and size of the generator are also reduced. Therefore, the overall efficiency is improved [7]. The solar systems individually [8] or in hybrid combinations with other renewable [9-10] can function in grid tied mode or in isolated generation. Solar systems are used with or without MPPT. The wind-solar MG (Micro grid) for rural electrification can be a good choice. Because during low wind seasons (winters) the solar power generation with battery bank can support the load demand and in rainy season when the wind is available however, sun light availability is poor the wind power with battery bank meets the demand. Therefore, this report contributes the wind-solar MG, the constant wind generation with PMSG and the solar power generation using two-stage boost converter control for maximum power extraction. By INC [11, 12] MPPT technique, extracted power is fed to the consumer loads and an excess power is fed in the battery. The battery bank is connected at the DC bus of the VSI (Voltage Source Inverter) to support the DC bus voltage. This VSI is connected at PCC between PMSG and the load. The voltage regulation, harmonic suppression, reactive power compensation and power management are provided by VSI at PCC with normalized sign least mean fourth (NSLMF) [13] control algorithm. This algorithm is used to get pulses for appropriate VSI switching.

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1.2 Motivation

Rural electrification is an essential drive for the sustained and inclusive growth of the developing nations [6]. As per international energy agency (IEA) report 22% of the people have not had access to electricity till 2008 . It is an estimation that, by the year 2030 still 16% (i.e. about 1.3 billion) people may not have access to electricity if major policy revision does not take place for rural electrification [16,]. Extension of grid in rural areas is costly since load demand is relatively low and land areas are vast. Difficult terrain in remote villages may also increase grid expansion cost as it needs more time and special machinery and manpower [6]. Also the population of rural areas is less so it further increases per unit cost for installation and maintenance. Therefore, government and power distribution utilities are motivated to explore other available solutions. Generation of electrical energy with locally available energy resources such as solar and wind energy may be a viable solution. Utilization of wind and solar energy sources are significantly popular for generating electrical energy at remote rural localities [16]. However, energy from these sources is available intermittently so far, therefore continuous power supply may not be ensured. To overcome this drawback electrical power generated by these sources may be integrated along with energy storage devices such as battery. A combination of two or more than two renewable power generation technologies along with energy storage may enhance performance and is termed as hybrid renewable energy system (HRES) [16] or wind solar power generation; although it is necessary to choose appropriate renewable energy (RE) technology, unit size and energy storage system (ESS) to improve reliability and performance of HRES .

1.2Rural Electrification

Power access to remote areas by electric connection is a process of rural electrification. A village would be declared as electrified according to vide letter No. 42/1/2001-D (RE) Issued by Ministry of power (MOP), if Basic infrastructure such as Distribution Transformer and Distribution lines are provided in the inhabited locality as well as the Dalit Basti hamlet where it exists. Electricity is provided to public places like Schools, Panchayat Office, Health Centers, Dispensaries, Community centers etc. The number of households electrified should be at least 10% of the total number of households in the village. Electricity is used for lighting and household activities, for mechanization of many farming operations, such as threshing, milking, in factories. The Rural Electrification Corporation Limited (RECL) was formed specifically to sort out the issues come in providing electricity in all the villages across the country. There are various other schemes launched by government from time to time like Rajiv Gandhi Garmin VidyutikaranYojana (RGGVY), Remote Village Electrification Programme, DeenDayalUpadhyaya Gram JyotiYojana (DDUGJY***),*** PradhanMantri Gram VidyutYojna to expedite the electrification and diversify the procedure. Work has been done for wastage reduction, providing better equipment and improving the overall infrastructure for electrical transmissions in villages etc. but Poverty, lack of resources, lack of political will, poor planning, and electricity theft which is a severe loss of power of one kind and keep away rural area without access to electricity**.**

II. WHAT IS A MICROGRID SYSTEM

A micro grid (MG) can be defined as a group of renewable energy sources and energy storage devices controlled by a monitoring system to provide power to the loads for which it is designed (Bouzid et al., 2015). The energy source may or may not include the local utility grid. A micro grid can be seen as a smaller version of the traditional power grids. The consortium of Electric Reliability Technology Solutions (CERT) describes the concept of a micro grid as an aggregation of loads and micro sources operating as a single system providing both power and heat. A micro grid consists of power generators, distribution and control systems for voltage regulation just like a conventional grid. However, the main difference between the conventional grid and the micro grid is the close proximity between the power generation and the end users. In recent years micro grids have gained a lot of attention due to the advancements in renewable energy technologies. The figure 1 describes one of the many concepts of micro grids. The figure contains power sources such as solar PV arrays, wind turbines, utility grid and energy storage devices. The diesel generators can be used as a backup power supply or as a regular power source running parallel to the renewable energy sources (RES). The control system denoted is used as a means to regulate the power from various sources to the load.

