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Result Analysis for Particle Swarm Optimization and Genetic Algorithm for Load Flow Study

Poulami Ghosh*, Anand Gopal Mukherjee,Siddharth Kumar Singh, Hari Prasad Dubey

Department of Electrical Engineering, St. Thomas' College of Engineering & Technology, Kolkata, India

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Abstract - This paper presents a comparative study between Particle Swarm optimization and Genetic Algorithm based methodology for solving load flow in electrical power systems. Load flow study provides the system status in steady-state and is required by several functions performed in power system control rooms.

Keywords—Particle swarm optimization, Genetic Algorithm, Load flow, Electrical Power System, Score

Introduction

Load flow study is required by functions performed in power system control points [1]. Under steady state point of electrical power system network the load flow problem study is considered [2,3]. The load flow problem is modeled by a set of non-linear equations which is commonly solved by the application of numerical methods[4,5].In the area of artificial intelligence, computational intelligence based algorithm have been applied successfully to electrical power system related problems, Particle Swarm Optimization (PSO)and Genetic Algorithm(GA) are pointed out among these techniques.PSO algorithms are applied for load flow study and they are based on the behavior of birds' flocks searching for food[6].PSO applications have provided good convergence properties, ease of implementation and low computational time[7].Genetic Algorithm offers a new and power flow approach to these load flow study by increasing availability of high performance computers at relatively low costs. Genetic Algorithms are parallel and global search techniques that use natural genetic operator [8].

Load flow study in Electrical Power Systems

Load flow or power flow study is done under steady state condition of power system. The study is done to know the system bus voltages in order to determine later generation necessary to supply the adjustment in the generation buses and the power flow in system brunches. Therefore, it is possible to obtain the amount of power demand plus the power losses in the system branches. Besides, the voltage levels must comply with the predetermined boundaries and overloaded operations added to those in the stability limit must be prevented[6].Each power system bus is associated with four variables, where two of them can be controlled and other two are results of the system conditions.

These variables are:
Real power (P), Reactive power (Q), Voltage magnitude (|V|) and Voltage phase angle (δ).
The power system buses are depending on variables.
Type1 Bus or PQ Bus: Pi and Qi are specified, |Vi| and δi are to be calculated;
Type 2 Bus or PV Bus: Pi and |Vi| are specified, Qi and δi are to be calculated;
Type 3 Bus or V δ Bus or Slack Bus:|Vi| andδi are specified, Pi and Qi are to be calculated;
The equation required for power system load flow computation is given by
Pi-jQi-yi1V1Vi*-yi2V2Vi*-…yinVnVi*=0 (1)

Where i=1…….n, busnumber; Pi= Real power generated or injected in the bus I; Qi= Reactive power generated or injected in the bus i; |Vi| = Voltage magnitude of the bus i; δi = Voltage phase angle of bus y;Vi=|Vi|ejδi, i.e. the voltage in the polar form; Vi* =|Vi|e-jδi ,i.e. the conjugate voltage; yik = Element of the nodal admittance matrix Ybus. The nodal admittance matrix can be computed as follows; if i=k,yik is sum of the admittances that come out from the bus i; yi is the admittance between the buses I and k multiplied by -1.
Equation (1) represents a complex and non-linear equation system, and its solution is usually obtained through approximation adopting numerical methods.

Particle Swarm Optimization approach for load flow study

The flowchart of Figure 1 presents the PSO based load flow study. In this method the mismatches for ΔP's and ΔQ's are important to get convergence point. Here firstly generation of swarm is most important.

Firstly, the Voltage Constraints, Swarm Size, No. of Iterations, Cognitive factors and Max Inertia and Min Inertia are defined. This comprises the Initialization

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Portion of the Program. After that initial generation of swarm is important while the voltages for slack bus and P-V bus should be same as given in bus data input. The angle for slack bus is here 0.

