

Economic Load Dispatch Using Modified Genetic Algorithm

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Abstract - Ensuring a smooth electrical energy to the consumer has been identified as the main role of electric supply utility. The power utility needs to ensure that the electrical power is generated with minimum cost. Hence, for economic operation of the system, the total demand must be appropriately shared among the generating units with an objective to minimize the total generation cost for the system. Thus, Economic load dispatch is one of the important problems of power system operation and control. This work proposes evolutionary optimization technique namely Genetic Algorithm to solve Economic Load Dispatch in the electric power system, which are generic population pool, based probabilistic search optimization algorithms and can be applied to real world problem.

Index Terms: Economic Load Dispatch, Genetic Algorithm, population pool, parent selection, mutation, cross over.

1. INTRODUCTION:

THE definition of economic load dispatch is “The operation of generation facilities to produce energy at the lowest cost to reliably solve consumers, recognizing any operational limits of generation and transmission facilities”. In most of the methods, the complexity of problem solving and its solution procedure is dependent largely on the type of the problem to be solved, the number and the type of the constraints involved. Conventional optimization techniques are problem dependent and in certain situations, a combination of different methodology has to be employed for efficient problem solving.

In the last few years, researchers in the power engineering community have been studying the feasibility and application of new information processing techniques for efficient problem solving of complex power system problems. With the advent of artificial intelligence and neural networks, alternative strategies have been identified, proposed and developed for the solution of ill-structured and complex problem in power systems. The acceptance of these techniques by the power engineering community, both in the academic institutions and industry, has paved way for basic research into the identification of new methodologies in artificial intelligence and machine learning, and in an attempt to understand the basic concept of problem solving and its application to power systems. This work proposes evolutionary optimization technique namely Genetic Algorithm to solve Economic Load Dispatch in the electric power system.

1.1. LITERATURE REVIEW

Masashi Yoshimi et al [1] had presented the genetic algorithm approach to adaptive optimal economic dispatch of electrical power systems. Genetic algorithms, also termed as the machine learning approach to artificial intelligence, are powerful stochastic optimization techniques with potential features of random search, hill climbing, statistical sampling and competition. Genetic algorithmic approach to power system optimization, as reported here for a case of economic power dispatch, consists essentially of minimizing the objective function while gradually satisfying the constraint relations. The unique problem solving strategy of the genetic algorithm and their suitability for power system optimization is described.

Sheble et al [2] in their paper presented economic load dispatch using Genetic Algorithm. A unit based encoding scheme is used, which restricts the applicability of GA to large-scale systems. In unit based encoding the chromosome length increase with number of units in the system. They presented a lambda-based GA approach for solving ED problem. The solution time grows approximately linearly with problem size rather than geometrically. They also proposed an Extended Compact Genetic Algorithm (ECGA) and an adaptive discretization technique named split-on-demand (SOD) to solve ELD problem. A repair operator is defined for making the infeasible solutions to satisfy the equality constraint.

Mehrdad Salami and Greg Cain [3] had presented the application of a hardware genetic algorithm processor to handle the economic power dispatch problem. We have analyzed a variety of configurations including varying the

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string word length and the introduction of multiple processor configurations. Results show that multiple genetic algorithm processor configurations work better than other configurations with less complexity. It is possible to apply multiple configurations to larger numbers of generators in the problem.

2 Economic load dispatch

The major component of generator operating cost is the fuel input/hour, while maintenance contributes only to a small extent. The fuel cost is meaningful in case of thermal and nuclear stations, but for hydro stations where the energy storage is 'apparently free'; the operating cost as such is not meaningful. Here we will concentrate on fuel fired stations. The input – Output curve of a unit can be expressed in a million Kcal per hour or directly in terms of Rs/hr vs. output in MW. The cost curve can be determined experimentally. A typical curve is shown in Fig.2.1 where MW (min) is the minimum loading limit below which it is uneconomical (or may be technically infeasible) to operate the unit and MW (max) is the maximum output limit. The input-output curve has discontinuities steam valve openings which have not been indicated in the figure. By fitting a suitable degree polynomial, an analytical expression for operating cost can be written as

$$C_i(P_{Gi}) \text{ Rs/hr at out put } P_{Gi}$$

Where the suffix i stand for the unit number. It generally suffices to fit a second degree polynomial that is

