Economic Dispatch Security and Reliability Assessment

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ABSTRACT

Power system engineers face difficulty in economic operation of large inter-connected power systems. Economic Load Dispatch (ELD) of large inter-connected power system is complex, constrained and non-linear problem which require rigorous and complex calculations before taking any decision appropriate to power dispatch. Genetic Algorithms (GA) which are referred to as Evolutionary Algorithms(EA) have been nowadays frequently used for optimum performance of non-linear and complex systems. This paper proposed to develop an Evolutionary Algorithm which considers Economic Load Dispatch (ELD) problem with security constraints of power systems. The objective is to minimize the non-linear function which is the total fuel cost of thermal generating units, while taking into account the security constraints (power generations, voltages and line flows).

General Terms

Economic Dispatch problems, Genetic Algorithm, Unit Commitment, Linear and Non-Linear Programming, Computational Intelligence.

Keywords

Economic Load Dispatch, Genetic Algorithm, Security constraints, Power system optimization, Artificial Intelligence.

1.0 INTRODUCTION

Energy is indispensable and contributes to the sustainable socio-economic and industrial development of any country. Electricity is most flexible form of energy we use today and is available in two forms: renewable and non-renewable. The renewable form is obtained from natural resources. Examples include: wind, hydro, biomass, geothermal, etc; while the non-renewable is obtained from fossil fuels such as coal, petroleum, natural gas, and nuclear power.

The world's energy demand is presently on the increase and to meet up with this trend, appropriate and timely up to date studies need to be constantly carried out in the subject of power systems. Sustainable inter-connected power system is a pre-requisite for transmitting power efficiently, effectively and optimally to the load centers. The Economic Load Dispatch (ELD) optimization problem is the determination of the optimal combination of generators' outputs with the lowest generation cost and while meeting consumers' load demand. Put in another way, it is an optimization problem, concerned with how electrical power generating stations can meet their customers' demands while minimizing under generation or over generation, and also minimizing the generation costs (running the generating units), and meeting up several constraints.

Escalating prices, depletion of fossil fuels and increasing environmental concerns associated with thermal power generation systems have stressed the need to use the energy resources at its optimum level. On the other hand the electricity cannot be stored on large scale, therefore, whatever electricity is to be generated must equate the power demand and network losses for economic operation of the power system.

Power system operation, planning and its control is complex by nature and engineers are facing challenging tasks of successful planning and economic operation of inter-connected complex power system. Power system is inter-connected with number of generating stations running in parallel and feeding the high voltage network and supplies electricity to the consumers. Operating such an automated complex power system is extremely multifaceted task. The Complications which the power system engineers are facing in planning and economic operation of power system are economic dispatch, environmental impacts, reliability, security, contingency planning like load shedding and generation reallocation, load flow and line losses in power system.

Genetic Algorithms (GA) also referred to by the more general term Evolutionary Algorithms (EA), are a rapidly growing and active area of research in Computational Intelligence. A GA is a heuristic search algorithm based on ideas from natural evolution theory. GAs has emerged as robust and successful tools in power system optimization in recent years. The ability of GAs to search vast problem spaces and find near-optimal results within short time periods is key to the growing interest in them. It is thought that GAs may be able to generate near-optimal combinations of generators' output with lower generation cost, while meeting consumers' load demand.

2.0 BACKGROUND STUDY

The electrical power system is the largest energy sector in the world. It is the combination of generation, transmission and distribution facilities. The operations of other industries and sectors depend wholly on electricity. Both developed and developing countries in the world strive to establish and maintain an effective electricity sector. It is a complex task and has to make the decision based on availability of generating facilities and load demand from the different consumers. To this end, Electrical Power Engineers are constantly engaged in all processes involved in power generation, transmission, distribution and consumption; and they encounter challenging problems in their quest to meet the demand of consumers in an economical manner. Analysis and computation of electrical power system load flow is a systematic procedure that involves both the electricity grid, as well as other network devices such as generators, transformers, etc; and performance evaluation mechanism of the network.

No two electrical power systems are exactly the same, but they share a range of common characteristic features. Electrical power generation is achieved by means of generators (synchronous machines driven by turbines). The generated power is conveyed from the power stations over long distances by means of transmission network through load centres to distribution network, and finally the consumers. Electrical power is generated, transmitted and distributed by three-phase alternating current systems, with voltage and frequency levels required to remain within acceptable and tolerance levels to ensure steady-state and high quality output.

The electrical power studies date back to the works of William Gilbert, who is regarded as the father of electricity and magnetism; and also the first electrical engineer; George Ohm, who quantified the relationship between the electric current and voltage; Michael Faraday, who discovered the principle of electromagnetic induction that explains the operation of generators and transformers; and James Clerk Maxwell, who published a unified theory of electricity and magnetism.

