Design and application of Genetic Algorithm for Fuel Cost Minimization to ensure secure operation of Power System

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Abstract— *Presented work focuses on optimal power flow analysis. The major objective for this system is to minimize fuel cost without violating system security constraints such as power output of generator; bus voltages, shunt capacitors/reactors and transformers tap setting. To achieve this, initially, IEEE-6 bus system and IEEE-30 bus system are tested for is Genatical Algorithm also. The work is carried out to make use of particle swarm optimization method for solving the optimal power flow (OPF) problem for units of the same systems. The optimal power flow (OPF) is being used to find the optimal setting to operate the system. When operating cost is minimized, the generator schedule is calculated by OPF. Traditionally, the cost function of each generator is represented by a simple quadratic function. However thermal units are sometimes made to run on multiple fuels like coal, natural gas and oil. The performance of the proposed method has been demonstrated under simulated conditions on IEEE- 6 bus system with 3-generator unit and IEEE-30-Bus system with 6-Generation units.*

Index Terms: **GA, OPF**

I. INTRODUCTION

The power industrial companies have been moving into a more competitive environment. OPF has been used as a tool to define the level of the inter utility power exchange. This work provides a new approach to solve the single objective OPF problem considering critical objective function of fuel cost minimization for utility/ industrial companies, while satisfying a set of system operating constraints, including constraints dedicated by the electrical network.

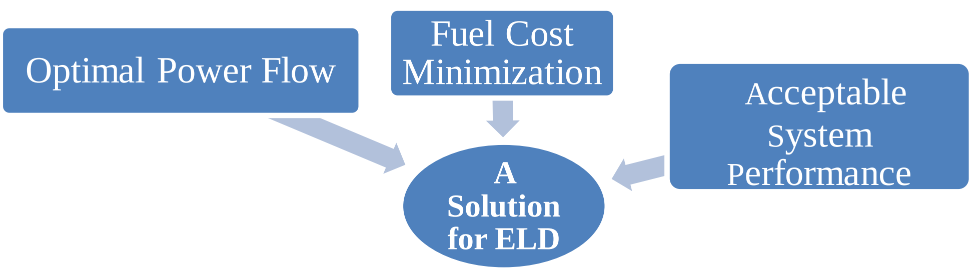


Fig. 1 Objective of presented work

Power system is interconnected so one must have to fulfill load demand. So for doing same all the constraints of the power system must keep in mind while generating any of the power plants. In order to achieve the best method, optimal power flow has been carried out and the main objective function as minimization of fuel cost of generator has been done. The first objective was to examine existing literature on various methods for optimal power flow.

II. INTRODUCTION OF OPF

Optimal power flow (OPF) has been widely used in power system operation and planning. In deregulated environment of power sector, it is of increasing importance, for determination of electricity prices and also for congestion management.OPF is a computationally intensive tool when analyzing many generation plants, transmission lines and demands. Finally the engineering constraints and economic objectives for system operations are combined by formulating and solving the optimal power flow problem.OPF is used in economic analysis of the power system as well. Optimal Power Flow (OPF) is a method to find steady state operation point which minimizes generation cost, loss etc. or maximizes social welfare, loadability etc while maintaining an acceptable system performance in terms of limits on generator's real and reactive powers, line flow limits, output of various compensating devices etc. The OPF problem may also have the formulation of active power generation dispatch (Economic Dispatch Problem, EDP) and reactive power generation dispatch. The main purpose of the EDP is to determine the generation schedule of the electrical energy system that minimizes the total generation and operation cost and does not violate any of the system operating constraints such as line overloading, bus voltage profiles and deviations. On the other hand, the objective of reactive power dispatch is to minimize the active power transmission losses in an electrical system while satisfying all the system operating constraints .The objective function of the OPF can take different forms other than minimizing the generation cost and the losses in the transmission system. The OPF can be used to obtain the settings of the control variables under the steady-state functions of the power system. These control variables may include generator control and transmission system control variables. For generators, the control variable can be generator MW output. For the transmission system, the control variable can be bus voltages of the generator buses, the tap ratio or phase shift angle for transformers, settings of switched shunt or flexible ac transmission system (FACTS) devices.