Now calculation for P, Q for all the buses is necessary and mismatch in terms of P and Q is calculated for P-Q buses and only P for P-V buses. After calculation of mismatches of P and Q, the apparent power mismatch dSis obtained. Here the aim throughout the process is to minimize the score for each swarm. The term Score is the mean of the apparent power mismatch. The particle with minimum score istaken as pbest and velocity is taken 0 initially and positions are updated for each particle in each swarm. Then, calculation for the velocity taking in consideration cognitive factors and inertia weights is important and updatation of positions is required step. For this case voltage in limits is defined earlier. Again the voltages of slack bus and P-V bus and angle of Slack bus are changed to predefined values and calculation for P, Q is mandatory. Again, dS is found and pbest and gbest are calculated and process repeats for calculation of velocity, new P & Q until mismatch reduces to 10^{-6}.Atlast Voltages and angle of best particle is taken and load flow and losses are formulated.

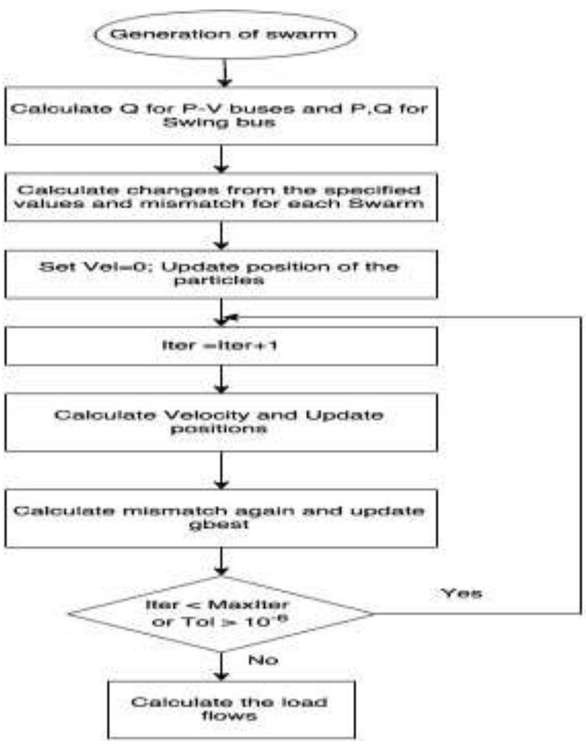

Figure 1: Flowchart of the PSO based load flow

Genetic Algorithm approach for load flow study

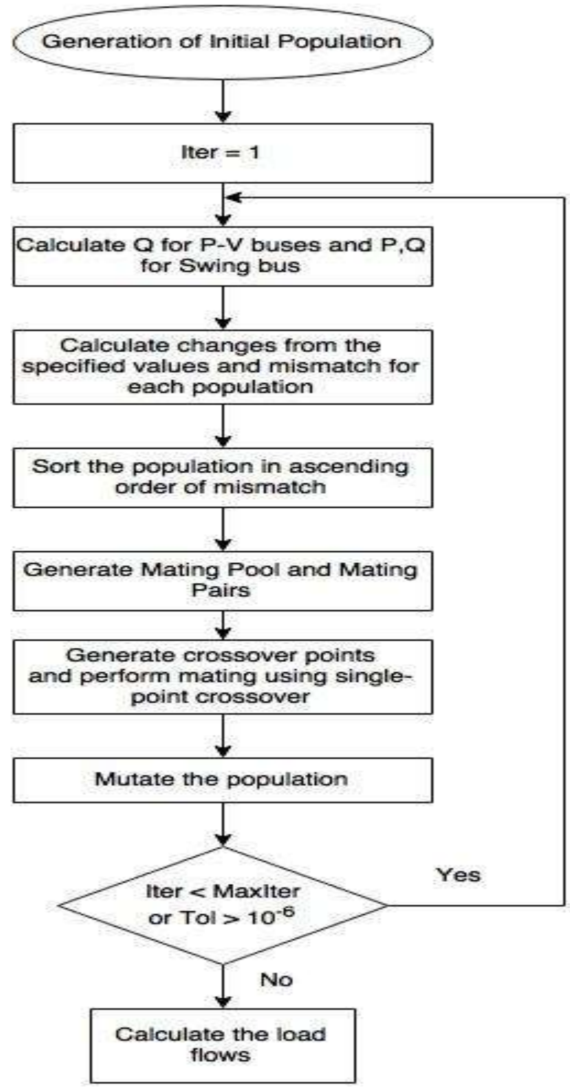

Figure2: Flowchart of the GA based load Flow

The flowchart of Figure 2 represents the GA based load flow study.

