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Review of Optimization Approaches for Optimal Placement and Sizing Capacitors

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ABSTRACT: The continuous improvement in CAPICATOR technology helps in providing electricity to its consumers in a very cost effective nature. In case of competitive (wholesale) deregulated environment, the users owing their CAPICATOR's responds to very high price swings in order to decrease the price volatility. The CAPICATOR's operated on utility are considered as the most suitable option for the process of planning. In emergency conditions, some part of the whole load is shifted on an isolated type of generator which provides some relief to the burden faced by utility [23, 24]. If a small unit of CAPICATOR fails, it does not affect the reliability of the working operation. Placement of Distributed generation (CAPICATOR) controls the real power flow of the system and minimizes the system real power loss while connecting the shunt capacitor system reactive power flow is optimized and system voltage will be within the specified limit. CAPICATOR is the electricity generation from renewable energy resources that are located near to the consumer side

I. INTRODUCTION

The use of renewable technologies is usually restricted to areas with low load and population densities. The distribution networks in such areas are constructed or designed to provide the increasing demands of the consumers that tend to decrease with transmission system distance. So, the use of such a network provides a great interest to the regulators of the industry and its utility [1]. This concept covers the additional benefits related to the distributed or dispersed types of compatible resources in the distinct locations of the network. These resources include small storage or modular based generation. Depending upon the changes done in the electrical industry, the use of such small portable or modular generation types provides a great interest. The rising issues of siting the big station plants, an increase in demand have made such modular resources as an additional benefit attracting the consumers based on the methods or the ability to change the projecting conditions [2]. This basically provides dispersed forms of small modular installations very close to point-of-end use. Hence, the dispersed or distributed network has become a major electrical energy driven source in the present as well as the future-based generation. So, the main reason to use such dispersed systems relies on the following fact:

1. The deregulation of power has encouraged the public investment in order to continue the power demand. This has resulted in breaking investments for the power development.
2. The emergence of new technologies with large profitability, benefits, and smaller ratings.
3. The rising demands and the saturation of the networks that already exist.

The distributed resources should be located optimally to minimize the line loadings, reactive power need, and the losses of the network [19]. The whole process of optimization should actively work on land costs, availability of the site, maintenance costs, plant operations conditions, etc.

The main goal of power system is to deliver the power at each location of the power system network economically and reliably. Before generating electrical energy only conventional energy resources are used. These conventional resources are coal, hydro, nuclear. Those generators deliver power widely distributed different types of users connected through long transmission and distribution networks. In nowadays the central power plant is becoming weakening. The Weakening of the central power plant is due to environmental issues and also due to a reduction in conventional resources. As a result transmission and distribution costs are also gradually increasing. Then the distributed generation comes into the picture and it offers a solution to many of these new challenges. CAPICATOR in simple terms can be defined as small scale generation or decentralized generation that is neither centrally planned nor centrally dispatched. CAPICATOR's are used near to the load side and they use energy sources such as solar photovoltaic, wind generators, fuel cells, gas microturbines, etc and its capacity is also less than 100 MW. The Capacitors supply the reactive power to