III. FEATURES & APPLICATIONS OF OPF

1. OPF Minimize cost function, such as operating cost, taking into account realistic equality and inequality constraints.
2. OPF is basically a combination of economic dispatch and losses.
3. The Equality constraints while formulating OPF are Bus real and reactive power balance, generator voltage set points, area MW interchange etc.
4. The Inequality constraints are transmission line transformer interface flow limits, generator MW limits, generator reactive power capability curves, bus voltage magnitudes.
5. The available Controls are generator MW outputs, transformer taps and phase angles etc.

The OPF has many applications which include:-

1. The OPF is routinely used in planning studies to determine the maximum stress that a planned transmission system can withstand.
2. The OPF can be set up to provide a preventive dispatch if the security constraints are incorporated.
3. In an emergency, that is when some component of the system is overloaded or a bus is experiencing a voltage violation, the OPF can provide a corrective dispatch, which tells the system's operators what kind of adjustments can be performed in order to mitigate the overload or voltage violation problems.
4. The calculation of the optimum generation pattern, as well as all control variables, in order to achieve the minimum cost of the generation together with meeting the transmission system limitations.

5. The OPF can also be used periodically to find the optimum settings for generation voltages, transformers taps and switch-able capacitors or static VAR components (called “Voltage-VAR” optimization).

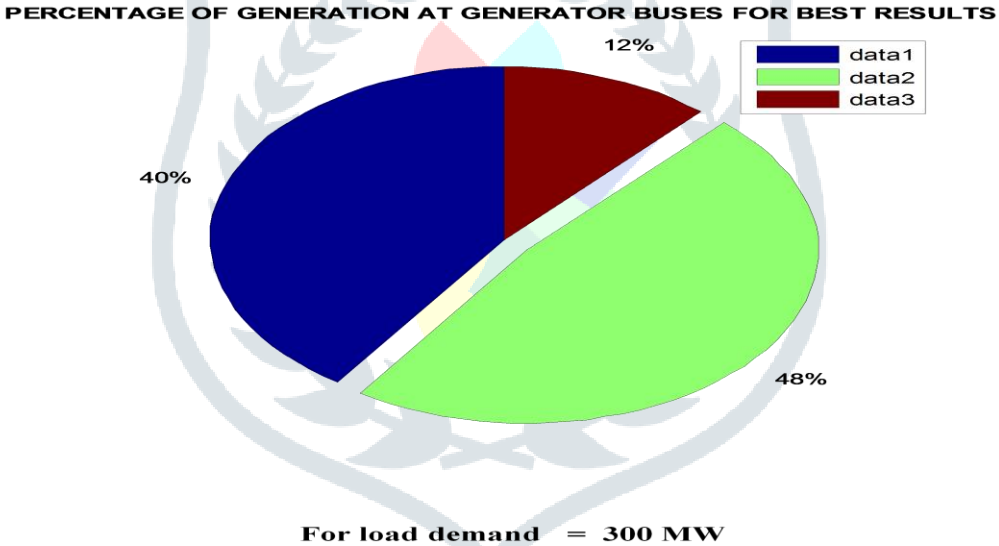
IV. OPTIMAL SCHEDULING OF GENERATOR FOR 3 UNIT SYSTEM

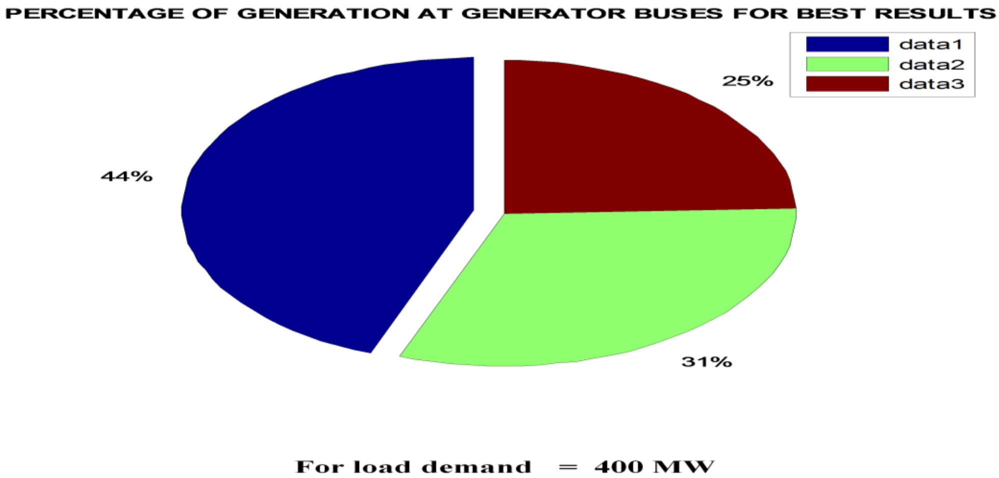
GA method parameters:
Enter the length of string l = 30
Enter the population size L = 60
Enter the probability of crossover pc = 0.9