Firstly, the Voltage Constraints, Population Size, No. of Iterations, No. of bits in a chromosome and Mutation rate are defined. This comprises the Initialization Portion of the Program. Then, generation of the initial population is prior thing. Here the voltages for slack bus and P-V bus should be same as given in bus data. Also, the angle for slack bus initialized with 0. The population generated in decimal in encoded to binary for later use in the program. Then, calculation of P,Q for all the buses and mismatch in terms of P and Q is done for P-Q buses and P only for P-V buses. After calculation of mismatches of P and Q, we find the apparent power mismatch dS. The aim throughout the process is to minimize the score for each population. Here, score is the mean of the apparent power mismatch .Now sorting on the population in ascending order of score is

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done. It allows the best population to come at first and the worst particle to go at the end.Then, the mating pool is framed, where the worst particle is replaced by the best particle for better characteristic of the population. Here generation of the mating pairs and crossover points important and mating using single point crossover is performed. Populations are then mutated according to the mutation rate defined. The first particle of each population is kept unaltered as the best particle is not altered (Elitist Strategy). Again decoding is necessary for the population from binary to decimal, the voltages of slack bus and P-V bus and angle of Slack bus is changed to predefined values andP,Q is calculated. Population is also encoded to binary again for next iteration and dS is foundand the above processes are followed until max. Iteration is reached or the mismatch reduces to 10-6. At the end Voltages and angle of best particle is taken and load flow and losses are formulated.

Numerical Results

The two methods have been run for IEEE 14 systems. Each method is executed for five times and table5 shows the comparative results for the two methods.

14-Bus system case study

The first test system is a 14-bus system proposed as shown in Figure 3. This test system comprises of 14 buses, 2 generator buses.

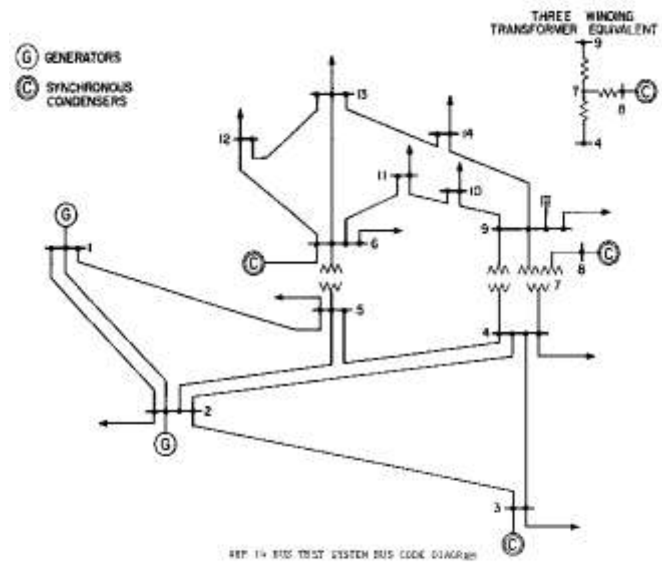

Figure3: IEEE 14 Bus Systems

Table1 represents the results for voltage, Angle, Injection of power, Generation of power and load for particular buses for PSO algorithm.

Table2 represents the line losses between two buses using PSO algorithm.

Bus	V	Angle	Injection		Generation		Load	
No	pu	Degree	MW	MVar	MW	MVar	MW	Mvar
1	1.0600	0.0000	95.407	-1.120	95.407	-1.120	0.000	0.000
2	1.0450	-2.0395	18.334	-3.843	40.034	8.857	21.700	12.700
3	1.0100	-7.9387	-96.415	5.042	-2.215	24.042	94.200	19.000
4	1.0235	-3.6668	-47.800	-47.816	0.000	-51.716	47.800	-3.900
5	1.0500	-3.1232	-7.600	82.815	0.000	84.415	7.600	1.600
6	1.0700	-1.6588	7.470	48.765	18.670	56.265	11.200	7.500
7	1.0238	-1.4327	0.097	-45.892	0.097	-45.892	0.000	0.000
8	1.0900	-0.9280	5.580	40.998	5.580	40.998	0.000	0.000
9	1.0204	-0.5701	-0.262	-30.938	29.238	-14.338	29.500	16.600
10	1.0418	-0.2966	6.594	29.196	15.594	34.996	9.000	5.800
11	1.0330	0.8087	19.674	-32.356	23.174	-30.556	3.500	1.800
12	1.0483	-1.6336	-0.620	4.472	5.480	6.072	6.100	1.600
13	1.0203	-0.5286	-13.403	-49.630	0.097	-43.830	13.500	5.800
14	1.0371	1.0138	20.016	2.116	34.916	7.116	14.900	5.000
Total			7.073	1.809	266.073	75.309	259.000	73.500

