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A Review on Hybrid AC/DC Microgrid

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ABSTRACT: Renewable energy sources are highly preferable which are used to access the conventional power system as a microgrid. Due to increment huge demand in population, these sources play a vital role in a hassle-free environment and ecosystem. Individually in an AC & DC Microgrid, it requires a huge amount of conversion of power at the vender side for AC and DC loads, which results in the system with less efficiency. Further to overcome substantial energy losses in multiple power conversion, hybrid AC as well as DC microgrid is one of the best solutions. In this paper, a piece of detailed information about hybrid AC/DC Microgrid (HADMG) is mentioned which reduces the conversion of AC-DC-AC or DC-AC-DC in AC or DC Micro-grid.

KEYWORDS:AC Micro-grid, DC Micro-grid, Hybrid AC/DC Micro-Grid (HADMG), Control Strategies, Protection Scheme

I.INTRODUCTION

Recently with an increase in awareness regarding environmental issues related to energy; renewable energy resources have come forward as clean and green resources. It has been used in many areas for the microgrid to access the conventional power system [1]. Recently renewable energy sources (RES) like solar, small hydro based power plants, wind, geothermal have achieved ample attention worldwide due to the fast depletion of fossil fuel, global warming together with growing energy demand. Generally, generation of power from these sources is in range of a fraction of kilowatts to megawatts and due to this, these sources are connected at a distributed level to reduce power loss in long transmission [2]. Therefore these sources are known as distributed generation. The application of distributed generation is provided in terms of reliability and security of power, the economics of power generations, etc.

The new challenges are identified in microgrid. Where, the power grid of a small scale which is to be operated independently or combined with other grid. The microgrid is the best remedy to implement different types of distributed generators with thehelp of renewable energy resources in combination with the conventional grid. A microgrid is used for smooth integration and control of distributed generation with a grid [2]. The components required for the formation of Microgrids are renewable energy sources, various batteries, small scale DC generators, and loads.

Microgrid has three forms:

- AC Micro-grid
- DC Micro-grid
- Hybrid AC/DC Micro-grid.

Microgrid has facilitated better power quality, high efficiency of operation, controllability, and bi-directional power flow among microgrid and utility grid [2].It will be difficult to convert micro-grid with AC sources and DC sources. To overcome this disadvantages of AC and DC micro-grid, a new concept is designed i.e. AC/DC hybrid micro-grid.

There are some detection methods which are used to detect various parameter and phenomenon. One of them is the islanded detection technique. The islanded detection method is highly preferable to protect the grid-connected system. This detection technique is used in AC/DC hybrid microgrid when faults occur in the system. When predetermined switching events or faults occurred in utility grids, under faulty conditions, the system gets electrically isolated from the utility grid. This system can be operated in an islanded mode. The important goals behind the detection of islanding grid phenomena are too controlling the grid and monitoring the electrical quantities frequency, voltage, and impedance offered by microgrid and also reactive power in the system as well as active output power delivered by distributed generations.

The islanded detection techniques are distributed into two groups: Remote detection and Local detection methods, again local detection methods are divided into three sub groups; active, passive, and hybrid detection methods.

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In case of preplanned operation of switching, AC as well as DC microgrid generation, are to be islanded as per the schedule, and load may be scheduled before islanding. In case of accidental switching, it is important to detect islanding situation and likewise apply control methods to it for operating microgrid safely [3].

II. AC MICROGRID

Nowadays AC microgrid is used in many areas of power system due to its merits. It has been introduced to apply the actual AC grid technologies, standards, and protections the same as an actual grid. However, the power generation output of the distributed generator is DC power which is then converted into AC by using power electronic converters i.e. DC/AC inverter. This power conversion is used for connecting them with the AC utility grid. Again further this power is converted back into DC as per the requirement of electrical loads such as fluorescent lights, hybrid electrical vehicles, LED lights, computer communication equipment, and data centres. Fig.1 shows the structure of AC Microgrid.

AC microgrid requires multiple conversion stages which causes power losses in the system. The problems associated with AC Microgrids such as stability issues, reactive power requirements, synchronization which may affects performance of the system.