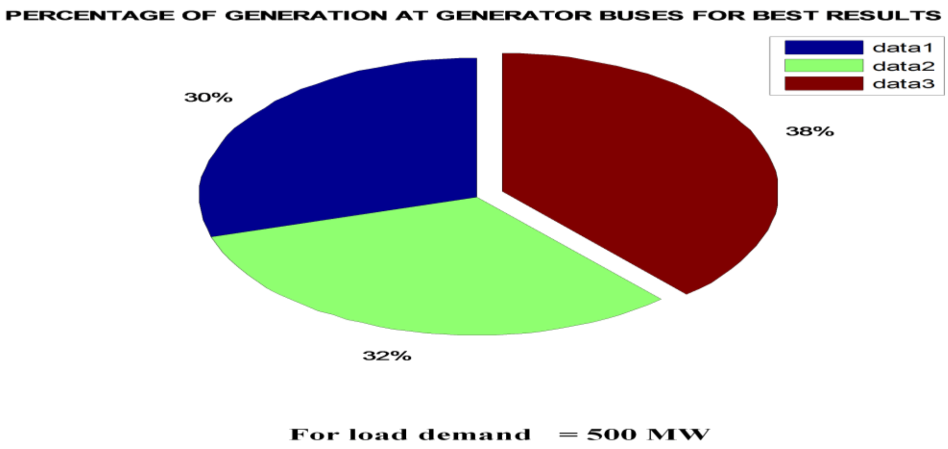
Fitness
1. f_{max}= 0.990234
2. f_{max}= 0.959731
3. f_{max}= 0.975902