Table1: Load Flow Analysis (PSO Method)

From	To	P	Q	From	To	P	Q	Line Losses

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Bus	Bus	MW	MVar	Bus	Bus	MW	MVar	MW	MVar
1	2	68.468	5.632	2	1	-67.654	-3.147	0.814	2.485
1	5	26.939	-1.022	5	1	-26.590	2.465	0.349	1.443
2	3	56.659	7.850	3	2	-55.251	-1.919	1.408	5.931
2	4	19.403	6.605	4	2	-19.179	-5.927	0.224	0.678
2	5	9.926	-6.131	5	2	-9.856	6.347	0.071	0.217
3	4	-41.164	9.848	4	3	42.341	-6.844	1.177	3.004
4	5	-40.522	-51.446	5	4	41.069	53.170	0.547	1.724
4	7	-19.972	0.236	7	4	19.972	0.543	0.000	0.779
4	9	-10.468	0.876	9	4	10.468	-0.309	0.000	0.568
5	6	-12.223	-8.794	6	5	12.223	9.277	-0.000	0.483
6	11	-11.538	25.939	11	6	12.206	-24.539	0.669	1.400
6	12	3.390	7.456	12	6	-3.318	-7.306	0.072	0.150
6	13	3.394	39.239	13	6	-2.498	-37.474	0.896	1.765
7	8	-5.580	-38.460	8	7	5.580	40.998	0.000	2.538
7	9	-14.295	3.300	9	7	14.295	-3.074	0.000	0.226
9	10	-13.784	-20.667	10	9	13.972	21.168	0.189	0.501
9	14	-11.241	-0.899	14	9	11.396	1.229	0.155	0.330
10	11	-7.378	8.028	11	10	7.468	-7.817	0.090	0.210
12	13	2.698	11.778	13	12	-2.404	-11.513	0.294	0.266
13	14	-8.500	-0.643	14	13	8.620	0.886	0.119	0.243
Total Loss								7.073	24.941

Table2: Line Flow and Losses (PSO Method)

Table3 represents the results for voltage, Angle, Injection of power, Generation of power and load for particular buses GA algorithm

Table4 represents the line losses between two buses using GA algorithm.

Bus	V	Angle	Injection		Generation		Load	
No	pu	Degree	MW	MVar	MW	MVar	MW	Mvar
1	1.0600	0.0000	42.737	19.070	42.737	19.070	0.000	0.000
2	1.0450	-0.7255	22.499	-9.631	44.199	3.069	21.700	12.700
3	1.0100	-3.9365	-57.034	-16.290	37.166	2.710	94.200	19.000
4	1.0341	-1.7430	-2.356	14.700	45.444	10.800	47.800	-3.900
5	1.0379	-1.3407	-2.573	9.458	5.027	11.058	7.600	1.600
6	1.0700	-1.2129	13.756	2.757	24.956	10.257	11.200	7.500
7	1.0391	-1.7790	2.159	-22.668	2.159	-22.668	0.000	0.000
8	1.0900	-0.9160	9.685	31.543	9.685	31.543	0.000	0.000
9	1.0220	-2.5016	-28.769	-28.056	0.731	-11.456	29.500	16.600
10	1.0261	-2.0387	-0.282	-6.659	8.718	-0.859	9.000	5.800
11	1.0494	-1.2819	6.084	-0.487	9.584	1.313	3.500	1.800
12	1.0596	-1.1264	1.066	-3.840	7.166	-2.240	6.100	1.600
13	1.0553	-1.3621	-2.662	-5.006	10.838	0.794	13.500	5.800
14	1.0339	-2.1722	-2.456	-0.426	12.444	4.574	14.900	5.000
Total			1.853	-15.535	260.853	57.965	259.000	73.500