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the load and also improves the system voltage profile. The Capacitor is also come under 2nd type CAPICATOR. When we connect the CAPICATOR and capacitors to the system we have a serious effect on the system power losses, system voltage profile. For achieving the serious effect on the system after connecting CAPICATOR and capacitor we have to select the optimal size and optimal location of CAPICATOR and capacitors during connecting it at the distribution system. Many researchers have done the work on this relevant topic for recent years for optimal placement and sizing of CAPICATOR and capacitors. Several types of research have been done in recent past on optimal siting and sizing of CAPICATOR and shunt capacitor bank (SCB). Different methodologies have been used to optimally allocate proper size of CAPICATORs. These methodologies include analytical tools, optimization methods or artificial intelligent based algorithms. In [1] loss reduction sensitivity and voltage improvement sensitivity method is used to determine the best location for CAPICATOR connection. In ref [2] presented a comprehensive review and Comparison of various CAPICATOR schemes used by utilities for mitigation of voltage dips in power networks. Optimal location and sizing of distributed generation in a distribution networks using Genetic Algorithm (GA) is discussed in [3]. In ref [4] also genetic algorithm (GA) based method has been used to determine the optimal location and size of the CAPICATOR's. In Ref. [5] the authors determine the optimal placement of CAPICATOR and capacitor by voltage stability index technique to minimize the both real and reactive power loss. In [7] an improved reinitialized social structures PSO algorithm has been developed for optimal placement of multiple CAPICATORs in a micro grid to minimize the real power loss within voltage and power generation limits. The authors in [6] reconfigure the distribution network using ant colony search algorithm to minimize the system losses. In Ref. [8] authors determined the optimal location of CAPICATOR's for uniformly distributed load and uniformly increasing load. The analytical approach has been demonstrated in [9]

1.1 CAPICATOR: DEREGULATED ENVIRONMENT

The process of distributed generation in a deregulated environment plays a significant role in fulfilling the energy demands of future providing the free environment and the flexibility to its users in developing and planning the type of installation required as per the load critical conditions. It has the capability to serve as an alternate possible solution with a great potential. The continuous improvement in CAPICATOR technology helps in providing electricity to its consumers in a very cost effective nature. In case of competitive (wholesale) deregulated environment, the users owing their CAPICATOR's responds to very high price swings in order to decrease the price volatility. The CAPICATOR's operated on utility are considered as the most suitable option for the process of planning. In emergency conditions, some part of the whole load is shifted on an isolated type of generator which provides some relief to the burden faced by utility [23, 24]. If a small unit of CAPICATOR fails, it does not affect the reliability of the working operation

II. CAPICATOR INSTALLATION: BENEFITS

The installation of CAPICATOR has become an interesting and attractive area of research providing a large number of benefits in the electrical engineering technology. Some of the major benefits of installing a CAPICATOR are as follows:

a) It can help to meet the power needs at the peak time.
b) It reduces the need for building new distribution/transmission lines.
c) It helps in reducing the distribution and the transmission losses with the help of a convenient form of local positioning. This local positioning provides benefit to use the generation (single or three phase).
d) The process of a generation that is adjacent to the load allows the tremendous use of energy in the form of heat, for, example combined heat and power (CHP) applications.
e) These types of units can be installed easily near the user/consumer end thereby, matching the requirements of the load.

III. CAPICATOR INSTALLATIONS: BARRIERS

As a topic of great interest, the interconnection process of distribution network along with the distributed resources of power brings down some of the major challenges such as stability of the network, protocol protection, regulation of the voltage, unwanted losses, reliability, condition of power balancing, power quality issues, power outage and fluctuations [16, 20s]. The CAPICATOR installation barriers are categorized into three parts described in the below section.

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3.1 ECONOMIC BARRIERS

These represent a major type of barrier to the process of installing a CAPICATOR. In the present scenario, the CAPICATOR owner gets a large amount of profit from the power that is generated, whereas the operator of the

CAPICATOR (CAPICATORO) with whom the unit is connected to the grid faces the problems related to cost upgradation and unpredictable implications of the power supplied to the grid [21]. Therefore, the CAPICATORO considers it as a matter of nuisance rather than a benefit or opportunity. Moreover, it does not help the independent customers or householder to expect the working of such generation units on the daily basis.

Bhowmik, S., et.al [1] described a new planning method for the distribution system. In order to obtain an optimized solution, an algorithm has been developed by considering an objective function (non-linear) with both the linear and non-linear type of constraints for radial distribution system at a very large extent. Here, the objective function was optimized through the reduction in cost functioning operation. Further, a three-step iteration was performed. The first step includes the substation optimization process which determined the substation sites number with its exact location, the second step covered the feeder optimization which determined the feeder number with the actual original route and the final stage represented the reliability of system node.