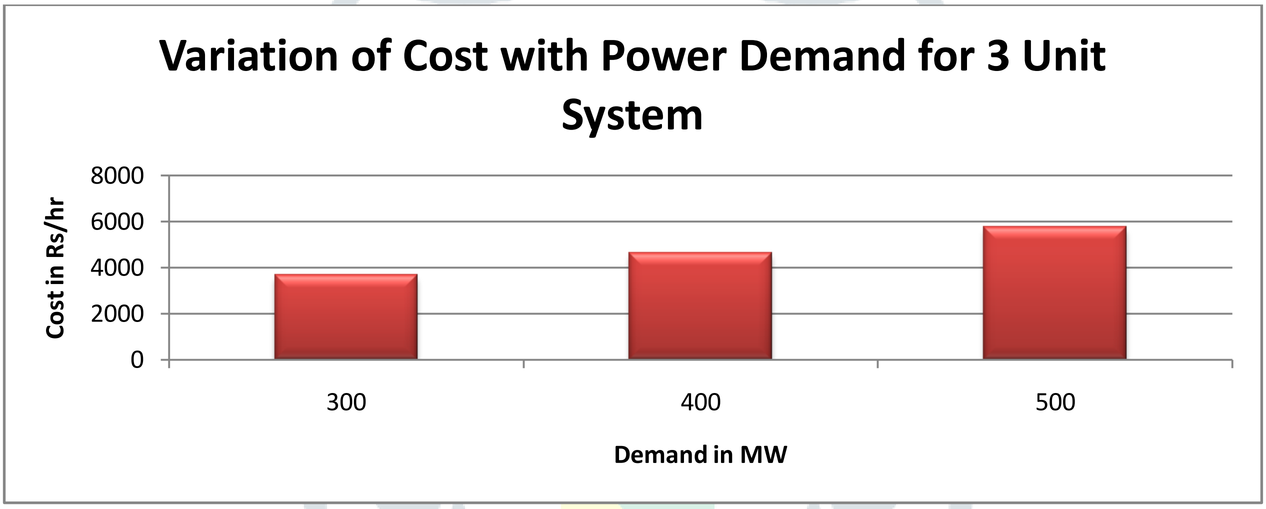
Table-1 generator data

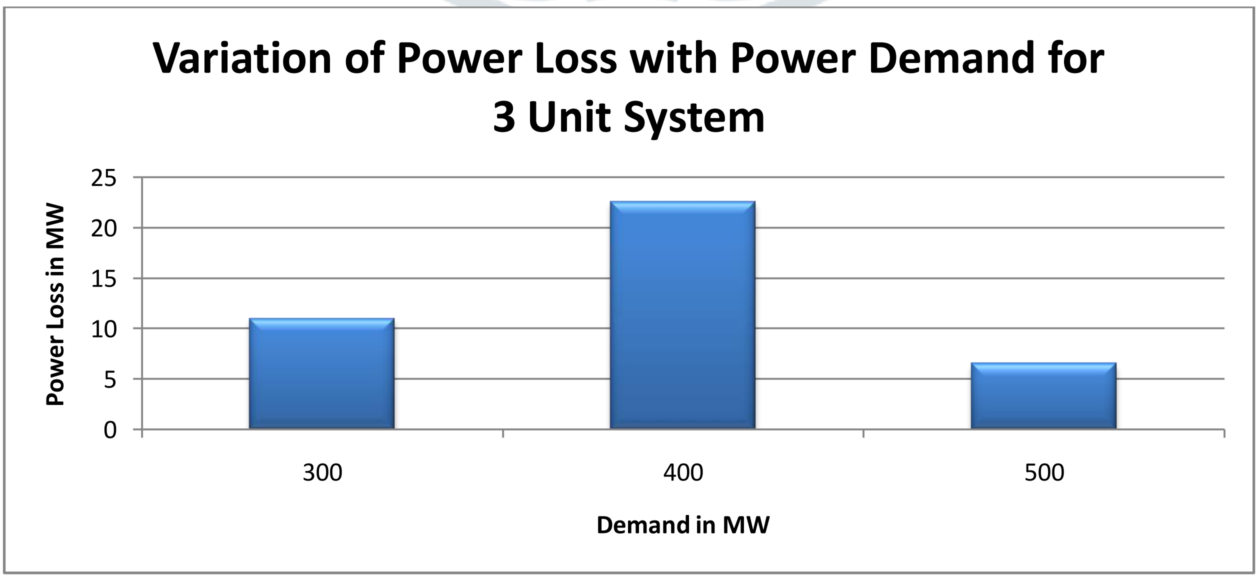
SR NO	POWER DEMND (MW)	PG1 (MW)	PG2 (MW)	PG3 (MW)	TOTAL FUEL COST (RS/HR)	LOSSES (MW)
1	300	124.589330	147.153552	36.283370	**3656.225311**	10.984991
2	400	210.037474	99.579403	96.207622	**4629.309632**	22.607754
3	500	146.670816	158.177066	189.338487	**5735.432042**	6.533146






PERCENTAGE OF GENERATION AT GENERATOR BUSES FOR BEST RESULTS
data1
data2
data3
30%
38%
32%
For load demand = 500 MW


Variation of Cost with Power Demand for 3 Unit System
Cost in Rs/hr
8000
6000
4000
2000
0
300
400
500
Demand in MW


Variation of Power Loss with Power Demand for 3 Unit System
Power Loss in MW
25
20
15
10
5
0
300
400
500
Demand in MW