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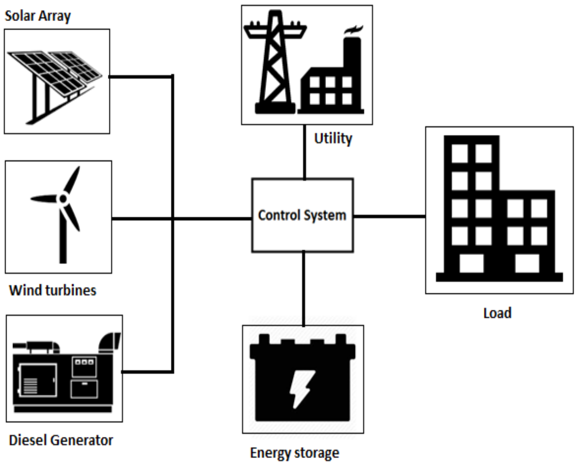

Fig.No 1Concept of a micro grid

As the name suggests, microgrids are smaller in size compared to conventional utility grids, which are normally sized at megawatts (MW). Micro grids comprise of micro sources such as PV arrays, diesel generators etc. for providing power for the load for which it is designed. In recent years due to the advancements in renewable energy technologies more renewable energy sources are employed in microgrids.

2.1Key Issues Of Microgrid

Technical benefits of the microgrid are an islanding implementation of distributed generation to improve the distribution system service quality and increased the power system reliability [8]. Microgrid can be implemented to meet the increasing growth in demand and distributed generation is used to perform special task for microgrid operation such as reactive and active power control, ability to correct voltage sags and system imbalances [9-10]. This section is a review of three technical challenges on micro grid with respect to voltage and frequency control, islanding and protection of micro grids.

III. OPERATION & CONTROL OF MICROGRID

The microgrid, an integrated form of DERs, is normally inter- faced with load and utility grid by power electronic inverters. It can operate in grid-connected mode or in islanded mode. In grid-connected mode, the microgrid either draws or supplies power from or to the main grid, depending on the generation and load with suitable market policies. The microgrid can separate itself from the main grid whenever a power quality event in the main grid occurs. Autonomous control of micro sources suggests that the microgrid should follow a peer-to-peer and plug-and-play model avoiding the installation of a single point of failure like microgrid control centre (MGCC) and dedicated storage units, so the micro sources should have integrated storage unit (Battery bank in the dc bus of the inverter). The microgrid should disconnect itself from main grid on occurrence of abnormal condition and to be shifted to islanded mode. The variation in voltage and frequency becomes more prominent when microgrid is switched over to islanded mode. Under grid connected situation of microgrid, the voltage and frequency are determined by the grid. When the microgrid islands, one or more primary or intermediate energy sources should be controlled by adjusting its voltage and frequency. If the frequency reaches to a very low value, the load may be temporarily shaded. Also, a balanced condition is to be maintained between supply and demand applicable to microgrid. If the microgrid is exchanging power with the grid before disconnection, then secondary control actions should be applied to balance generation and consumption in island mode to ensure initial balance after a sudden fluctuation in load or generation. The microgrid is supposed to preserve an adequate power quality while in island operation with sufficient supply of reactive energy to shrink voltage sags. The energy storage device should be capable of reacting rapidly to frequency and voltage change and exchanging large amounts of real or reactive power. The micro- grid has no spinning reserves like usual grid. Most micro sources have delayed response when implementing secondary voltage and frequency control. The intermediate storage units and micro- sources with built-in battery banks are therefore expected to offer the advantages like spinning reserves. The power electronics devices react promptly to fast demand signals and adjust the power flow levels. The implementation of communication infra- structure linking the microgrid components is another aspect considered when selecting the control approach on an islanded microgrid. Including the above factors, the microgrid should be prepared for planned

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islanding which is an important aspect in microgrid concept used to maintain the continuity of supply during planned outages, like substation maintenance period etc.

