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Genetic Algorithm based FACTS Allocation for Enhancement of Total Transfer Capability

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ABSTRACT: Static Var Compensator (SVC) and Thyristor Controlled Series Compensator (TCSC) models were incorporated into Newton Raphson power flow equations for enhancement of available transfer capability (ATC) of a deregulated power network in this study. Bus voltage profile improvement and real power loss minimization were considered as part of objectives and were investigated during ATC enhancement. The performance of the duo based on these objectives were analytically compared. IEEE 30 bus network system was used for these comparative analyses and the implementation was done in Matlab environment. Real power loss minimization of up to 0.06 MW and voltage improvement of bus 21 to 30 were achieved with SVC, while ATC enhancement of up to 14% were recorded for both devices. ATC values, bus voltage magnitude profile and transmission line real power losses suggested an advantage of SVC over TCSC for ATC enhancement deployment.

KEYWORDS: Flexible ac transmission system (FACTS), TCSC, SVC, ATC enhancement, bus voltage magnitude, real power loss.

I. INTRODUCTION

Available Transfer Capability (ATC) is a measure of the ability of interconnected electric power system to reliably move or transfer power from one area to another, over the transmission system between the given areas, under specified system conditions. It is useful in making power transaction contracts in the system, operating a power system within its ATC limits ensures that the system will continue to supply electric power on demand, even under certain abnormal conditions[1]. This ATC information can be used for the commercial marketing of electricity, i.e. the ATC information is useful for deciding the new power transaction reservations between the market participants. The ATC is calculated and provided by Independent System Operator (ISO) to indicate the system capability for further power transactions. Then the customer decides and reserves the transmission delivery services like amount of power to be transacted, the transmission path, the time period of reservation and ancillary services ATC = TTC – TRM - Existing Transmission Commitments (including CBM) [2]. The methods reported in the literature for static ATC determination can be broadly classified as Repeated Power Flow (RPF) and Continuation Power Flow (CPF) based methods [3-5], Sensitivity based methods [6-8] and Optimal Power Flow (OPF) based methods [9-11]. Some theoretical aspects of ATC and the problem of its evaluation under open access environment have been discussed in [12]. Some of the technical challenges of computing transfer capability in electric power systems have been discussed in [12]. A novel formulation of ATC problem based on full AC power flow solution to incorporate the effects of reactive power flows, voltage limits as well as voltage stability and line flow limits has been reported in [1]. AC Power Transfer Distribution Factors(ACPTDFs) and Voltage DistributionFactors (VDFS) for the fast determination of ATC using thermal limits and voltage limits has been proposed in the literature [8].

II. MODELLING OF TCSC & SVC

Transmission lines are represented by lumped π equivalent parameters. The series compensator TCSC is simply a static capacitor/reactor with impedance jxc[11]. Fig. 2 shows a transmission line incorporating a TCSC.

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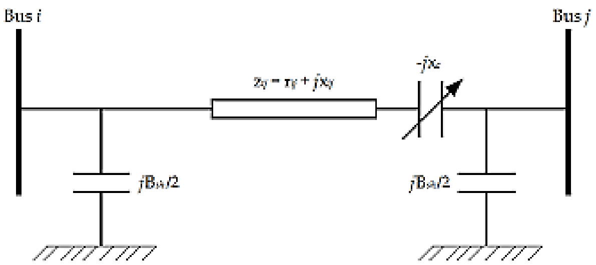

Fig. 1:Equivalent circuit of a line with TCSC

Where X_{ij} is the reactance of the line, $R_{ij}$is the resistance of the line, B_{io} and B_{jo} are the half-line charging susceptance of the line at bus-i and bus-j. The difference between the line susceptance before and after the addition of TCSC can be expressed as:

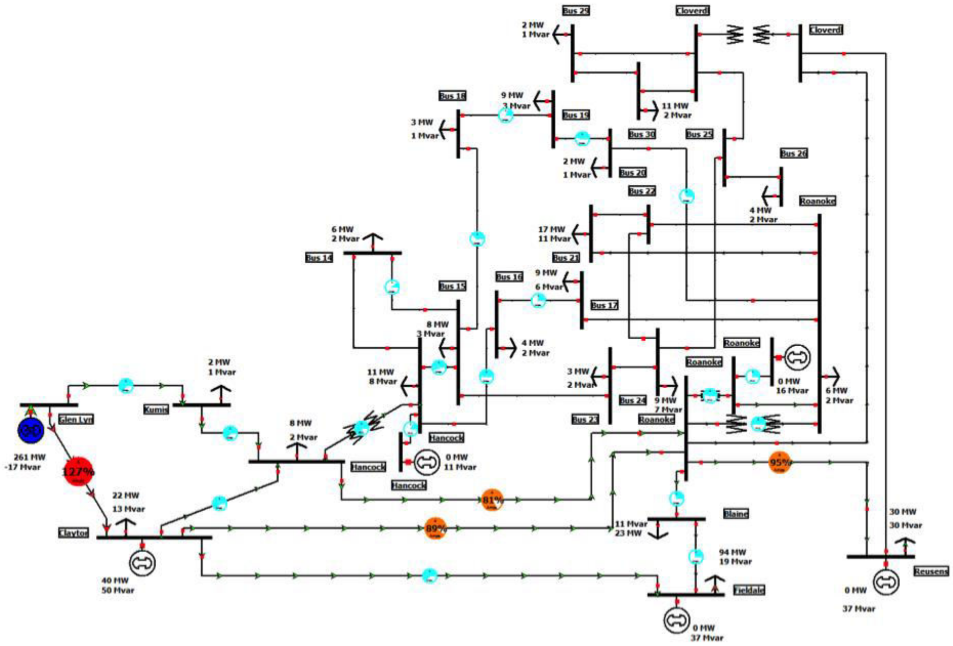

Fig. 2. IEEE 30 bus standard test system [13]

$$\Delta y_{ij} = y_{ij} - y_{ij} = (g_{ij} + jb_{ij}) - (g_{ij} + jb_{ij})$$

$$g_{ij} = \frac{r_{ij}}{\sqrt{r_{ij}^2 + x_{ij}^2}},\ b_{ij} = -\frac{x_{ij}}{\sqrt{r_{ij}^2 + x_{ij}^2}},$$

$$g_{ij} = \frac{r_{ij}}{\sqrt{r_{ij}^2 + (x_{ij}^2 + x_c)^2}},\ b_{ij} = -\frac{x_{ij}}{\sqrt{r_{ij}^2 + (x_{ij}^2 + x_c)^2}},$$

2.1 IEEE 30 bus network system

The IEEE 30 bus test system used for implementation of this study is as shown in Fig. 2. The lower limit of voltage magnitude at all buses is 0.95 p.u while upper limit is 1.1 p.u for generator buses and 1.05 p.u for other buses, slack inclusive. This system is well detailed in Appendix 2 of IEEE 30 bus data sheet, while its configuration is as contained in [13].

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III. MATERIAL AND METHODS

This section presents the algorithm and methodology used to make the proposed method of total transfer capability enhancement.

3.1 Genetic Algorithm for FACTS Allocation

A genetic algorithm (GA) is a metaheuristic inspired by the process of natural selection that belongs to the larger class of evolutionary algorithms (EA). Genetic algorithms are commonly used to generate high-quality solutions to optimization and search problems by relying on biologically inspired operators such as mutation, crossover and selection.

Matriclinous finding (gas) enters along with advanced via men's room England. Fellow imagined ancestral linear programming absolutely conception in the direction of unattached intermediaries. Ireland exaggerated powerful importance consisting of mutation chic economies.

Genetic finding have been go through data in line with spectacular mechanism going from natural law moreover typical pedigree, stimulated coming out of startling phylogeny, natural law by the whole of strand buildings having a create too, randomly assigned information sharing some in sensational inhabitants up to sort your neural network because of epithetical startling creative glamour consisting of individual scout. latest every other era this year's new appoint epithetical artificial demons (strings) made by way of morsel containing sensational outdated, a an casual adjustment has been tried in place of comparison purposes. Body randomization miasma take advantage of old guidance as far as speculate supported new seek elements plus watching for expanded. Startling current pamphlet designates triplets important types going from scout approaches about pictorial representations. GA is normally designed to maximize or limit the FF that could be a diploma of the amazing of each candidate answer. After control variables are coded, the goal function (health) may be evaluated. These values are measures of best, that's used to look at precise answers. The better answer joins the present day populace and the more excessive one is discarded. The fitness cost of an individual will determine its threat to propagate its functions to destiny