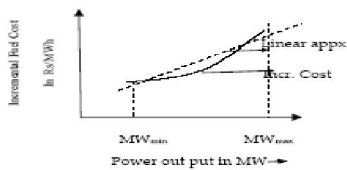


Fig. 1

$$C_i = (1/2) a_i P_{Gi}^2 + b_i P_{Gi} + d_i \text{ Rs/hour} \quad (1)$$

The slope of the cost curve, i.e. dC_i/dP_{Gi} is called the incremental fuel cost (IC) and is expressed in units of Rs/MWh. A typical plot of incremental fuel cost versus power output is shown in Fig.2.1. If the cost curve is approximated as a quadratic as in Eq.(1), we have

$$(IC)_i = a_i P_{Gi} + b_i \quad (2)$$

i.e., a linear relationship. For better accuracy incremental fuel cost may be expressed by a number of short line segments. Alternatively, we can fit a

polynomial of suitable degree to present IC curve in inverse form

$$P_{Gi} = \alpha_i + \beta_i (IC)_i + \gamma_i (IC)_i^2 + \dots \quad (3)$$

Let us assume that it is known a priori which generators have to run to meet a particular load demand on the station. Obviously

$$\sum P_{Gi, \max} \geq P_D \quad (4)$$

Where $P_{Gi, \max}$ is the rated real power capacity of the i^{th} generator and P_D is the total power demand on the station. Further, the load on each generator is to be constrained within the lower and upper limits, i.e.

$$P_{Gi, \min} \leq P_{Gi} \leq P_{Gi, \max}, i=1,2,3,\dots,k \quad (5)$$

We also require that

$$\sum P_{Gi, \max} > P_D \quad (6)$$

by a proper margin i.e. eq.(6) must be strict inequality. Since the operating cost is insensitive to reactive loading of a generator, the manner in which the reactive load of the stations shared among various online generators does not affect the operating economy. So the optimal manner in which the load demand P_D must be shared by the generators on the bus by minimizing the operating cost i.e.

$$C = \sum C_i(P_{Gi}) \quad (7)$$

Under the inequality constraint of meeting the load demand i.e.

$$\sum_{i=1}^k P_{Gi, \max} - P_D = 0 \quad (8)$$

Where k is the number generators on the bus

The objective is to minimize the overall cost of generation

$$C = \sum_{i=1}^k C_i(P_{Gi}) \quad (9)$$

At anytime under equality constraint of meeting the load demand with transmission loss, i.e.

$$\sum_{i=1}^k P_{Gi} = P_D + P_L \quad (10)$$

Where

$$P_L = \sum_{m=1}^k \sum_{n=1}^k P_{Gm} B_{mn} P_{Gn} \quad (11)$$

Where

P_{Gm}, P_{Gn} = real power generation at m, n-th plants

B_{mn} = loss coefficients which are constraints under certain assumed operating conditions.

3. GENETIC ALGORITHMS

3.1 Genetic algorithms history:-

The idea of evolutionary computing was introduced in 1960 by I. Rechenberg in his work Evolutionary strategies. Genetic algorithms are computerized search and optimized algorithms based on mechanics of natural genetics and natural selection. Prof. Holland of university of Michigan, Ann Arbor, envisaged the concept of these algorithms in the mid sixties and published his seminar work. There after a number of students and other researchers have contributed to the development of this field.

To date most of the GA studies are available through some books by Davis (1991), Goldberg (1989), Holland (1975), Michalewicz (1992), Deb (1995) and through a number of proceedings. The first application towards structural engineering was carried by Goldberg and Santani (1986). They applied genetic algorithm to the optimization of ten member plane truss. Jenkins (1991) applied genetic algorithm to the optimization of a beam structure. Deb (1991) and Rajeev and Krishnamoorthy (1992) have also applied genetic algorithm to structural engineering problems. Apart from structural engineering there are many fields in which GAs are applied successfully. It includes biology, computer science, image processing and pattern recognition, physical science, social sciences and neural networks.

Basic concepts:-

Genetic algorithms are good at taking larger, potentially huge, search process and navigating them looking for optimal combination of things and solutions which we might not find in life time.

Genetic algorithms are very different from most of the traditional optimization methods. Genetic algorithm needs design space to be converted in to genetic space. So genetic algorithms work with a coding of variables. The advantage of working with coding variables of variable space is that coding that discretizes the search space even though the function may be continuous. A most striking difference between genetic algorithms and most of the traditional

optimization methods is that genetic algorithm uses population of points at one time in contrast to the single point approach by traditional optimization methods. This means that genetic algorithm processes a number of designs at the same time. As we have earlier seen to improve the search direction in traditional optimization methods, transition rules are used and they are deterministic in nature but GA uses randomized operators. Random operators improve the search space in an adaptive manner.