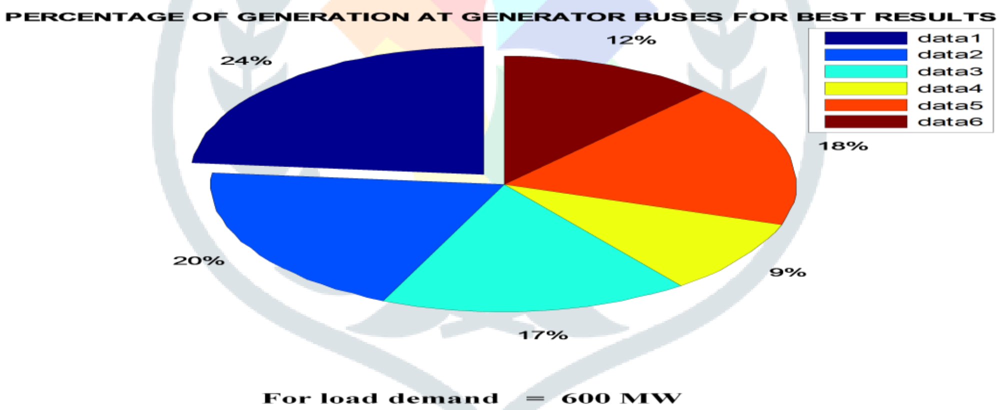
V. OPTIMAL SCHEDULING OF GENERATOR FOR 6 UNIT SYSTEM

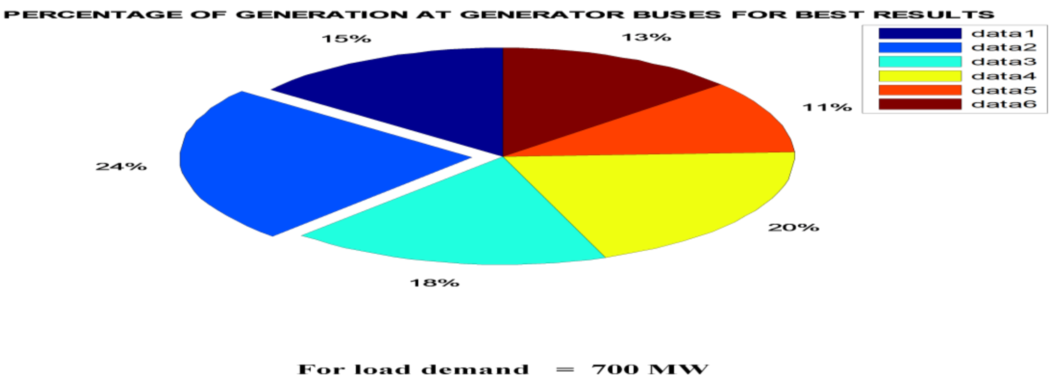
GA method parameters:
Enter the length of string l= 50
Enter the population size L = 120
Enter the probability of crossover pc = 0.9

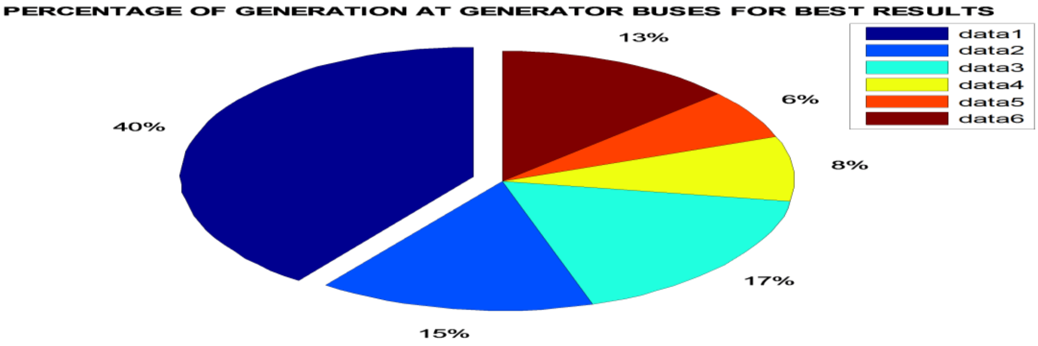
Fitness
1. f_{max} = 0.988412
2. f_{max} =0.982938
3. f_{max} =0.995440