T. C. Green, et.al [2] presented a methodology for the sizing and the siting of the CAPICATOR constraint system based on the security. The case of optimal siting was determined by analyzing the sensitivity of the power row equations. A method known as siring method was used for penetration level of generation, set of loading conditions, and power factor formulated such that it worked as a constraint problem of optimization based on security. The use of optimal generation site information was considered to optimize the reliability of the system via the indices obtained from the reliability calculations. In order to design such a method for solving the re-closing positions, a genetic algorithm was used.

El-Khattam, et.al [3] presented a survey on CAPICATORs approaches which would change the working operation of electric power systems. This research was based on the important concepts, the definition of CAPICATORs, and their working constraints fair enough to help in understanding the regulations methodology of CAPICATORs. For the process of implementation, the economic and the operational benefits were also considered. Here, the researcher’s main objective was to provide a comprehensive survey which would add new types and classifications related to CAPICATOR technologies, types and the applications.

Quezada, et.al [4] presented an approach in order to calculate the energy losses (annually) when different concentration and penetration levels of CAPICATOR gets connected to the distribution type network. Additionally, various impacts have been calculated considering the wind power, combined heat and power, fuel cells, and photovoltaics. The results have shown that variation in energy losses that seemed to be a function of the penetration level of CAPICATOR has presented the U-shape characteristics trajectory. Moreover, high loss reduction can be expected if the units of CAPICATOR get more dispersed along the feeders of the network. In the context of technologies related to CAPICATOR, it was noted that the wind power shows the worst type of behavior in curing the losses. In the end, the CAPICATOR units along with reactive power control have provided the better network for controlling losses and the voltage profile.

Piccolo, et.al [5] conducted a study to obtain or capture the postponed or deferral network investment effects on the expansion system of CAPICATOR, several regulations for the operators of the distribution network and how they attracted optimized new generation combination with its existing forms. Here, the optimal power flow (multi-period), sizing and siting of CAPICATOR installation are analyzed.

Saint, Bob [6] proposed a study based on reviewing the languages in the Act that reviewed the characteristics and the value of Smart Grid defined by Department of Energy, discussed the unique characteristics that could be applied to rural-based utility systems, and described various technologies of smart grid that are in use today for the rural type distribution networks.

Albu, et.al [7] conducted a study based on an algorithm establishing the best methods for the storing the system electrically for the virtual synchronous generator (VSG) that usually worked on its nominal power (desired) and the case of application. The resulting form of application helps in providing a wide description of the technologies that

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exist already depending upon the matching of characteristics with its required storage properties described accordingly from the user point of view.

Falaghi, H., et.al [8] proposed a framework which has solved the issues related to the planning of distributed multi-stage system expansion where the distributed generation and feeder units along with substations installation has been considered as one of the best solutions for the expansion of the system's capacity. It further involved system's outage costs, investment, and its operation and the methodology of expansion was based on the procedure of pseudo-dynamic system. A joint study of optimal power flow (OPF) and genetic algorithm (GA) was developed as a tool for solving the problem of the system. The proposed strategical performance was illustrated and assessed by studies (numerical) on a complex distribution system.

Ochoa, et.al [9] conducted a research using a multi-period optimal power flow (OPF) that was used to find the optimized form of accommodation of CAPICATOR such that it minimized the losses occurring in the system. Additionally, the controlled schemes were expected to become a part of Smart grid technologies for extracting large benefits from the dispatchable CAPICATOR power factor, coordinated type of voltage control. These are embedded in the formulation of OPF to grab the extra benefits with such types of technologies. The process of trade between the capacity of generation and losses of energy was also investigated. This strategy was applied to U.K based generic distribution network and further the results have shown the impacts while considering the characteristics (time-varying) in context of minimization of energy loss and highlighted the flexibility gain given by controlling strategies that can have both the generation capacity and the minimization of loss.