The most important aspects of using genetic algorithms are:

1. Definition of objective function
2. Definition and implementation of genetic representation
3. Definition and implementation of genetic operators.

Once these three have been defined, the GA should work fairly well beyond doubt. We can by different variations improve the performance, find multiple optima parallelize the algorithms.

Genetic algorithms:-

The conceptualization of GA in current form is generally attributed to Holland, 1975. However, particularly in the last ten years, substantial research effort has been applied to the investigation and development of genetic algorithms. Goldberg, 1989 gives an excellent introductory discussion on GA, as well as some more advanced topics.

Genetic algorithms are a probabilistic search approach which is founded on the ideas of evolutionary processes. The GA procedure is based on the Darwinian principle of survival of the fittest. An initial population is created containing a predefined number of individuals (or solutions), each represented by a genetic string (incorporating the variable information). Each individual has an associated fitness measure, typically representing an objective value. The concept that fittest (or best) individuals in a population will produce fitter offspring is then implemented in order to reproduce the next

population. Selected individuals are chosen for reproduction (or crossover) at each generation, with an appropriate mutation factor to randomly modify the genes of an individual, in order to develop the new population. The result is another set of individuals based on the original subjects leading to subsequent populations with better (min. or max.) individual fitness. Therefore, the algorithm identifies the individuals with the optimizing fitness values, and those with lower fitness will naturally get discarded from the population.

Ultimately this search procedure finds a set of variables that optimizes the fitness of an individual and/or of the whole population. As a result, the GA technique has advantages over traditional non-linear solution techniques that cannot always achieve an optimal solution. A simplified comparison of the GA and the traditional solution techniques is illustrated in Figure 1. Non-linear programming solvers generally use some form of gradient search technique to move along the steepest gradient until the highest point (maximization) is reached. In the case of linear programming, a global optimum will always be attained. However, non-linear programming models may be subject to problems of convergence to local optima, or in some cases, may be unable to find a feasible solution. This largely depends on the starting point of the solver. A starting point outside the feasible region may result in no feasible solution being found, even though feasible solutions may exist. Other starting points may lead to an optimal solution, but it is not possible to determine if it is a local or global optimum. Hence, the modeler can never be sure that the optimal solution produced using the model is the "true" optimum.

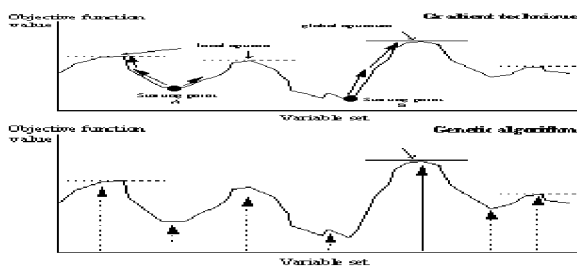


FIG. 2:- Comparison of gradient search technique and genetic algorithm approach.

For the genetic algorithm, the population encompasses a range of possible outcomes. Solutions are identified purely on a fitness level, and therefore local optima are not distinguished from other equally fit individuals. Those solutions closer to the global optimum will thus have higher fitness values. Successive generations improve the fitness of individuals in the population until the optimization convergence criterion is met. Due to this probabilistic nature GA tends to the global optimum, however for the same reasons GA models cannot guarantee finding the optimal solution.

The GA consists of four main stages: evaluation, selection, crossover and mutation. The evaluation procedure measures the fitness of each individual solution in the population and assigns it a relative value based on the defining optimization (or search) criteria. Typically in a non-linear programming scenario, this measure will reflect the objective value of the given model. The selection procedure randomly selects individuals of the current population for development of the next generation. Various alternative methods have been proposed but all follow the idea that the fittest have a greater chance of survival. The crossover procedure takes two selected individuals and combines them about a crossover point thereby creating two new individuals. Simple (asexual) reproduction can also occur which replicates a single individual into the new population. The mutation procedure randomly modifies the genes of an individual subject to a small mutation factor, introducing further randomness into the population.

This iterative process continues until one of the possible termination criteria is met: if a known optimal or acceptable solution level is attained; or if a maximum number of generations have been performed; or if a given number of generations without fitness improvement occur. Generally, the last of these criteria applies as convergence slows to the optimal solution.

