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Power Loss Minimization in Distribution Systems with Network Reconfiguration Using Genetic Algorithm

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ABSTRACT: Deregulation of the power grid and a scarcity of transmission capacity have sparked a surge in interest in distributed generation (DG) sources. The proper reconfiguration in electricity systems is critical for maximizing their potential benefits. The Genetic Algorithm is evolutionary algorithm based on fundamental principle of survival of the fittest. In this paper, theory of genetic algorithm along with its use in solving optimization problem is discussed. Adaptive genetic algorithm is proposed here for solving network reconfiguration problem for optimizing multiple objectives. This proposed algorithm is tested with IEEE-33 distribution test feeders of different complexities. Obtained results are presented for analysis.

KEYWORDS: Distributed generation (DG), IEEE 33 bus, Reconfiguration, Genetic algorithm, Voltage profile

I. INTRODUCTION

Optimal reconfiguration of electrical distribution network is a complex combinatorial optimization problem with the purpose of identifying a radial network that optimizes given objectives. A reasonable solution to a multi-objective problem is to investigate a set of solutions, each of which satisfies the objectives at an acceptable level without being dominated by any other solution. Evolutionary algorithms are well suited for this class of problems. The advantage of evolutionary algorithms compared to other optimization methods is their "black box" character that makes only few assumptions about the underlying objective functions. Furthermore, the definition of objective functions usually requires lesser insight to the structure of the problem space than the manual construction of an admissible heuristic. Evolutionary Algorithms therefore perform consistently well in many different problem categories.

Genetic algorithm is a subclass of evolutionary algorithms where elements of search space are binary strings or arrays of other elementary type. It is multidimensional and stochastic search strategy performing on the basis of the idea of natural selection of chromosomes during the process of evolution. The main concentration of this algorithm is setting a reasonable tradeoff between exploitation and exploration. If it focuses more on exploitation, the probability of getting stuck in local optimum increases and higher exploration leads to slowing down the convergence process. Therefore, there should be meaningful interaction between the genetic algorithm parameters. Normally genetic algorithm parameters are fixed for the process.

In order to set a better balance between exploitation and exploration and avoid poor parameterization, it is proposed to use a technique to determine genetic algorithm parameters dynamically as the algorithm proceeds and adjust them so that genetic algorithm does not fall in local optimums and its convergence speed does not slow down. In this chapter solution is proposed for optimization of electric distribution network using genetic algorithm to determine fitness of chromosome and dynamically determine crossover and mutation rates.

II. LITERATURE SURVEY

"Optimal Placement of Distributed Generation on Radial Distribution System for Loss Minimisation & Improvement of Voltage Profile", MohdIlyas, Syed MohmmadTanweer, Asadur Rahman,International Journal of Modern Engineering Research (IJMER) Vol. 3, Issue. 4, Jul. - Aug. 2013 pp-2296-2312,This paper presents, the Identification of Optimal DG Locations by Single DG Placement algorithm evaluates the voltage profile using the Newton-Raphson method and then it calculates the total I^2R loss of the system. After that by placing the DG at each

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bus, it evaluates the corresponding total I²R losses and hence obtained the optimal placement of DG for loss reduction and best suited voltage profile evaluation.

"Optimal Distributed Generation Placement in Power Distribution Networks: Models, Methods, and Future Research",Pavlos S. Georgilakis, Senior Member, IEEE, and Nikos D. Hatziargyriou, Fellow, IEEE,IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 28, NO. 3, AUGUST 2013. In this paper,the optimal DG placement (ODGP) is to provide the best locations and sizes of DGs to optimize electrical distribution network operation and planning taking into account DG capacity constraints. genetic algorithmand various practical heuristic algorithms models and methods have been suggested for the solution of the Optimal Distributed Generation Placement (ODGP)an overview of the state of the art models and methods applied to the ODGP problem.

"Analytical Approaches for Optimal Placement ofDistributed Generation Sources in Power Systems",Caisheng Wang, Student Member, IEEE, and M. Hashem Nehrir, Senior Member, IEEE, IEEE Transactions On Power Systems, Vol. 19, No. 4, November 2004. This paper acquaintsPower system deregulation and the shortage of transmission capacities have led to increased interest in distributed generation (DG) sources. Proper location of DGs in power systemsis important for obtaining their maximum potential benefits. Analytical methods to determine the optimal location to place a DG in radial as well as networked systems to minimize the power loss of the system.