Table-2 generator data

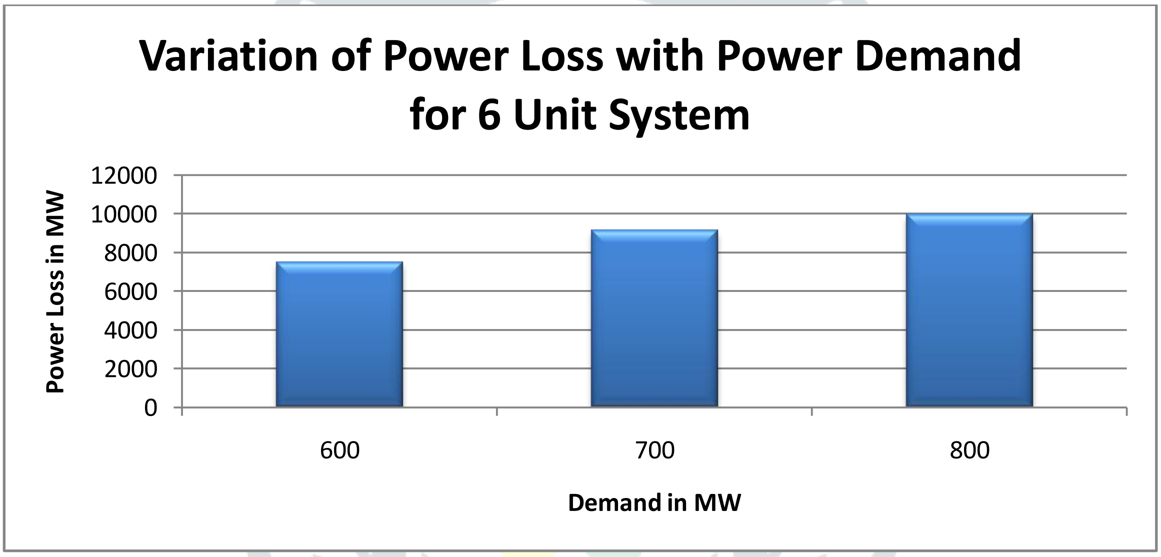
NO	DEMAND (MW)	PG1 (MW)	PG2 (MW)	PG3 (MW)	PG4 (MW)	PG5 (MW)	PG6 (MW)	**FUEL COST (RS/HR)**	LOSSES (MW)
1	600	140.785	118.08	102.03	56.691	108.53	71.6	**7524.3**	4.8428
2	700	104.468	169.10	127.49	142.36	78.612	96.9	**9162.8**	6.9018
3	800	323.589	124.02	142.25	65.399	50.189	107.	**9985.4**	9.6118

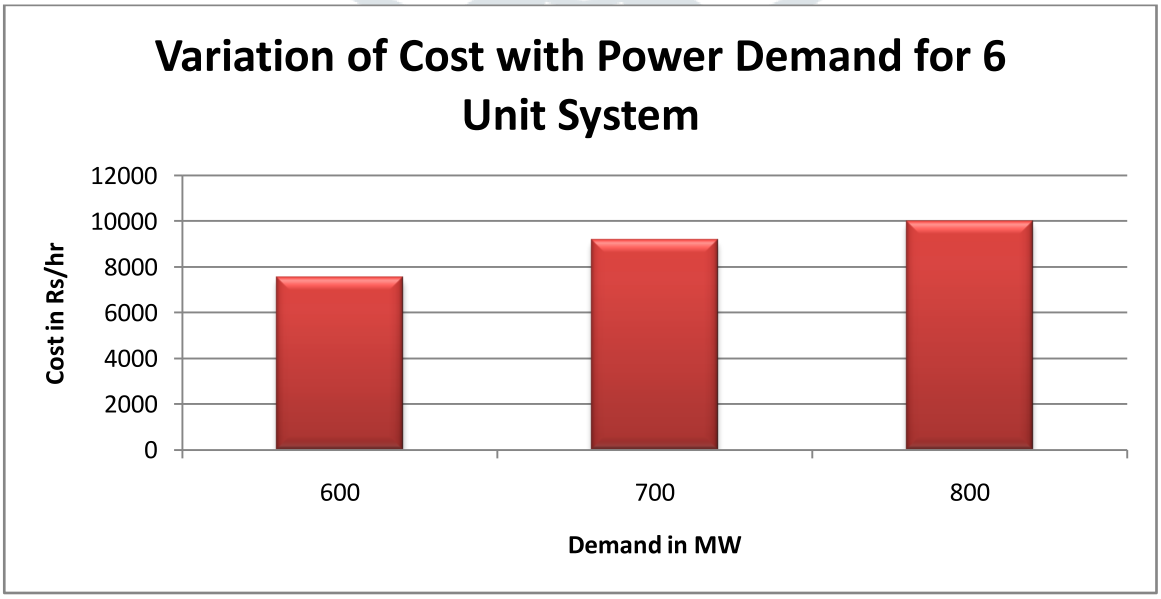






For load demand = 800 MW





CONCLUSIONS

The objective in the OPF (Optimal Power Flow) problem has been decided as minimizing of total cost of real power generation. The economic power flow problem for IEEE-6 and IEEE-30 Bus systems has been solved by genetic algorithm (GA).
The proposed method was indeed capable of obtaining higher quality solutions with better computation efficiency and convergence property.

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