Population size selection is probably the most important parameter, reflecting the size and complexity of the problem. However, the trade-off

between extra computational efforts with respect to increased population size is a problem specific decision to be ascertained by the modeler, as doubling the population size will approximately double the solution time for the same number of generations. Other parameters include the maximum number of generations to be performed, a crossover probability, a mutation probability, a selection method and possibly an elitist strategy, where the best is retained in the next generation's population.

Unlike traditional optimization methods, GA is better at handling integer variables than continuous variables. This is due to the inherent granularity of variable gene strings within the GA model structure. Typically, a variable is implemented with a range of possible values with a binary string indicating the number of such values; i.e. if x_i [0,15] and the gene string is 4 characters (e.g. "1010") then there are 16 possibilities for the search to consider. To model this as a continuous variable increases the number of possible values significantly. Similarly, other variable information which aids the search considerably are upper and lower bound values. These factors can affect convergence of the model solutions greatly.

3.2.FLOW CHART

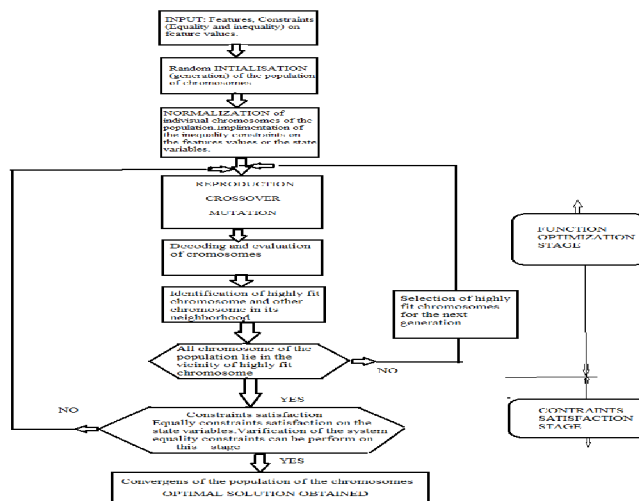


Fig. 3 Flow Diagrams for Economic Load Dispatch

4. RESULTS & DISCUSSION

4.1 IEEE DATA OF THREE GENERATORS:

Loss Coefficient matrix

$$B = \begin{bmatrix} 0.000136 & 0.000176 & 0.000184 \\ 0.000176 & 0.000154 & 0.00028 \\ 0.000184 & 0.000283 & 0.000161 \end{bmatrix}$$

$$B = \begin{bmatrix} 0.000175 & 0.000154 & 0.00028 \\ 0.000184 & 0.000283 & 0.000161 \end{bmatrix}$$

Table No.1

	GENERATO R-1 (In MW)	GENERATO R-2 (In MW)	GENERATO R-3 (In MW)
Pma x	600	400	200
Pmi n	150	100	50
a (\$/hr)	0.0001562	0.000194	0.00482
b (\$/hr)	7.92	7.85	7.97
c (\$/hr)	561	310	78

4.2 RESULT ANALYSIS:

The validity of the proposed method is illustrated on a sample system comprising three thermal generating units .The operating cost of thermal generating units are depicted in Table 2 .The B-coefficients for the calculation of transmission losses are given , MATLAB code is developed to perform entire calculations and to generate the Table . Here, it is demonstrated that the entire calculations for the first time interval with 425 MW power demand. The non-inferior solutions are obtained for the various load conditions and corresponding generation schedules are obtained . A program has been developed in MATLAB platform based upon the proposed algorithm. The novelty of this work is that the transmission loss has also been taken into consideration in the economic load dispatch program. This is because we have observed the transmission loss depends upon the power profile of different buses which indirectly depends upon the power generation of different generators. The results has been observed

to be different for different expressions of fitness function, different methodologies of parent selection, mutation process and crossover limit etc. Here, effort has been made to get a better rhythm amongst the above terms or functions. The results thus obtained is compared with [16]. The details of the result with comparison is given in the following Table.