"Optimal placement of distributed generation in distribution networks, Satish Kansal1", B.B.R. Sai, BarjeevTyagi, Vishal Kumar, International Journal of Engineering, Science And Technology. 2011.In this paper the application of Particle Swarm Optimization (PSO) technique to find the optimal size and optimum location for the placement of DG in the radial distribution networks for active power compensation by reduction in real power losses and enhancement in voltage profile, the optimal size of DG is calculated at each bus using the exact loss formula and the optimal location of DG is found by using the loss sensitivity factor. The analytical expression is based on exact loss formula. It is tested on standard 33-bus test system and the obtained results are compared with the exhaustive load flows.

III. BASIC STRUCTURE OF GA

GA starts with an initial population which may be generated at random or seeded by other heuristics and then parent is selected from this population for mating. Crossover and mutation operators are applied on the parents to generate new off springs. Finally, these off-springs replace the existing individuals in the population and the process is repeated. In this way genetic algorithms actually try to mimic the human evolution to some extent. This process is shown in figure.
A generalized pseudo code for genetic algorithm is given below:

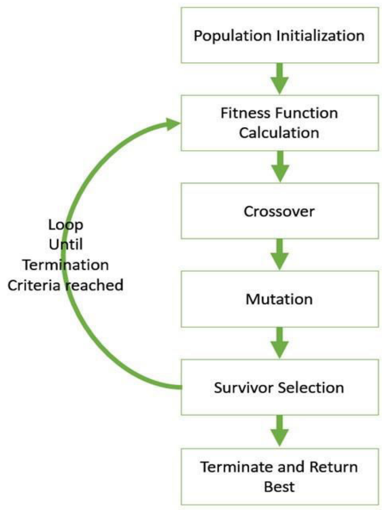

Figure GA Process

III. ELECTRICAL DISTRIBUTION NETWORK RECONFIGURATION USING GENETIC ALGORITHM

Paradigm based on genetic principles is proposed here to reconfigure electric distribution network taking multiple objectives in to consideration for optimization. The multiple objectives considered for optimization are: Minimization of the system power loss, Minimization of deviation of node voltages, Minimization of branch current constraint violation, Load balancing among various feeders.

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Block diagram for multi objective network reconfiguration using adaptive genetic algorithm is shown in figure .

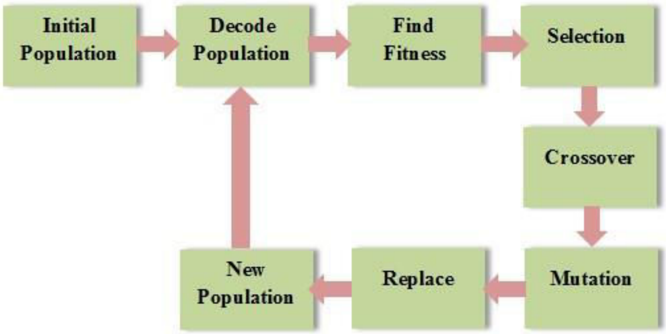

Figure Genetic Algorithm for network reconfiguration

Chromosome Encoding

The chromosome encoding strategy adapted in present study is based on the number of loops in distribution network. Number of loops in distribution network is equal to number tie switches. Each gene in the chromosome presents the branch number of corresponding loop that should be open. If more than one branch in a loop is open then the relevant chromosome stands for the configuration that is not radial.

Each chromosome gives the numbers of the switches that are to be kept open. It means chromosome represents possible network configuration. Goal of proposed system is to find the best network configuration for specific load conditions that optimizes above stated multiple objectives. In other words the system chooses the most suitable chromosome by evolving population.

Initial Population

Every genetic algorithm starts with the initial population, which is the set of chromosomes that represents possible solutions of the problem. In present study using loop based encoding technique 100 chromosomes are randomly generated as initial population. Each chromosome in population represents possible radial network.

Fitness Function

In multi objective optimization there are more than one objective are to be satisfied simultaneously, so compromise has to be made to get the best solution. It is efficient to use fuzzy logic to define fitness function in such multi objective environment. In fuzzy environment membership function indicates the degree of satisfaction of the objective.

$D_i = \min \{\mu L_i , \mu V_i , \mu_i , \mu B_i \}$, for i= 1,2,…N (3.1)

Load flow calculation is performed for each chromosome in the population which specifies one of the possible network configurations. The fitness is evaluated for each chromosome by using equation 3.1.