Edward J., et.al [10] addressed several types of possibilities which handled issues on grid planning processes. Effects on voltage control, grid protection, and fault levels are investigated and described. Such aspects were illustrated in addition of simulation techniques on the already existed grid distribution. The study demonstrated that in the case of a compact form of grid distribution, the problem of voltage control does not occur likely but the issues related to fault levels and the false tripping needs a special care.

Wen-Shan, et.a al [11] presented reviews on some of the populous renewably based distributed generation locating methods that include the Optimal Power Flow, Mixed-Integer Non-linear Programming 2/3 Rule, Analytical Methods, Hybrid Intelligent System, and various intelligent optimization techniques. Each and every method represented its exceptional potential and feature for the promotion of distributed generation in accordance with renewable energy systems.

Abapour, et.al [12] proposed a model that determined the location, investment of time, and optimal size for CAPICATOR units. A modeling approach based on the present scenario has been used for determining the uncertainty of load growth rate and the energy price. In order to demonstrate the merits of CAPICATOR planning, the result of the process was compared with the static models along with a comparison of active network CAPICATOR planning with that of a mode based on a passive operation. Additionally, a technical comparison and evaluation were done between passive, active and conventional networks. The model has been proposed was applied 33-bus system based on a radial distribution network. The study indicates that the use of AM results in minimizing the losses and the cost function effectively as compared to the passive type management.
Sravanthi, S., et.al [13] conducted a research study on renewable and load generation of CAPICATOR following a probabilistic nature. This methodology was started with the help of selecting the candidate busses that were sensitive to the voltage for the CAPICATOR unit installation processes. Here, CAPICATOR level of penetration, the capacity of the feeders, and system voltage limits represent the constraints for the proposed study.

Georgilakis, et.al [14] conducted a study on the planning of power distribution systems used to design or model the systems in order to meet the demand growth with the best possible methods based on reliable, safe, and economic conditions. The process of gradual transforming from passive to active type of distribution grid imposed the need to consider certain effects of CAPICATOR, the demand (active) during the planning process, and the benefits of control. This study presented an overview of the methods and the models that were applied to modern PDP-based analyzation and classification of the current and future trends in the field of technology.

Muñoz-Delgado, et.al [15] proposed a study based on planning problem with the multi-stage expansion of distribution system where the financial investment in distributed generation and distribution network have been considered jointly. The expansion of the network was comprised of various alternatives for the transformers and the feeders. Similarly, the

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CAPICATOR installation was based on various alternatives for wind and other conventional type's generators. Here, the approach basically consists of different types of set-nodes for the installation of the generator. Therefore, the expansion plan that has been optimized helps in identifying the best suitable location, alternative, and installation time for the candidate's assets. Usually, this model was driven by minimizing total cost's present value (net-value) that included the cost linked to its maintenance, investment, unserved energy, production, and the losses. The energy losses cost was modeled by linear approximated method prices. Consisting of an additional feature which was based on radial conditions that uniquely tailored to entertain the distribution generation presence and the problems linked with transfer nodes. The results have shown the optimization issue enlightened a linear program mixed-integer method where the process of convergence (finite) relying on optimization process was guaranteed, with the availability of the software. This methodology out-performs the proposed approach.

Kumarappan, et.al [16] investigated optimized installation of multiple-CAPICATORs in the radial type of distribution network with the use of competitive swarm optimizer (CSO) based algorithm. This CSO-algorithm was basically derived from PSO-algorithm but the concept was different from each other. In cased of CSO-algorithm, a competition among particles is done pairwise, so that if the particle gets failed, it would learn the program of updating the position from the winner. The problem of CAPICATOR sizing and location was solved from the main idea of minimizing the real power loss (total). The experimental results have shown a great effectiveness of the method proposed and the dominance of the method was proved by comparative study of results based on simulations performed.