IV. PERFORMANCE ANALYSIS

A Simulink model is used to simulate its performance and simulated results are presented in detail. The behaviour of MG under linear and nonlinear loads is illustrated. The boost converter and the VSI operation for maximum power tracking and power quality improvement of wind-solar MG are discussed here.

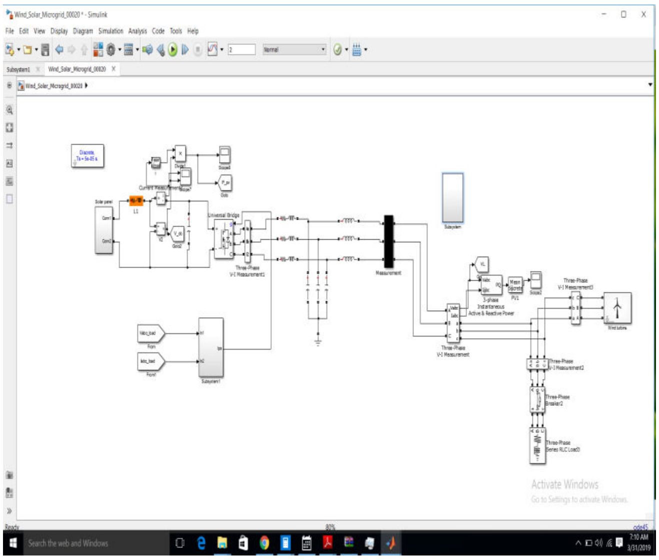

Fig No. .2. A Simulink model of wind-solar MG

4.1 MPPT of Solar Panel

Fig. 6 depicts the MPPT process of solar power using incremental conductance (INC) approach. It is seen that with the variation in insolation (G), the input voltage (Vpv) is maintained constant at almost 80% of DC bus voltage while the input current (Ipv) changes its value according to the variation in insolation. Therefore, the panel output (Ppv) on the input side of boost converter also varies and tracks the MPPT depending upon the insolation

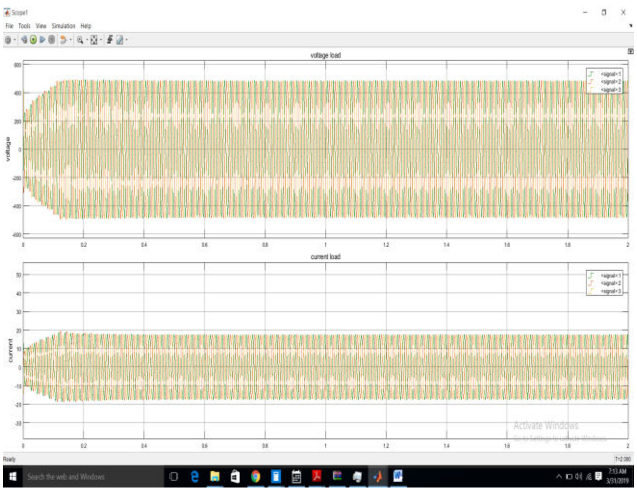

Fig No 3 Voltage and current for load side

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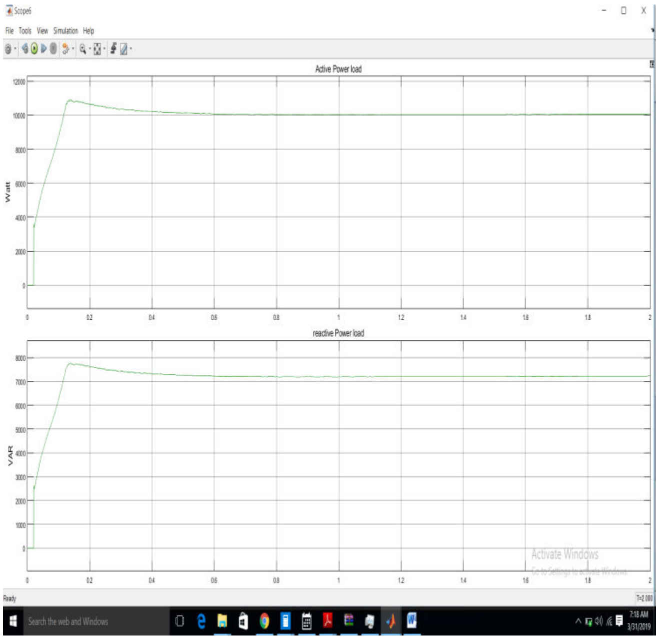