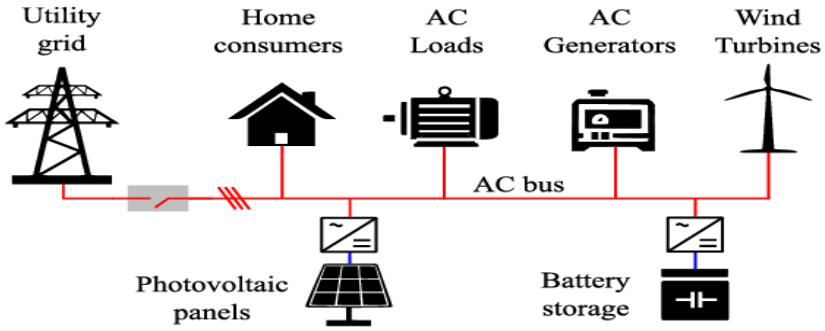

Fig.1 Structure of AC Microgrid

III. DC MICROGRID

DC microgrid is a better solution for renewable energy-based distributed generations due to the modern load and also it can operate in DC. There are so many distributed energy sources like Mobile batteries, fuel cells and PV generations requires to operate in DC. The DC micro-grid has high reliability and uninterrupted power supply, less reactive power loss, no frequency aspect, etc. the key advantage of a DC bus in a microgrid, it may avoid many conversion steps. Fig.2. shows the structure of DC Microgrid.

In DC Microgrid, The power generation from various sources is mixed up with AC as well as DC power. But it is impractical to design DC microgrid due to some equipment which is operated on Pure AC and due to these losses are more. So there is a lot of conversions required to eliminate or to wipe out the losses. So these systems have also some disadvantages to the elimination of losses.

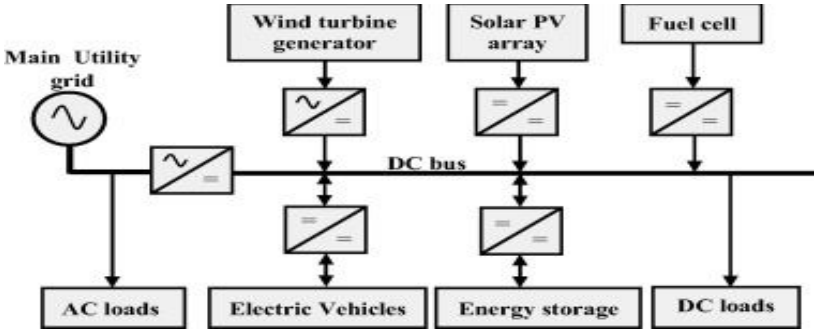

Fig.2 Structure of DC Microgrid

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IV. HYBRID AC/DC MICROGRID

The issues related to the AC & DC micro-grid as mentioned in the above paragraph. A lot of conversions are required in individuals AC & DC microgrid. Thus, we move towards the better option, i.e. HADMG rather than particular AC or DC micro-grid. Hybrid micro-grid is nothing but a sub-grid of AC and DC grids.

The utility purpose of the microgrid can be considered as a controlled cell of the power system. It has provisions such that it can be directly coupled to the main power grid. The microgrid can be located to meet their special demand like improvement of voltage, local reliability, minimization of feeder losses, increased ability through waste heat recovery technique and voltage sag improvement.As compared to the conventional Micro generation the Microgrid, Distributed network subsystem will generate less disturbance to the utility network, if there is proper perceptive planning of load & micro generation.

This paper represents a review of HADMG & various strategies for controlling purpose, stability issues, and protection scheme of bidirectional converter in HADMG are discussed.

V. SYSTEM CONFIGURATIONS

The conceptual design of system configuration of HADMG as expressed in Fig.3, whereas AC sources and DC sources, and loads are coupled to the network. The AC and DC grid are terminated with transformer and main converter i.e. three-phase bi-directional AC/DC converter interface converter (IC), while the normal converter is used to elaborate the concept. However, the various topologies are considered and the concept is achieved through the microgrid, specially advanced devices of the power converter are widely used. The AC side bus of a hybrid grid is a tie-up with utility grids through circuit breakers and transformer.