The demand for electrical energy is continuously increasing from residential, commercial as well as industrial consumers, with the highest increase being in residential consumption. The efficient and optimum operation of electric power systems has always been of great concern. It is necessary for utility companies to run their power systems with minimum cost while making profits, and satisfying customers' demands at all times.

The introduction of computers facilitated the approach adopted in the analysis and studies for optimum performance. To this end the following three stages of power system control are adopted: Unit Commitment and Generator Rescheduling, Security Analysis, and Economic Dispatch.

2.1 Unit Commitment/ Generator Scheduling

Generator scheduling involves the hour-by-hour ordering of generator units to on and off them so as to match the anticipated load and to allow a safety margin.

2.2 Security Analysis

With a given power system topology and number of generators on the bars, security analysis assesses the system response to a set of contingencies and provides a set of constraints that should not be violated if the system is to remain in secure state.

2.3 Economic Dispatch

Economic dispatch is short term determination of the optimal operation of generating facilities to produce energy at lowest cost to reliably serve the consumers, considering generation and transmission system operational limits. Economic dispatch calculations are carried either off-line or on-line and degree of human intervention or supervision varies from utility to utility. In other words, Economic dispatch orders the minute-to-minute loading of the connected generating plant so that the cost of generation is a minimum with respect to the satisfaction of the security and other engineering constraints.

3.0 ECONOMIC DIPATCH PROBLEM

The economic dispatch problem involves two separate steps. The first of these are the unit commitment (pre-dispatch) or selection of units to be operated to meet the expected load of system over some immediate future period of time at minimum total cost and provide a specified margin of operating reserve. The second step is the on-line economic dispatch. The function of the on-line economic dispatch is to distribute the load among the generating units actually parallel with the system in such a manner as to minimize the total cost of supplying the minute-to minute requirements of the system.

Economic load dispatch (ELD) is a non-linear optimization problem and before we formulate types of economic dispatch problems we shall first state non-linear programming.

3.1 Non-Linear Programming

The term non-linear programming is used to classify those methods in mathematical programming which optimize non-linear problems.

By "optimize" we mean either maximize or minimize

The general non-linear problem can be stated as follows:

Minimize $F(X)$ 1

Subject to the constraints:

$Hí(X) = 0 \quad í = 1, 2 \ldots, p$ 2

$Gj(X) \leq 0 \quad j = 1, 2 \ldots, m$ 3

F(X) is the objective function, Hí (X) is the equality constraint, Gj(X) is the inequality constraint, X is the vector of control and state variables.

The control variables are generator, active and reactive power outputs, bus voltages, shunt capacitor/reactors and transformers tap-setting. The state variables are voltage and angle of load buses.

3.2 Unconstrained Minimization

For unconstrained minimization of F(X)

We have m = x = 0

We now must seek the necessary conditions for an optimum for F= F(X).

Since F is a function of the variable X, we form first its total differential, i.e.

$$dF = \frac{\partial F}{\partial x1}dx_1 + \frac{\partial F}{\partial x2}dx_2 + \ldots + \frac{\partial F}{\partial xn}dx_n \quad 4$$

or in compact vector form

$$dF = dX^T \quad \frac{\partial F}{\partial X} \quad 5$$

The superscript T stands for transposition

Here we have defined the new vector

$$dX \triangleq \begin{pmatrix} \partial x_1 \\ \partial x_2 \\ . \\ . \\ . \\ \partial x_n \end{pmatrix} \quad 6$$

and also

$$\frac{\partial F}{\partial X} \triangleq \begin{pmatrix} \frac{\partial F}{\partial x1} \\ . \\ . \\ . \\ \frac{\partial F}{dx1} \\ . \\ . \\ . \\ \frac{\partial F}{dxn} \end{pmatrix} \quad 7$$

If the system were operating at its optimum state, characterized by X=X opt, the arbitrary differential change in any of the X variables would not change F. By requiring that dF be zero, and we conclude from equation (5), that the necessary condition for optimum is defined by:

$$\frac{\partial F}{\partial X} = 0 \qquad 8$$

$$\text{Or} \quad \frac{\partial F}{dx1} = \frac{\partial F}{dx2} = \frac{\partial F}{dx3} = \ldots \frac{\partial F}{\partial xn} = 0 \qquad 9$$

3.3 Constrained Minimization

The classical approach to the constrained minimization problem is the method of the Lagrange multipliers.
Consider the case when m = 0 and p > 0
The general non-linear problem can be stated as follows:
Minimize F(X) 10

Subject to the equality constraint

$$H\acute{\imath}(X) = 0 \quad \acute{\imath}=1, 2, \ldots p \qquad 11$$

In making use of the Lagrange multiplier method, we first form the function as follows:

$$F^* = F(X) + \sum_{\acute{\imath}=1}^{p} \lambda\acute{\imath} H\acute{\imath}(X) \qquad 12$$