Jalali, et.al [17] conducted their research dealing with the problem related to distribution system optimized planning that consisted of CAPICATOR placement, conductor sizing, and shunt capacitor sizing. A new approach, PSO optimized Binary selective method was used that was capable to handle binary, selective, and continuous variables. At the same time, it enlightened the main focus on distribution system planning. The main objective of the problem was to reduce or minimize the cost of the system. The points that were taken into account includes the cost of energy, inflation rate, cost of energy, and load growth rate. The main test was performed on a 26-bus system.q1

Ahmadian, et.al [18] proposed a work Plug-in Electric Vehicles (PEVs) that addressed its certain effects on distribution network planning processes. The process of planning becomes an interesting concept when the uncertainty is also considered. This research was based on the problems faced by the system that arose from the uncertain behavior of the PEVs, which made the researchers to opt planning for CAPICATOR. Here, the capacity and the location of dispatchable form of CAPICATOR's and stationary battery power rating, capacity, and the optimal location are determined to reduce the objective of the cost-based function working under the constraints performing technical operations. The problem of long and short interval planning are solved using distinct methods such as Simulated Annealing (SA) and Tabu Search (TS). The experimental analysis has shown that the distribution network gets connected to the PEV's, both the CAPICATOR units and the stationary batteries required a proper planned consideration based on the economic as well as the technical point of view.

V. Madhusudhan, et.al [19] conducted a study on Hybrid generation systems under various distinct scenarios that were based on sources of renewable energy. In the first step, a hybrid system linked with the grid was designed without any kind of uncertainty insertion. Then, the evaluation was done based on its reliable condition based on probabilistic strategies with accounting failures in the equipment, load variations/ stochastic generation, and sources of energy (time-dependent). Particularly, the unpredictable nature of the solar insolation, the speed of wind including time-series models, random load variation were used to provide reflection based on their stochastic characteristics. The study relying on sensitivity was carried out to observe the impact of distinct parameters of the system that was based on the global designing performance.

Adefarati, T., et.al [20] presented a study based on assessing the distribution system reliability that satisfied the customer-based requirements of the load with penetration of electric storage system (ESS), photovoltaic (PV), and wind turbine generator (WTG). Here, a model (Markov) was proposed for accessing the characteristics of major parts of CAPICATOR and to update and enhance the reliability of the system. The experimental results have shown that the use of ESS, PV, and WTG provided a best possible solution to enhance the reliability of operation of CAPICATOR systems.

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Sl. No	Method used	Objective function	Number of bus system	Either CAPICATOR or SCB or both simultaneously	Minimum voltage at bus before connecting the unit	Voltage improvement after connecting the unit	Ref
1	Meta heuristic approach PSO Algorithm	Power loss minimization	33 and 69 bus system	Both CAPICATOR and SCB simultaneously	For 33 bus at bus 18 voltage is 0.9038 p.u For 69 bus at bus 65 voltage is 0.9092 p.u	For 33 bus minimum voltage at bus 18 voltage will be 0.9570 p.u For 69 bus minimum voltage at bus 27 voltage will be 0.9724 p.u	16
2	Analytical+ PSO method	Minimize distribution loss	33 and 69 bus system	Both CAPICATOR and SCB	For 33 bus at bus 18 voltage is 0.905 p.u	For 33 bus after one and two type I CAPICATOR placement 0.943 p.u and 0.962 p.u respectively After one and two type II CAPICATOR placement 0.9177 p.u and 0.931 p.u respectively	12
3	Meta heuristic approach Moth flame method	Minimize power loss	33 bus system	Only CAPICATOR	At bus 18 voltage is 0.9295 p.u	At bus 18 and voltage will be 0.9571 p.u	11

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4	Loss reduction sensitivity method and voltage improvement	Minimizing total power loss	IEEE 24 bus system	Only CAPICATOR	At bus 18 and voltage is 0.93 p.u	At bus 1 , bus 6 and bus 22 Voltage is 1 p.u	1
	method						