In AC grid side, small diesel generator and wind turbine generator termed as power sources through double fed induction generator, tidal plant, and all AC loads is connected towards AC side [4].

Whereas in DC grid side solar module, fuel cells, electric vehicles, an energy storage device such asbatteries through converter & all DC loads are coupled to the DC side [4].

For co-ordination control of converter, there are various forms of converter used in a hybrid grid system, which co-ordinately control with utility grid for a continuing supply of high quality and high efficiency of power to AC as as well as DC load, when hybrid system operated in different modes of operation.

The HADMG are categories in various modes of operations:

- Grid-connected mode
- Islanded mode
- The transition between the first two modes.

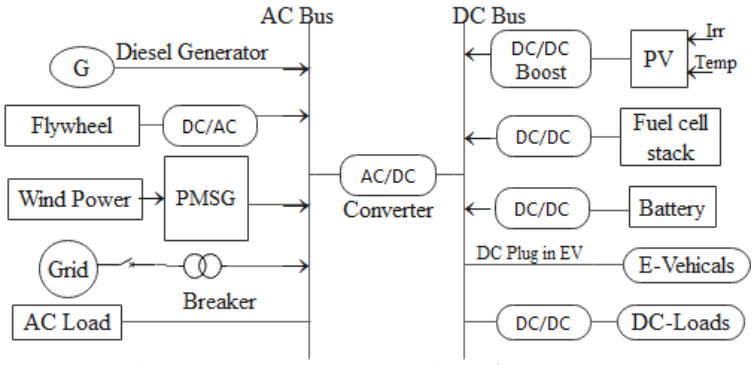

Fig.3 A Compact Representation of HADMG

The field of research community has been attracted to form the DC side bus voltage and power balance in between DC & AC Microgrid unlike AC microgrid. Assist with the main converter and batteries, VDC termed as DC bus voltages are getting energies.

In grid-connected mode, there are two control strategies are existed for bidirectional AC/DC converter termed as U-Q and P-Q respectively. They are used for the exchange of power in AC & DC system. The former method (P-Q) controlmethods, the excessive PV power is inserted into AC micro-grid as a constant power, which used for the protection of the converter. In the latter method (U-Q) control method, the excessive PV power is inserted into AC micro-grid as a maximum power, which used for utilization of DC side, simultaneously the main converter switched in

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between the modes named as U-Q and P-Q mode. By taken consideration of the above constraints the power balancing equation for HADMG is given as:

$$P_{IC} = \sum_{i \in N_{DG,DC}} P_{DC,i}^{Gen} - \sum_{i \in M_{Load,DC}} P_{DC,i}^{Load} \quad (1)$$

Where,
P_{IC} **:** Active power flow among interface converter
$P_{DC,i}^{Gen}$ **:** Power generation at an ith node in DC side sub grid
$P_{DC,i}^{Load}$:Power load at an ith node in DC side sub grid
$N_{DG,DC}$**:** No. of distributed generation units in DC side
$M_{Load,}$DC**:** No. of load in DC side

$$P_{grid} = \sum_{j \in L_{DG,AC}} P_{AC,j}^{Gen} + P_{IC} - \sum_{i \in M_{Load,DC}} P_{DC,i}^{Load} \quad (2)$$

Where,
P_{grid}**:** Active power flow among grid and microgrid
$P_{AC,j}^{Gen}$**:** Power generation at a jth node in the AC sub grid
$P_{DC,i}^{Load}$:Power load at an ith node in DC side sub grid
$L_{DG,}$ AC**:** No. of distributed generation units in AC side
$M_{Load,}$ DC: No. of load in DC side

In islanded mode, the controlling of a microgrid is little difficult as compared to grid-connected mode because a total load of grid side system is shared by DG's (distributed generation) on each sides of sub-grid while the voltage and frequency kept in an admissible limit. The main grid is not connected to the supply-demand side because of that demand-side have to maintain the battery and converter. Therefore, V/F control method is selected by the bi-directional AC/DC converter which used for keeping the voltage and frequency stable [6].