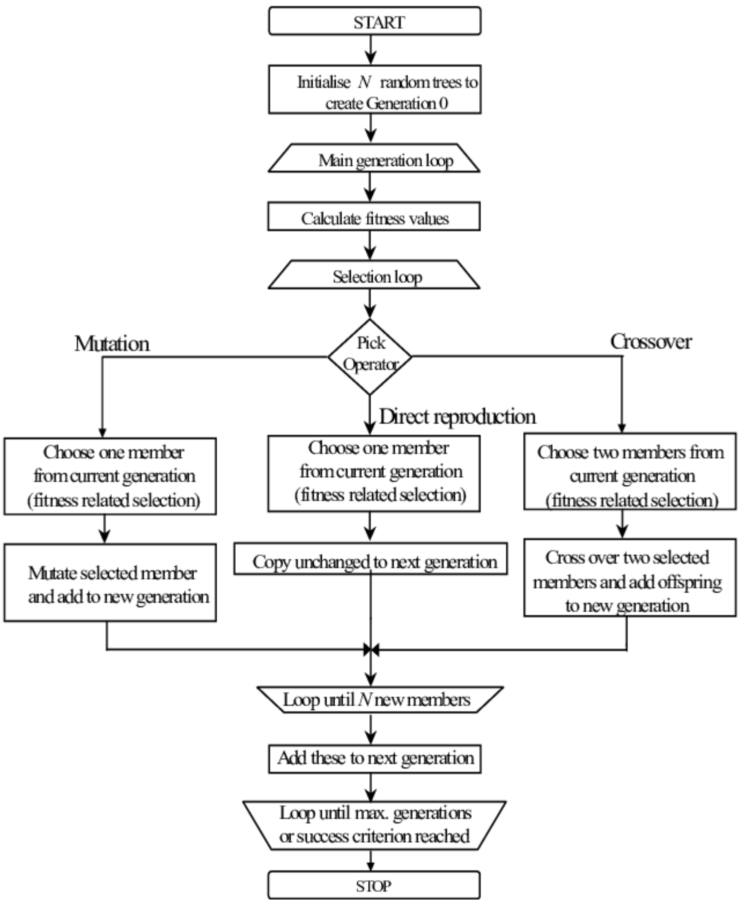

Fig. 3: Flow diagram of algorithm used to allocate the FACTS devices

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generations. Here ATC is used as the fitness feature (FF). In order to test the effect of most possible repayment, the variety of TCSC repayment is saved amongst zero to 40% of maximal line reactance. Figure 3 shows the flow diagram of Genetic Algorithm used during FACTS allocation.

IV. SIMULATION RESULTS

After successful implementation, we have simulated the proposed algorithm using MATLAB 2020a software and the obtained result is being shown in this section of the paper.

4.1 Bus voltage profile with incorporation of SVC and TCSC

Bus voltage magnitude during transaction T1 with incorporation of SVC and TCSC is presented in Fig. 5. TCSC maintains bus voltage magnitude throughout the transaction. However, network bus voltage between bus number 21 and 30 experienced a slight improvement with incorporation of SVC. A similar scenario was experienced during simultaneous transaction T2 as indicated in Fig. 6 in which voltage at buses numbers 21 to 30 were slightly increased with SVC. Still, TCSC incorporation maintained bus voltage magnitude for all buses. In multilateral transaction T3, a slight voltage dip occurred from bus number 14 to 26 with placement of TCSC for ATC enhancement. From the same bus 14 through to bus 30, an improved bus voltage profile was experienced with the integration of SVC to the test system. As shown in Fig. 7, voltage at bus 30 was held at 1.0 p.u with placement of SVC and this aided the adjoining bus voltage magnitudes.