Crossover and Mutation

Using Roulette wheel selection method most competent parent chromosomes are selected for crossover. The two point crossover technique is applied on selected individuals.

The process begins with selection of random number between 0 and 1. If it is higher than crossover probability pc, then two individuals survive and become part of next step. Otherwise two numbers between 1 and the length of chromosome are randomly selected, which are the points of crossover. Genes between two points are exchanged among two individuals to generate two children. Now generated children take part in next step and not the parents. The crossover probability taken for this study is 0.6.

Diversity of population is guaranteed by mutation of chromosomes. For this purpose a random number between 0 and 1 is generated. If it is less than mutation probability pm then mutation are performed otherwise both individuals are sent for next step. To carry out mutation, a random number is generated between 1 and length of chromosome. Then that gene is replaced by random switch number belonging to that loop. Mutation rate taken here is 0.04

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IV. RATIONALE FOR PROPOSED METHOD

Proposed algorithm is explained by using standard 33 bus test system (E33G) which is as shown in figure. It is assumed that every branch has a sectionalizing switch. This system has one feeder, five tie branches, and five tie switches. Sectionalizing switches are normally close and tie switches are normally open.

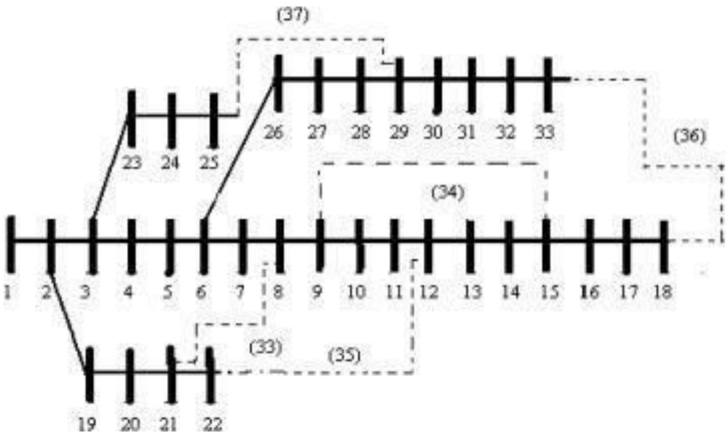

Figure Standard IEEE 33 Bus

The Chromosome encoding strategy adopted here is based on number of tie branches. As for the test case there are 5 tie branches, chromosome consists of five genes. Each gene presents the branch number which is to be opened. It can take any value between 2 to 33. If more than one branch in a loop is open then relevant chromosome represents the configuration that is not radial. This coding method is more fast and efficient than branch and node based coding strategy where chromosome has 37 and 33genes.

In present study chromosome is represented as CH = [33, 34, 35, 36, 37] which means all branches except 33, 34,35,36,37 are open. Here initial population size is taken to be 100, which represents 100 possible network configurations and evolution will be carried up to 100 generations, which will be stopping criteria.

The load flow is run which is elaborated for all chromosomes in initial population. The fuzzy based fitness function as given in equation 3.1 is used to decide best overall satisfaction of all objectives. The fittest chromosome will have higher probability to be selected for next generation. To compute fitness probability first fitness of each chromosome is computed. The probability of each chromosome is formulated as

P[i] =Fitness[i] /Total for i^{th} chromosome.

After computing cumulative probability, chromosome selection is performed by using roulette wheel selection. Now, two point crossovers are performed taking crossover rate of 0.6. Pseudo code for crossover process is as follows.

```
Start k=0;
While (k<population) do
R[k]=random(1-0);
If
(R[k] < crossover rate)  then
                              Select Chromosome[k] as parent;
                              End
k=k+1;
                    End;
End;
```

IV. PERFORMANCE ANALYSIS OF GA BASED NETWORK RECONFIGURATION

Testing of proposed algorithm is done with standard 33 Bus (E33G), 69 Bus (E69G) and 119 Bus (E119G) test systems. Results obtained for System power loss, node voltage deviation, Branch current and load balancing are presented in this section.

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Results for E33G

Results of the reconfigured electrical distribution network for E33G are shown in table 3.1, to 3.4 for all four load combinations.