VI. CONTROL STRATEGIES

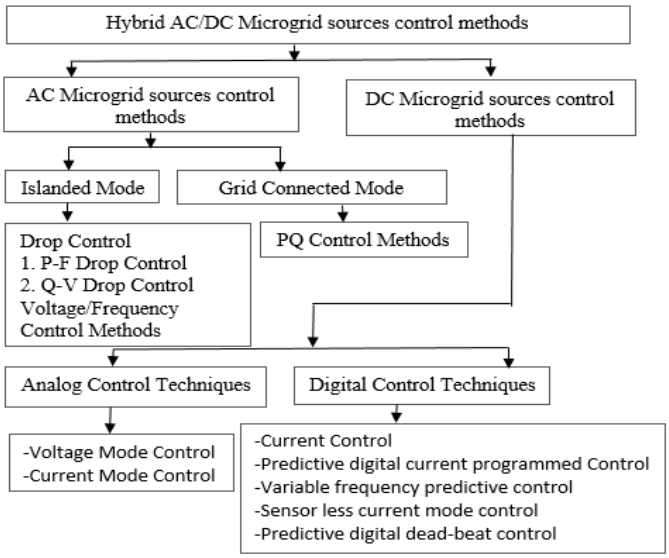

Fig.4 Hybrid AC/DC Micro-grid Source Control Methods

A. MICRO-GRID CENTRAL CONTROLLER

The microgrid central controller is mainly used for the control & management of Microgrids. It used to co-ordinate operation and control of local micro sources and to maintain stability in a microgrid. There are various types of micro source and their control methods in all modes. In the hybrid system, the discrete & continuous value, depends upon dynamic behaviour of the system. The work of a microgrid central controller is to supply set point for error controlled regulation using negative feedback for automatic control to distributed generation unit, bidding of demands side,

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economic scheduling, the system losses get minimize with the local controller when the grid is restored to the monitor power flow through the local generating unit.

In grid-connected mode, the summation of incoming supply from the grid and source side is coordinate with the urging for power for maintaining proper balance. In islanded mode, the various drop control methods are used for the microgrid central controller [7].

The control strategies for HADMG as a source control methods are expressed into two groups: AC microgrid source control methods and DC microgrid source control methods. The AC micro source control methods are work in two control modes of operations; Islanded Mode (Offline Mode) and Grid-connected Mode (Online Mode). The control strategies are designed at two-level: component level and system level.

The main aspect of the control methods is to set the AC microgrid with utility grid to maintain a power balancing in-between generation and loads in offline mode of operation i.e. in islanded mode, to restrain the stable constant voltage of AC as well as DC bus in AC microgrid & DC microgrid, to maintain stable frequency and reliable transfer of power in between AC & DC micro-grid for stable system operating condition under varying loads.

Control strategies are depend upon the mode of operation. In isolated mode, the voltage of the DC bus side is regulated by the energy storage element while the voltage and frequency of the AC side bus is dependent upon or regulated by parallel inverter. In the grid-connected (online mode) voltage of DC, the bus side is kept constant by the help of the inverter controller while the VAC termed as AC bus voltage is controlled by the utility grid controller. There are different controller methods for microgrid as micro sources.

B. MICRO-SOURCE CONTROLLERS

The HADMG is interfaced through different converters AC-AC, DC-DC, AC-DC-DC, DC-AC, and bidirectional converter. These converters help control the micro source in online and offline modes. Fig.4 shows the controlling micro-source devices in AC & DC Microgrids. In AC grid, sources are controlled by active & reactive droop control methods. Analog and digital control in DC micro-source control method.