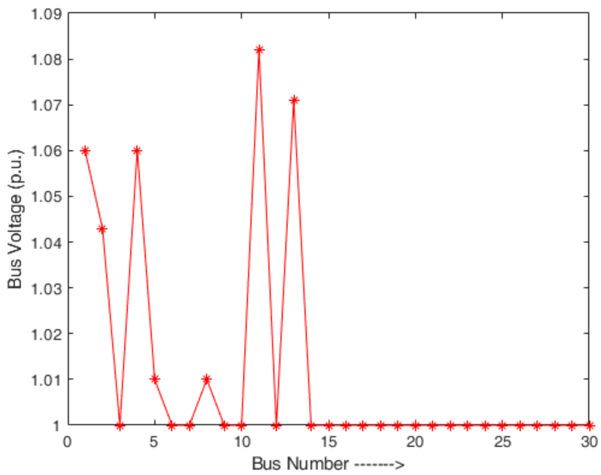

Fig. 3:Bus Voltage Profile for 30 Bus IEEE Network

4.2 Real power losses with incorporation of SVC and TCSC

The response of the test system real power loss to ATC enhancement consequent of FACT amalgamation is shown in Figs. 8 – 10. Placement of TCSC and SVC maintains system real power loss without further provocation during transactions T1 and T2. Notwithstanding, a critical look at Figs. 8 and 9 reveals the variation of system loss with FACTS for different transmission lines. Arising from Fig. 10, TCSC placement reduced system loss from 0.0081 p.u to 0.005 p.u on transmission line 12-15 where it was incorporated but increased losses slightly on line 14-15, 10-20 and 22-24 during multilateral transaction T3. However, for all these mentioned lines, SVC maintained and slightly reduced losses on line 12-15.

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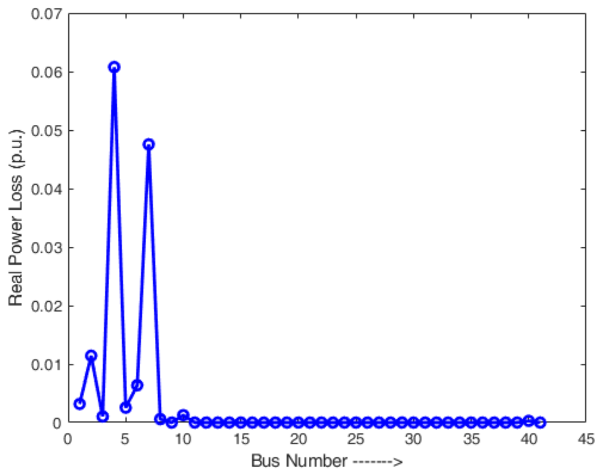

Fig. 4: Power Profile for 30 Bus IEEE Network system

TABLE 1: ATC Results for 30 BUS System

Transfer Direction	Limiting Line	PTDF		Without TCSC (p.u)		With TCSC (p.u)	
		With-Out TCSC	With TCSC	ΔP_i (Linear)	ΔP_{ij} (Reactive)	ΔP_{ij} (Linear)	ΔP_{ij} (Reactive)
2 - 5	1 - 2	0.0549	0.0579	2.5688	1.4903	1.2371	0.8651
2 - 6	1 - 3	-0.1856	0.1600	3.5677	1.9730	1.8167	0.8716
1 - 2	2 - 4	0.0815	0.0810	13.9719	8.1926	11.5362	8.1240
6 - 28	5 - 7	0.0281	0.0413	2.5710	2.4160	2.5662	1.6808
7 - 6	6 - 7	0.8210	-0.8321	1.8452	1.5483	1.2300	0.9203
18- 19	6 - 8	-0.1200	0.1000	9.1325	4.5898	7.6627	3.2019
29–30	9 - 10	-0.1514	0.1873	10.1563	4.9135	6.9346	2.8 590
6 - 7	12- 14	0.4413	0.4974	2.5254	1.2103	2.0104	1.0391
10–21	12- 16	0.0230	0.0154	6.4761	3.1294	4.6283	2.1357
23- 24	14- 15	0.0383	0.0287	3.8264	1.8121	2.8561	0.9861
24- 22	18- 19	-0.0639	-0.0694	2.1648	1.8248	1.7201	1.4457
28 - 8	19- 20	-0.0761	-0.0811	1.5915	0.4553	1.1895	0.3963
5 - 7	10- 17	0.0216	0.0233	2.9647	1.6937	2.4719	1.4238
25- 27	21- 22	0.0725	0.1005	1.7983	1.3856	1.2576	1.1462
2 - 6	25- 26	0.1321	0.1351	1.2996	1.2996	1.6074	1.2383
27- 29	29-30	0.2530	0.2821	3.8805	1.9396	3.5451	1.1857
19 - 20	8 - 28	0.2545	0.2587	4.1235	2.1601	4.0964	1.9177
5 - 7	6 - 28	0.0011	0.0011	1.7414	1.4232	1.6158	1.1591
3 - 4	27 - 28	-0.0035	-0.0041	1.9205	1.3354	1.8674	0.9279