Table E33G1

Bus (Node) No.	Branch No	Node Voltage (kV)	Node Voltage (p.u)	Branch Current (A)	Branch Power Loss (kW)
2	1	12.6242	0.99717	345.089	11.044818
3	2	12.4999	0.98736	224.59	25.365926
4	3	12.4446	0.98299	134.678	7.0653241
5	4	12.3485	0.9754	126.216	10.743034
6	5	12.2138	0.96476	124.52	12.711251
7	6	12.2057	0.96411	12.5913	0.0628278
8	33	12.1822	0.96226	53.4567	6.6763341
9	8	12.1336	0.95842	38.3	1.6189109
10	9	12.1272	0.95791	4.99023	0.0283949
11	11	12.2171	0.96502	4.26806	0.0073371
12	35	12.2188	0.96515	26.9139	1.5221072
13	12	12.1862	0.96258	17.4443	0.4511986
14	13	12.1762	0.96179	11.1967	0.0759832
15	34	12.0572	0.95239	26.9931	1.7306757
16	15	12.0351	0.95064	23.9991	0.4498129
17	16	11.9981	0.94772	17.1707	0.4844211
18	17	11.9851	0.94669	13.9677	0.1472729
19	18	12.5997	0.99524	107.792	2.1168448
20	19	12.391	0.97875	103.116	17.408651
21	20	12.3333	0.9742	91.4773	4.1031032
22	21	12.2949	0.97116	32.6786	0.8864434
23	22	12.4551	0.98381	82.0354	3.1045803
24	23	12.3712	0.97719	73.3396	5.0789288
25	24	12.3292	0.97387	36.7939	1.2755499
26	25	12.1918	0.96302	96.7436	2.1410406
27	26	12.1626	0.96071	91.6464	2.7343137
28	27	12.0307	0.95029	93.4224	9.4181057
29	28	11.9355	0.94277	89.1979	6.5936276
30	29	11.8949	0.93956	71.363	3.2515035
31	30	11.8515	0.93613	31.6953	1.0995715
32	31	11.8429	0.93546	17.9561	0.1197688
33	36	11.981	0.94636	5.90196	0.018113

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	7	These are Tie branches which are open. So no current will flow through it and hence no power loss.
	10	
	14	
	32	
	37	
Total Power Loss		139.53578

Table E33G2

Bus (Node) No.	Branch No	Node Voltage (kV)	Node Voltage (p.u)	Branch Current (A)	Branch Power Loss (kW)
2	1	12.636	0.99811	230.952	4.9389585
3	2	12.553	0.99155	149.994	11.263365
4	3	12.5169	0.9887	87.9807	2.9832463
5	4	12.4548	0.98379	81.5749	4.4509478
6	5	12.3681	0.97695	80.1049	5.255547
7	6	12.3486	0.97541	30.1795	0.1718794
8	33	12.4459	0.98309	18.3001	0.7718529
9	8	12.4373	0.98241	6.79886	0.052204
10	9	12.4329	0.98206	3.40724	0.0132377
11	11	12.352	0.97567	2.53287	0.002584
12	35	12.353	0.97575	35.563	2.8079871
13	12	12.2953	0.97119	30.8896	1.4710353
14	13	12.2729	0.96942	25.0793	0.4344862
15	14	12.2578	0.96823	19.0143	0.2424587
16	15	12.2426	0.96703	16.5144	0.2129999
17	16	12.2172	0.96502	11.8024	0.2289308
18	17	12.2083	0.96432	9.59866	0.0695501
19	18	12.6239	0.99715	53.4118	0.5171924
20	19	12.5245	0.9893	49.0938	3.9279128
21	20	12.4976	0.98718	42.6701	0.8848773
22	21	12.4536	0.9837	37.4794	1.2450263
23	22	12.5223	0.98912	56.2973	1.4624877
24	23	12.464	0.98452	50.9527	2.4517537
25	24	12.4348	0.98221	25.5362	0.6144437
26	25	12.354	0.97583	62.0577	0.8642906
27	26	12.3354	0.97436	58.4719	1.0908449
28	27	12.2526	0.96782	58.6316	3.6852008
29	28	12.1934	0.96314	55.5256	2.5345336
30	29	12.1677	0.96111	45.1204	1.2608482
31	30	12.138	0.95877	21.6613	0.5136522
32	31	12.1321	0.9583	12.2693	0.0559217
33	36	12.2054	0.96409	4.0554	0.008552

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	7	These are Tie branches which are open. So no current will flow through it and hence no power loss.
	10	
	32	
	34	
	37	
	Total Power Loss	56.488809

V. CONCLUSION

The Genetic Algorithm is evolutionary algorithm based on fundamental principle of survival of the fittest. In this paper, theory of genetic algorithm along with its use in solving optimization problem is discussed. Adaptive genetic algorithm is proposed here for solving network reconfiguration problem for optimizing multiple objectives. This proposed algorithm is tested with IEEE-33 distribution test feeders of different complexities. Obtained results are presented for analysis. Total power loss is reduced when it is tested for different complexities.