There are two methods that come under islanded mode: Drop control & v/f control method. Further, there are two methods that comes under Drop mode i.e. P-F and Q-V control method [8]. In the P-F control method, by controlling active power it controls the frequency, and in the Q-V control method by controlling reactive power it controls the voltage magnitude by the distributed generations.This method minimizes the voltage fluctuations as well as frequency fluctuations. The drop control method is used to minimize the small number of fluctuations. In v/f methods, the proportional integral derivative (PID) controller is used to wipe out oscillations in voltage and frequency. The designing of the controller in such a way that in islanded mode, for small disturbances the PQ control methods are converted into drop control and vice versa for the large disturbance. These methods are used for minimizing a large number of fluctuations. The voltage and current mode control come under analog technique where comparison of the actual value of voltage and current with reference value is carried out. In the digital control technique sensor less control [9], current control, digital current programmed to control, and dead-beat control are carried out [2].

C. ENERGY MANAGEMENT SYSTEM (EMS) CONTROLLER

In energy management system, controller power should be release or absorb quickly to reduce the fluctuation in generating system, SOC of batteries energy storage & super-capacitor, price of electricity, and so on and load with the same utility grid according to the grid condition.

In islanded mode, DC side bus voltage is controlled by the storage system. The amplitude, magnitude and frequency of the supply of the AC side and the voltage regulation are done by parallel inverter with drop control or v/f control methods [10].

D. LOAD CONTROLLER

Generally, two types of loads are used in the load controller:

- Critical or high priority load
- Non-critical or low priority load.

Usually, the non-critical load is used in the load controller for power balanced. The various types of control methods depend upon the configuration of individual micro source and their rating, types of loads. The different types of control strategies are explained in various literature, which are mentioned decentralized control method [11], wireless control method [12], reference frame control method [13], hierarchical control [14], distributed control [15], coordinated control [16], cooperative control [17], multi-agent control or multi-level control etc.

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VII. PROTECTION SCHEMES

In HADMG, the magnitude & direction of fault current, load flow distribution are different topologies and considerations as compared to a radial distribution network. Due to the effect of HADMG, the original relays which are design for radial distribution network are not responding properly. So the conventional protection scheme in HADMG may cause mal-operation in switchgear and protection schemes.There are different protection schemes for different modes of operation which are explained in various literature.

In grid-connected mode:

- Wide area protection
- Current limiter protection
- Improved current protection scheme

In islanded mode:

- Harmonic distortion protection [18]
- Amplitude voltage protection scheme

VIII. STABILITY PROBLEMS

Due to the existence of various kinds of energy sources in distributed generation, there is a more vital communication problem with converters, and batteries cause instability. Due to electronic interfaces, DC micro-grid suffers instability.

Generally, AC micro-grid shows poor voltage stability due to the reactive power, current limiter, and dynamic loads like IM, on load & offload tap changers. The transient instability problem arises due to the fault with islanded losses of distributed generation, losses in hybrid micro-grid, and large changes in loads.

The key remedy of small-signal stability will be upgraded by the help of a supplementary control loop, energy management system, and co-ordinate control of the micro source. The problem of transient stability will be upgraded by controlling of energy storage system, load shedding method, adaptive protection devices.

Various protection and stability problems, operational issues of hybrid system are supplementary complex, conceptually and theoretically non identical in nature than the existing AC distribution system. The pragmatic performance of hybrid ac/dc microgrid requisite to develop various technical and economical challenges as explained.

- Assemble a new DC grid and improve the present AC grid is as durable cycle.
- Evolution of suitable control techniques and protection schemes for safe and reliable performance of hybrids system in isolated as well as grid connected mode.
- Designing and plotting the various control coordination in between the different types of PE converter for sharing of power among different types of DGs at different operating conditions.
- Modifying of domestic and commercial products to detach the embedded AC/DC rectifiers.
- Optimal of voltage level is requisite to determine for easy interrelation of different types of DC loads.

IX. CONCLUSIONS

The HADMG gives one of the attentive solutions for distributed generation. AC microgrid requires multiple conversion stages which causes power losses in the system and DC Microgrid is impractical to design due to some equipment which is operated only on Pure AC and due to these losses are more. So, to mitigate the problems identified in AC & DC Microgrid, the newly identified HADMG is introduced which minimizes the multiple conversions in renewable energy sources. A brief overview of the HADMG presented in this paper. The control techniques and protection schemes are explained in detail and also depicts the problems associated with stability in HADMG. To overcome above mentioned problems, the various control techniques and protection schemes associated with RES are reviewed from the updated literature. The field of research community in Microgrid can do rigorous research work to mitigate stability issues and improve the dynamic behaviour of the system.