Fig No 4 Load side parameters(Linear And Non-linear)

The response of control scheme is depicted in Fig. 2 and Fig. 3 with intermediate signals under nonlinear and linear loads. During the contingency when load unbalance is created by opening the switch at phase ‘a’ for 0.1s, the load current of phase ‘a’ (iLa) is disappeared during this period, therefore the load active power and load reactive power components of phase ‘a’ (ipa and iqa) become zero. The step size (µi) is maintained throughout. The load active power and average load reactive power components (Ipav, Iqav) are decreased with load reduction due to one phase disconnection. The VSC current (Iv) coming from the PI controller to provide voltage regulation, active component of reference source current (Ipf) and reactive component of this current (Iqf) are also changed with load variation. The reference source currents (i* abc) are reduced during load disconnection at phase ‘a’. The control scheme is able to settle the response within two cycles which is quite satisfactory performance.

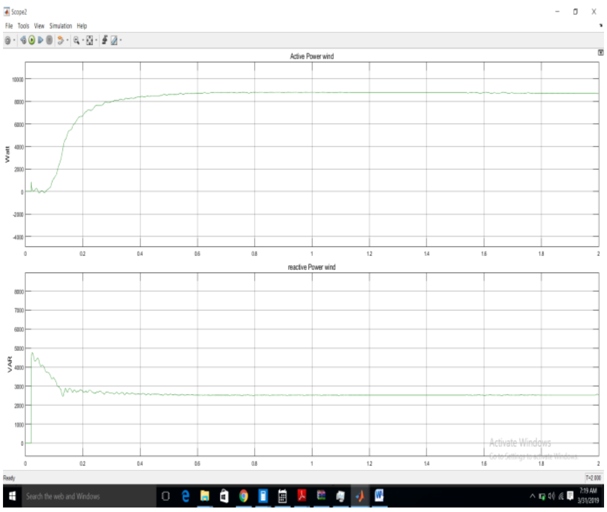

Fig No 5 Active And Reactive Power For Wind Side

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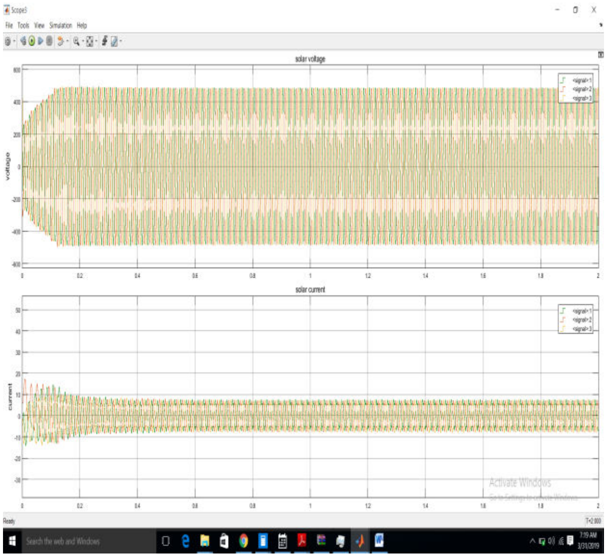