Table3: Load Flow Analysis (GA Method)

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From Bus	To Bus	P MW	Q MVar	From Bus	To Bus	P MW	Q MVar	Line Losses MW	Line Losses MVar
1	2	29.401	17.392	2	1	-29.200	-16.777	0.201	0.615
1	5	13.335	7.408	5	1	-13.223	-6.946	0.112	0.462
2	3	32.609	11.572	3	2	-32.094	-9.402	0.515	2.170
2	4	11.770	2.689	4	2	-11.692	-2.454	0.078	0.235
2	5	7.321	1.906	5	2	-7.291	-1.814	0.030	0.091
3	4	-24.940	-4.002	4	3	25.359	5.071	0.419	1.070
4	5	-18.949	-3.308	5	4	18.995	3.453	0.046	0.146
4	7	0.330	-2.559	7	4	-0.330	2.572	0.000	0.013
4	9	2.596	2.342	9	4	-2.596	-2.281	-0.000	0.062
5	6	-1.054	-14.183	6	5	1.054	14.624	0.000	0.441
6	11	4.870	8.776	11	6	-4.787	-8.601	0.084	0.175
6	12	1.147	3.781	12	6	-1.131	-3.746	0.017	0.035
6	13	6.685	8.722	13	6	-6.615	-8.584	0.070	0.137
7	8	-9.685	-29.929	8	7	9.685	31.543	0.000	1.614
7	9	12.174	16.304	9	7	-12.174	-15.883	0.000	0.422
9	10	-10.418	-1.045	10	9	10.452	1.134	0.033	0.089
9	14	-3.582	-2.840	14	9	3.607	2.894	0.025	0.054
10	11	-10.734	-7.793	11	10	10.871	8.114	0.137	0.321
12	13	2.196	-0.094	13	12	-2.187	0.103	0.010	0.009
13	14	6.140	3.475	14	13	-6.063	-3.320	0.076	0.156
Total Loss								1.853	8.315

Table4: Line Flow and Losses (GA Method)

Figure 4 represents the graphs for PSO method. Graph is plotted between the avg., min, and max score vs. number of iterations.

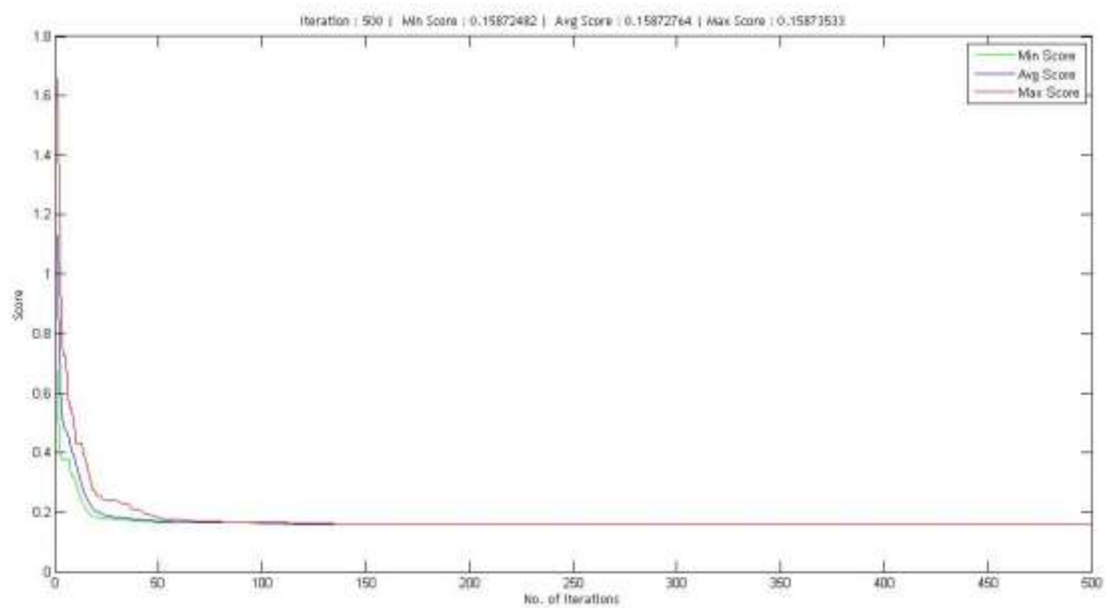

Figure 4: Score (Mismatch) vs. Iteration Plot for IEEE 14 Bus System (PSO Method)

Figure 5 represents the graphs for GA method. Graph is plotted between the avg., min., and max score vs. number of iterations at the end of the program.