5	Meta heuristic approach Slap swarm optimization method	Minimizing total power loss, generation costs and generation emission	IEEE 33 and 69 bus radial distribution system	CAPICATOR and SCB	At bus 18 for 33 bus system and bus voltage is 0.91 p.u At bus 62 for 69 bus system and bus voltage is 0.911 p.u	At bus 7 for 33 bus system and bus voltage is 0.9918 p.u At bus 65 for 69 bus system and bus voltage is 0.9971 p.u	17
6	Sensitivity analysis based heuristic method and quadratic curve fitting method	Minimizing the real power loss	IEEE 12 and 33 bus system	CAPICATOR and SCB	For 12 bus system bus voltage is 0.94414 p.u at bus 12 For 33 bus system bus voltage is 0.9065 p.u at bus 18	For 12 bus system CAPICATOR with upf and capacitor bus voltage is 0.9815 p.u at bus 8 For 33 bus system CAPICATOR with upf and capacitor bus voltage is 0.96003 at bus 30	18
8	Genetic algorithm	Minimizing total cost		28 bus System	CAPICATOR and SCB Here cost analysis is done so total cost	Total cost after placement is 4985172 $/P.p	20

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					before placing is 7108454 $/P.p		
9	Genetic algorithm and moth swarm algorithm	Power loss minimization	IEEE 33 and 69 bus system	CAPICATOR and SCB	At bus 18 for 33 bus system and voltage is 0.9036 p.u For 69 bus system at bus number 64 and voltage is 0.9092 p.u	At bus 18 and voltage is 0.9938 p.u for 33 bus system At bus 28 and voltage is 0.9976 p.u for 69 bus system	21
10	Multiobjective evolutionary algorithm	Minimizing Real and reactive power loss	IEEE 33, 69, 119 bus system and practical 83 bus system	CAPICATOR and SCB simultaneously	At bus 18 for 33 bus system and voltage is 0.9032 p.u For 69 bus system at bus number 64 and voltage is 0.9094 p.u	For 33 bus system at bus 18 for 1 CAPICATOR and 1 SC and bus voltage is 0.935 p.u For 69 bus system at bus 28 for 1 CAPICATOR and 1 SC and bus voltage is 0.9711 p.u	12
11	Ant Lion Optimization	Minimizing Real and reactive	IEEE 33,69 bus system	Only CAPICATOR	At bus 18 for 33 bus system and	For 33 bus system at bus 18	3

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	Algorithm	power loss			system at bus number 64 and voltage is 0.9102 p.u	voltage is 0.9040 p.u For 69 bus For 69 bus system at bus 27 for 1 PV cell & bus voltage is 0.9679 p.u	for 1 PV cell and bus voltage is 0.9503 p.u
12	Genetic Algorithm(G A)	Minimize the cost and maintain the voltage within permissible limit	70 bus system	Locally controlled voltage regulator(V.R)	Before V.R placement minimum voltage occurs at bus 36 and minimum voltage is 0.86 p.u	After V.R placement minimum voltageoccurs at bus 29 and minimum voltage is 0.885 p.u	2
					For 38 bus	For 38 bus	
13	Chaotic Artificial Bee Colony (CABC) algorithm	Multi-objective function consists of voltage profile enhancement, active power loss minimization and improvement of VSI	38 and 69 bus system		system for mixed load at bus 18 and minimum voltage is 0.952 p.u For 69 bus system for mixed load at bus 65 and the voltage is 0.92 p.u	system for mixed load at bus 18 and minimum voltage is 0.99 p.u For 69 bus system for mixed load at bus 65 and the voltage is 0.97 p.u	4

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V. CONCLUSION

In power system economics, distribution systems play an important role because it is responsible for transferring electrical energy to the end users. There is a high amount of power loss when operates on the low voltages and high currents. The high power loss makes it costly because it depends on the system conductors. The voltage and current profile of the system keep in an acceptable range because the size of the conductor affects the most. The small size conductor has a low flow of current and it drops the voltage across the system. The main objective for the problem is to reduce the system cost on the basis of loss and conductor cost.