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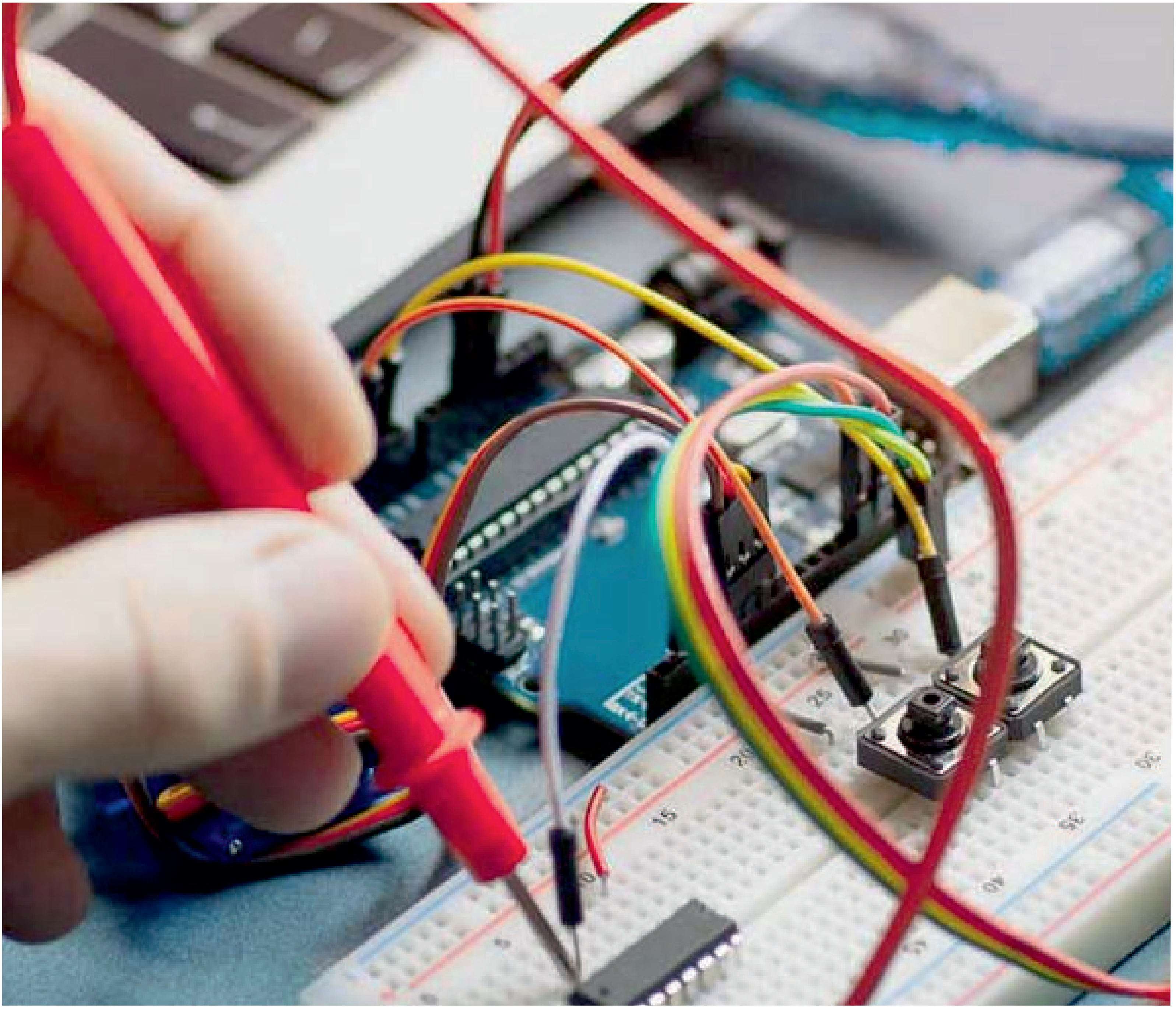

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