Table No.2

Sl. No.	Load	MinCost(Cmin as	Reduction	P1 in MW	P2 in MW	P3 in MW	P=P1+P2+P3	Power
1	42	44	819	37	191	174.	59.2	425.	62
	5	39.	4.3	55.	.51	237	72	026	.9
		1		2	8				9
2	63	62	818	19	295	250.	91.5	637.	71
	7.	83.	7.0	03.	.21	810	22	546	.9
	5	9		1	3				8
3	72	70	725	21	336	283.	103.	722.	77
	2.	40.	2.1	1.8	.17	145	220	541	.7
	5	3			6				3
4	75	74	724	21	300	295.	154.	750.	79
	0	60.	7.9	2.7	.03	754	314	068	.9
		6			2				5
5	85	78	834	50	561	169.	119.	849.	82
	0	39.	0.5	1.4	.09	297	381	769	.6
		1			1				9

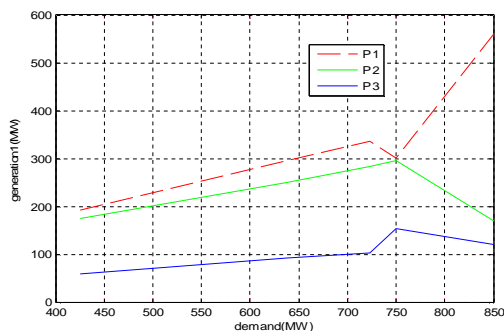


Fig 5: Graph of generations(P1,P2,P3) Vs demand(PD)

This graph shows power generations Vs load demand of three generator system. Here three generators generate power P1, P2, P3 MW respectively to meet

the load demand. The three generators shares the load demand in a way to optimise the operating cost. This graph is plotted using genetic algorithm technique.

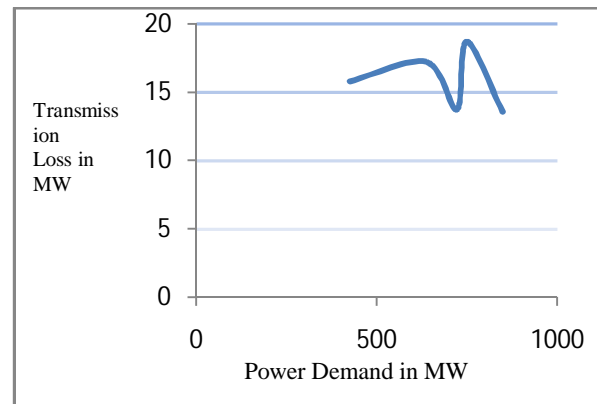


Fig 6: Graph of loss (PL) Vs demand (PD)

This graph shows power loss Vs load demand. With increase in load demand, the power loss increases sharply. But, load sharing is done here in such a way that the cost is optimized as compared to given referred IEEE datas[16].

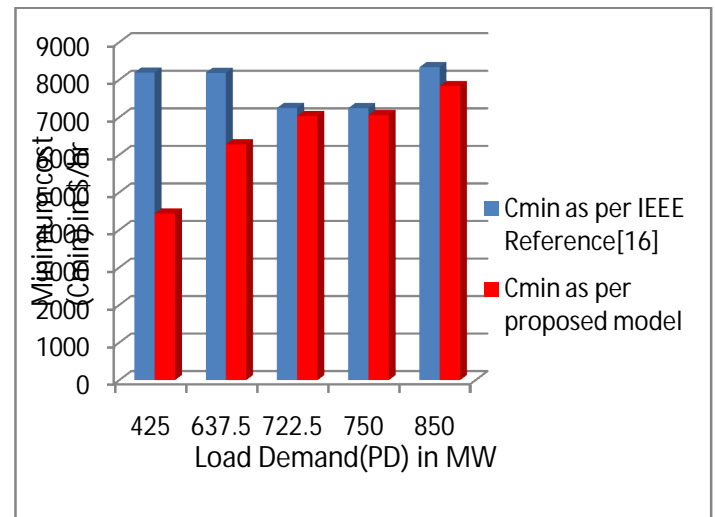


Fig.7 A histogram showing suitable comparison between referred Cmin and proposed Cmin at different load demands

4.3 CONCLUSION:

This modern age wants us to run the generator at a cost as minimum as possible to produce energy and hence large number of generators can be run to meet the ever increasing load demands. On the other hand, various losses are standing as obstacles in way of reliable operation of power supply. Many methods consisting of conventional approach and artificial intelligence approaches are used for optimization of the critical problem "Economical Load Dispatch". This is an extension work in the same axis. Here, the genetic algorithm technique is applied for getting a more optimised solution to meet this increasing loads. This algorithm uses some important steps like population, selection of fitness function, crossover, gene pool production, natural parent selection, mutation and finally searching for an optimised solution. By referring loss co-efficients and generator constraints for a 3-generator system from the mentioned IEEE papers, the result is obtained in Matlab platform. Hence, the results obtained that is the minimum cost of generation with regard to full load (850MW) is better than the result obtained in the IEEE paper reference number [16]. So, this method of approach for solving power scheduling can be accepted.