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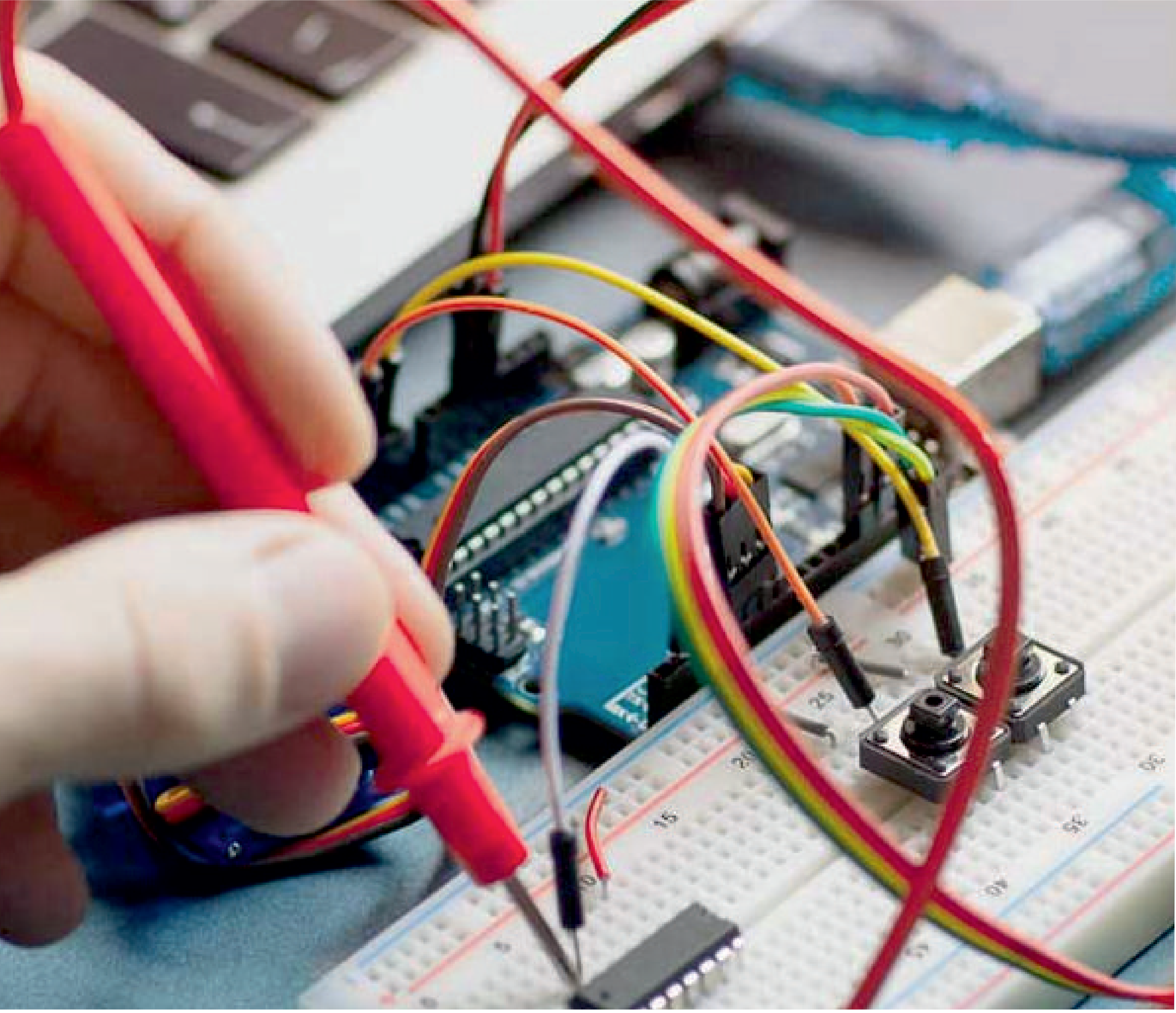

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