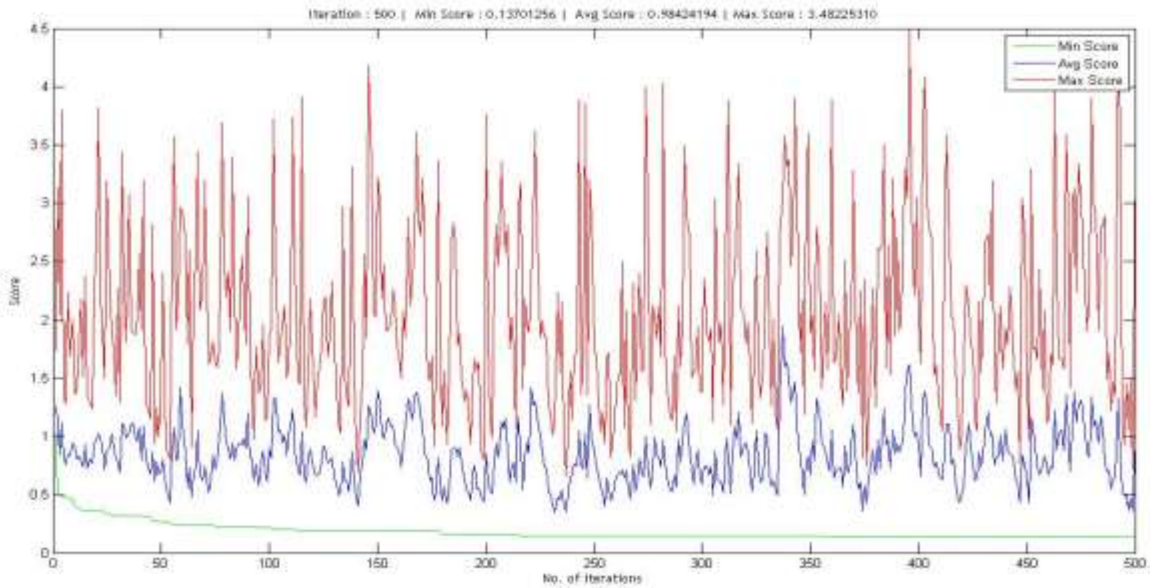

Figure 5: Score (Mismatch) vs. Iteration Plot for IEEE 14 Bus Systems (GA Method)

Table 5 shows the comparative studies for PSO and GA methods for load flow study.

Algorithm	Exec 1	Exec 2	Exec 3	Exec 4	Exec 5	Average Loss(Active Power)
PSO	3.265	7.391	5.216	4.317	2.690	4.5758
GA	4.240	5.184	1.653	2.909	3.283	3.4538

Table5: Comparison for load flow studies for PSO and GA methods

Conclusion

This paper presents the solutions for load flow computations for 14 Bus and the proposed GA method has acceptability as less line loss is obtained than PSO method.

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Authors Profile

Poulami Ghosh is an Assistant Professor at the Department of Electrical Engineering, St. Thomas’ College of Engineering and Technology, Kolkata. Her research interest is in the area of Power System.

Anand Gopal Mukherjee is a 4th Year Undergraduate at the Department of Electrical Engineering, St. Thomas' College of Engineering and Technology, Kolkata. He will be completing his degree in July 2016. Hisfield of interest is Power System.

Siddharth Kumar Singh is a 4th Year Undergraduate at the Department of Electrical Engineering, St. Thomas' College of Engineering and Technology, Kolkata. He will be completing his degree in July 2016. Hisfield of interest is Power System.

Hari Prasad Dubey is a 4th Year Undergraduate at the Department of Electrical Engineering, St. Thomas' College of Engineering and Technology, Kolkata. He will be completing his degree in July 2016. Hisfield of interest is Power System.

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