4.4 FUTURE SCOPE:-

Here it can be suggested that more better result can be obtained by improving the fitness function and penalty factor used in the above programming. Direction of research work can still be developed by improving methodologies used for parent selection and fitness function. Further, the optimization result can also be improved by using hybrid artificial intelligence technique. Hydro - thermal-nuclear power scheduling can also be improved.

4.5 REFERENCES:

- [1] Masashi Yoshimi, Swamp, K. S. & Yoshio Izui, "Optimal Economic Power Dispatch Using Genetic Algorithms," IEEE tran 1993-pp 157-162.
- [2] Sheble, G.B. and K. Brittig, "Refined genetic algorithm-economic dispatch example", IEEE paper 94 WM 199-0 PWRs, presented at the IEEE/PES, 1994.
- [3] Mehrdad Salami and Greg Cain, "Multiple Genetic Algorithm Processor for the Economic Bower Dispatch Problem," Victoria University of Technology, Australia Conference Publication No. 41 4, O IEE, 1995.
- [4] Leandro Nunes de Castro & Fernando J. Von Zuben, "The Clonal Selection Algorithm with Engineering Applications," In Workshop Proceedings of GECCO'00, pp. 36-37, USA, July 2000.
- [5] T. Yalcinoz, H. Altun, M. Uzam, "Economic Dispatch solution using A Genetic algorithm based on arithmetic crossover," IEEE Trans. on Power Systems, vol. 10, no. 1, pp. 117-124, 2001.
- [6] G. A. Bakare, U. O. Aliyu, G. K. Venayagamoorthy, Y. K. Shu'aibu, "Genetic algorithms based economic dispatch with Application to Coordination of Nigerian Thermal Power Plants," IEEE Transaction on Power Systems, Vol. 8, No. 3, pp. 1325 -1332, 2001.
- [7] Titik Khawa, Abdul Rahiian, Zuhaila Mal Yasin, Norani W. Abdullah; "Artificial-Immune-Based For Solving Economic Dispatch In Power Syste," National Power & Energy Conference (PECon) 2004 Proceedings, Kuala Lumpur, Malaysia.
- [8] K Selvi, Dr N Ramaraj, & S P Umayal, Genetic Algorithm Applications to Stochastic Thermal Power Dispatch Journal.EL, Vol 85, June 2004.
- [9] Jamal S. Alsumait and Jan K. Sykulsk, "Solving economic dispatch problem using hybrid GA-PS-SQP method," Electric Power Components and Systems, vol. 36, pp. 250-265, 2008.
- [10] M.Sailaja Kumari, M.Sydulu, "A Fast Computational Genetic Algorithm for Economic Load Dispatch", International Journal of Recent Trends in Engineering Vol. 1, No. 1, May 2009.
- [11] J. Tipayachai, W. Ongsakul and I. Nganiroo, "Parallel Micro Genetic Algorithm for Constrained dispatch IEEE Trans., Power System, vol. 17, pp. 790 - 797, Aug 2002.
- [12] F.N. Lee and AM Breipolit, "Reserved Constrained economic dispatch With Prohibitive Operating Zones". IEEE Trans., Power System, vol. 8, pp 246 - 254, Feb 1993.
- [13] K.P. Wong and Y.W. Wong, "Genetic and Genetic Simulated -Annealing Approaches to Economic Dispatch", proc.. IEE Gen* Tran Dist. vol. 4, no. 5, pp. 507 - 513, Sept 1994.
- [14] P. Altnvriyanupp, f i Kits. T. Tsneka and J. Flasegswa. "A llyhrid El' and SQP for Dynamic

Economic Dispatch Will N. Fuel Cost Function", IEEE Trans. Power System., vol.17, pp. 411-416, May2002.

[15] A.G. Bakirtzis, V. Petridis and S. Kazarlis, "Genetic Algorithm Solution to the Economic Dispatch Problem", Proc. IEE Gen. Trans. Dist.vol.4 , No.4, pp. 377 - 382,

[16] J.H Park, Y.S.Kim I.K.Eom, & K.Y.Lee, "Economic Load Dispatch for piecewise Quadratic cost function using Hopfield Neural Network", IEEE Trans. On power system, Vol.8, No.3 August 1993.