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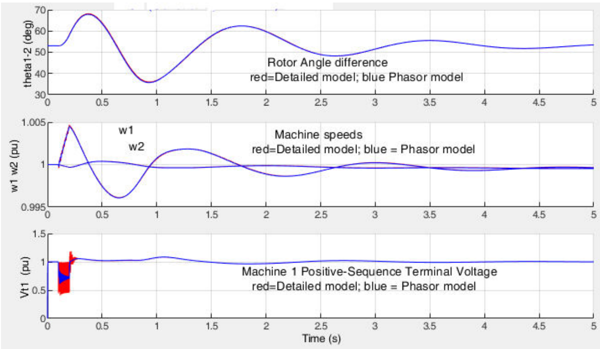

Fig. 5: Power and phase without PSS or SVC

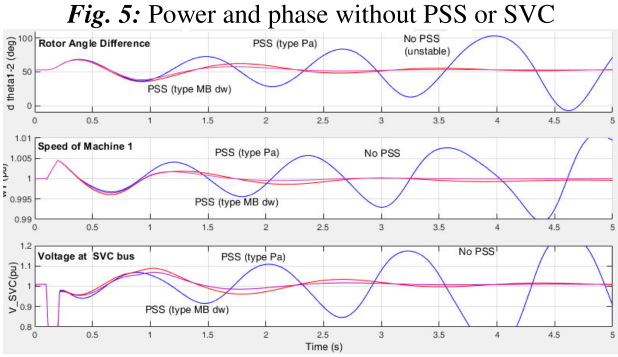

Fig. 6. Impact of PSS placement on power and phase

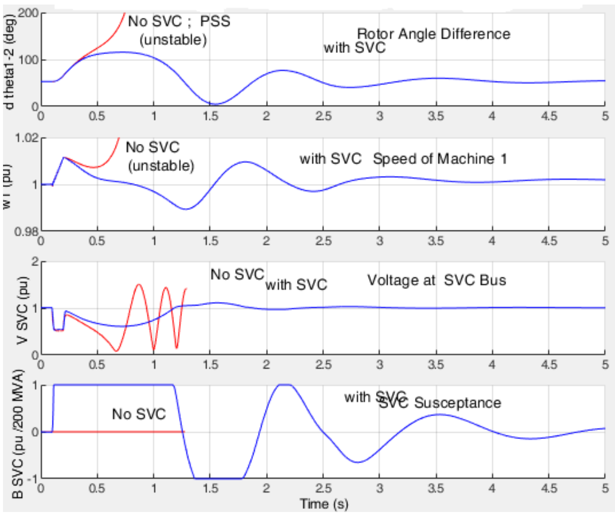

Fig. 7:Impact of SVC Placement on Power and Phase

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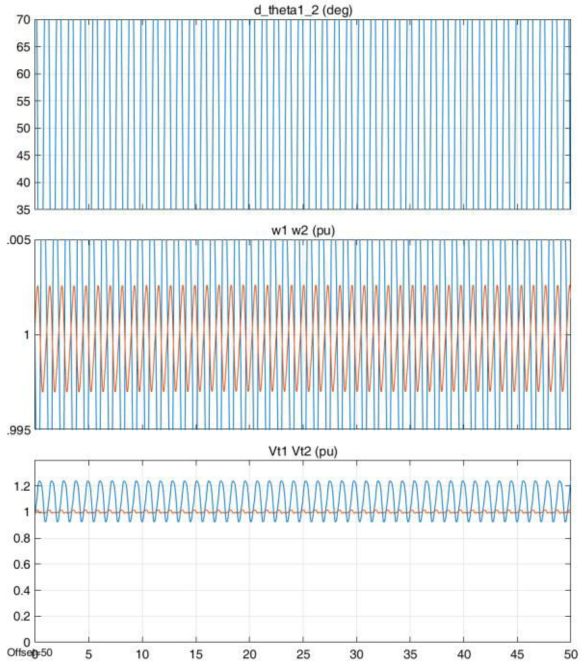

Fig. 8: Line Power and Bus Voltage Transient Analysis for 30 Bus IEEE Network system.