Fig No 6 Solar Voltage And Solar Current

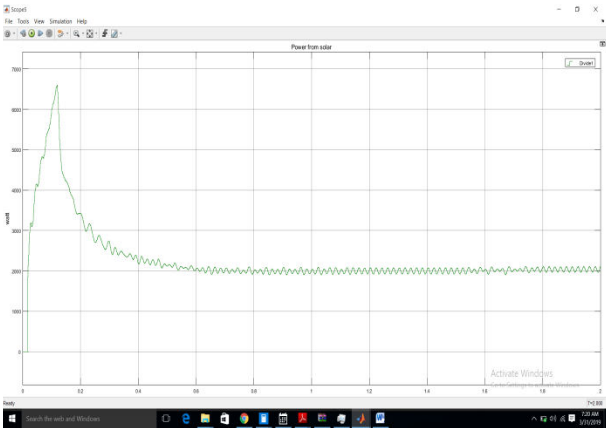

Fig No 7 Power for solar side

4.2 Dynamic Performance of The Wind-Solar MG

Fig.No2,Fig.No3,are illustrating the dynamic behavior of wind-solar MG under linear and nonlinear loads. At 1.4s the insolation (G) is increased from 800 W/m2 to 1000 W/m2. Therefore solar power (PPV) is also increased. With the constant load demand (PL) and constant wind power generation (Pwind) the excess power is stored into the battery bank. Therefore the battery charging current (Ibt) and powerN (Pbt) are increased.

At t= 1.5s contingency (dynamic) condition is created by disconnecting the load at phase 'a' using a switch. It is observed that with the load unbalance created as phase 'a' load current (iLa) is zero. The terminal voltage (Vt) and the PCC phase voltages (vabc) are maintained constant and sinusoidal. The compensating currents (iCa, iCb, iCc) are changed to provide reactive power compensation during load unbalance condition. At t=1.7s the load demand is increased. The wind generator is delivering power at its full capacity the VSC power and currents (Pvsc, iCabc) are increased to supply increased demand. During this process the battery discharges in terms of the Pbt and Ibt. These results support the wind-solar MG satisfactory performance during the dynamics.

4.3. Steady-State Response Of The Wind-Solar Mg

Fig. 10 shows the steady state behavior of the wind-solar MG under nonlinear load. It shows the wave shapes and harmonic content of PCC voltage (va), source current (ia) and load current (iLa) during normal running conditions. The source current and source voltage are sinusoidal and the THD (total harmonic distortion) is below 5% at the highly

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nonlinear load of 25% THD. These results demonstrate that the MG performance is satisfactory during normal operating conditions.

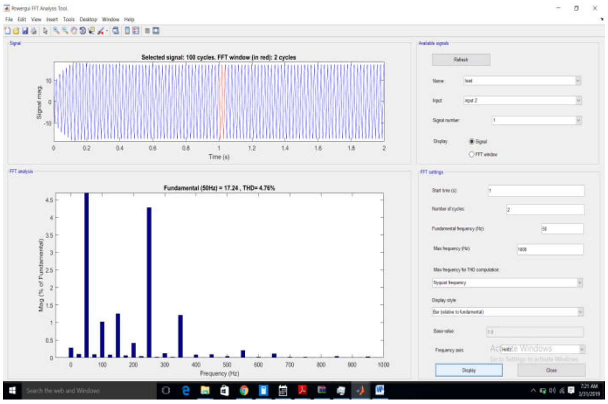

Fig.No8 THD load

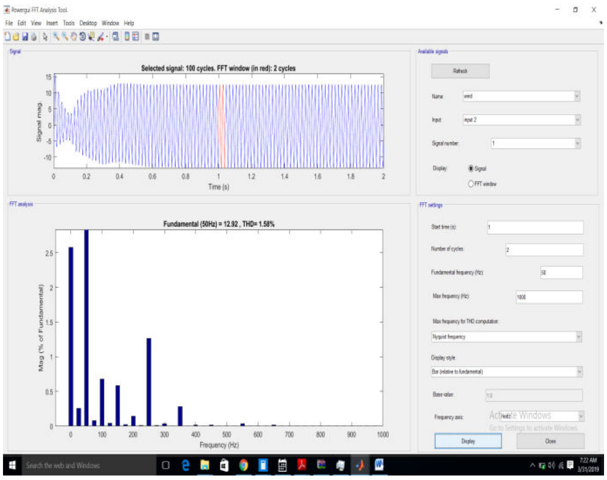

Fig.No9 THD

V. CONCLUSION

The performance of a three phase wind-solar MG has been simulated in MATLAB/ Simulink. The MG converts solar energy into electricity to feed loads and battery charging using boost converter. The MPPT has been achieved using INC approach. The PMSG transforms the wind power into AC electrical power to feed the loads. The performance of the MG is shown with the application of NSLMF control scheme to provide power quality solutions i.e. harmonic suppression, reactive power compensation, load balancing and voltage regulation. The microgrid is also capable of maintaining the balance among generation, demand and storage. Such a wind-solar MG has been found capable to serve the remote places where grid is not feasible due to adverse geographical conditions.