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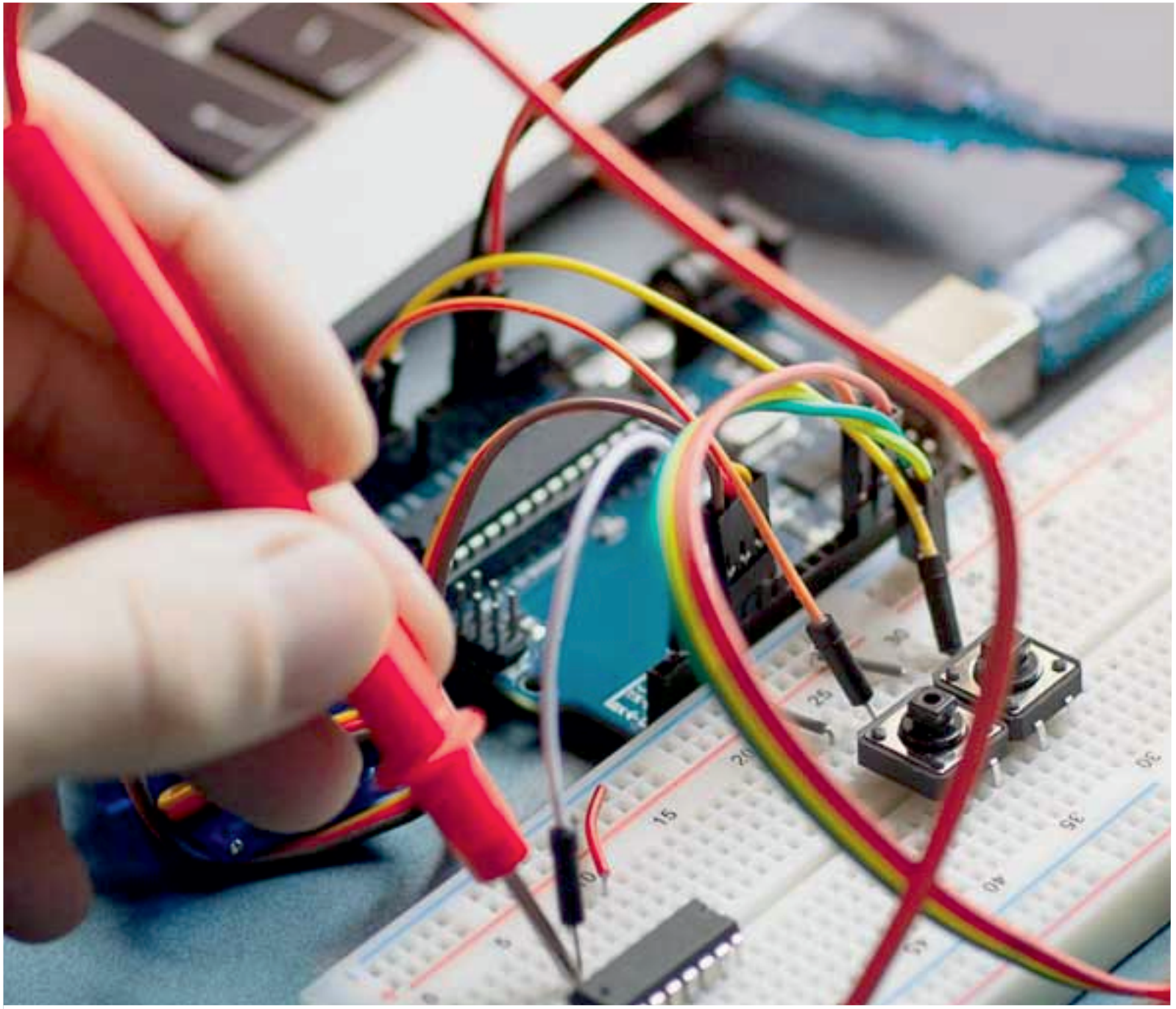

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