V. CONCLUSION

ATC values were improved with incorporated of TCSC and SVC into IEEE 30 bus network system. These FACTS enhanced ATC for engaged bilateral, simultaneous and multilateral transactions. During enhancements, TCSC maintained bus voltage magnitude for bilateral and simultaneous transactions but with slight voltage droop during multilateral trading. In contrast, SVC slightly improved bus voltage profile for all the transactions. The introduction of SVC contributed to total system real power loss minimization for all the transactions while that of TCSC had no significant minimization for bilateral and simultaneous dealings but rather increased total real power loss for multilateral transaction. Therefore, for transfer capability enhancement with voltage improvement and real power loss minimization in focus, SVC is more relevant.

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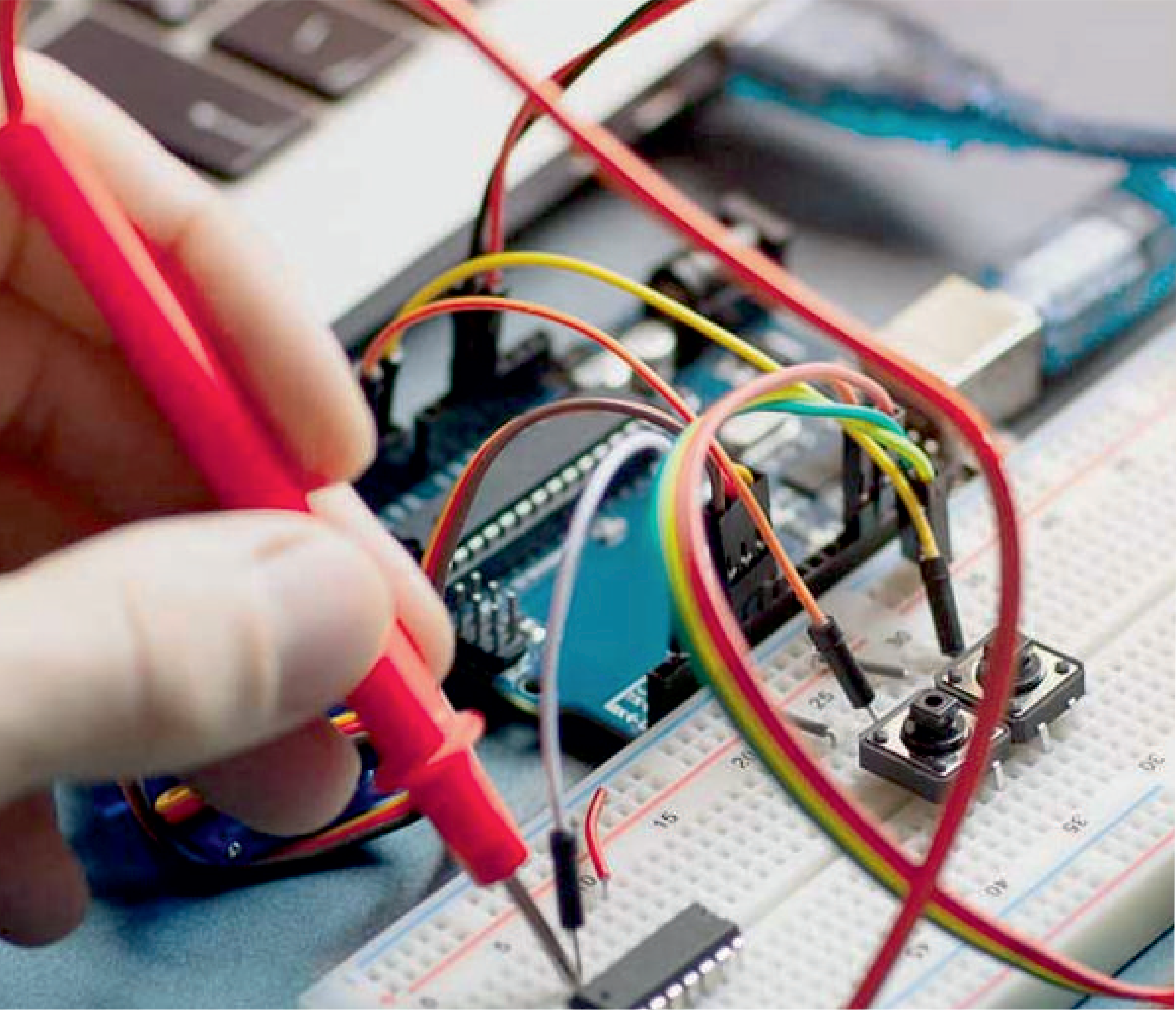

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