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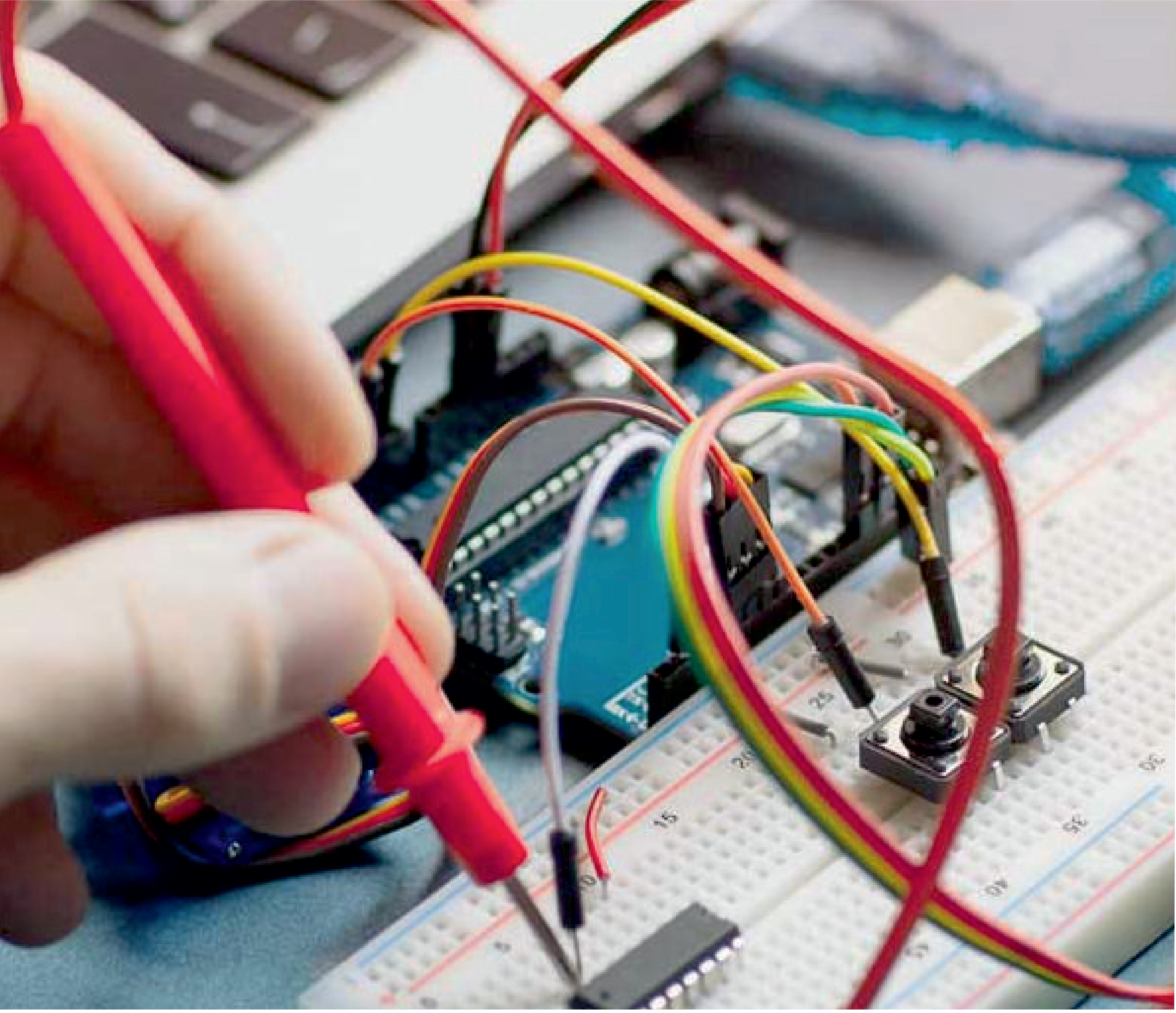

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