If we now define the vectors:

$$\lambda \triangleq \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ . \\ . \\ . \\ \lambda_p \end{pmatrix} \qquad 13$$

and

$$H \triangleq \begin{pmatrix} H_1 \\ H_2 \\ . \\ . \\ . \\ H_P \end{pmatrix} \qquad 14$$

Then we can write equation (12) more compactly

$$F^* = F\lambda^T H \qquad 15$$

We now must seek the necessary conditions for an optimum for F*
Since F* is a function of the variable X, we first form its total differential, that is,

$$dF^* = \frac{\partial F}{\partial x1}dx_1 + \frac{\partial F}{dx2}dx_2 + \ldots \qquad 16$$

or in compact vector form,

$$dF^* = dX^T \frac{\partial F*}{\partial X} \qquad 17$$

where

$$\frac{\partial F*}{\partial X} \triangleq \begin{pmatrix} \frac{\partial F*}{\partial x1} \\ \frac{\partial F*}{\partial x2} \\ . \\ . \\ . \\ . \\ \frac{\partial F*}{\partial xn} \end{pmatrix} \qquad 18$$

For optimum condition dF* is zero and we conclude from equation (17) that the necessary condition for optimum is defined by

$$\frac{\partial F*}{\partial X} \qquad 19$$

If equation (15) is substituted into equation (19)

$$\frac{\partial F*}{\partial X} = \frac{\partial F}{\partial X} + \left(\frac{\partial H}{\partial X}\right)^{T} \lambda = 0 \qquad 20$$

Here we have introduced the matrix:

$$\frac{\partial H}{\partial X} \triangleq \begin{pmatrix} \frac{\partial H1}{\partial x1} & \frac{\partial H1}{\partial x2} \cdots & \frac{\partial H1}{\partial xn} \\ \frac{\partial H2}{\partial x1} & \frac{\partial H2}{\partial x2} \cdots & \frac{\partial H2}{\partial xn} \\ \cdots & \cdots & \cdots \\ \frac{\partial Hp}{\partial x1} & \frac{\partial Hp}{\partial x2} \cdots & \frac{\partial Hp}{\partial xn} \end{pmatrix} \qquad 21$$

We arrive at the optimum value of F(X) by solving the simultaneous equation defined by equations (11) and (21).

4.0 ECONOMIC DIPATCH IMPEDIMENTS

The Objective of power system is to deliver the secure and reliable electricity at least cost, least environmental pollution and least power losses. However, curtailing with total fuel cost, operational effort, line losses and emissions while maintaining the reliability and security of inter-connected power system are conflicting in nature. Hence, economic dispatch problem is highly constrained and multi criteria optimization problem.

The Load on the power system is always changing form minute- to- minute, hour- to- hour and day –to- day. On the other hand, equality (network) constraints and inequality (transformer on load tap changing and nodal voltages) constraints directly influence the economic operation of the inter-connected power system. The constraints which directly influence the economic operation of power system are power generation, system voltage, running reserve capacity at peak loads, transformer tap settings, transmission line, sudden change in weather, fuel, acceptable low frequency, and reliability and security. Under such constrained conditions it becomes very difficult for the Engineer in control center to dispatch the load on power system economically. Therefore, it needs to adopt a multi criteria optimization approach which considers all constraints and help to economically operate the inter-connected power system.

5.0 PREVIOUS APPROACHES

It is very difficult to obtain solutions for Economic Load Dispatch problems through the conventional methods of solving simultaneous equations. Solution is only possible if the number of variables is reduced by specifying values for some of the variables so that the number of variables and equations are equal. Power system problems have been solved by means of analogue and digital methods. Analogue solutions were achieved through matrix algebra, and in using Gauss-Seidel iterative algorithm and Newton -Raphson's methods. But the major problems were slow rate of convergence, complex computations, more computer time per iteration, and large computer memory required. Besides, the solution was only restricted to the computation of bus voltages, bus powers and network losses for a section of the transmission grid. It had nothing to do with power generation.

Many traditional techniques have been used to solve Economic Load Dispatch problem through digital methods, including: Linear and Non-linear Programming, Interior Point Method, Lagrangian Relaxation Method, Integer Programming, Dynamic Programming, Lambda-iterative and Quadratic Programming. In most of these algorithms, optimality of solutions was mathematically formulated, and could be extended to several optimization tasks, including, power systems planning, generation scheduling, unit commitment etc; with high computational efficiency, with ease of implementation. They can also handle problems with hundreds and thousands of variables and constraints with inexpensive computers.

However, solutions obtained using these approaches have their inherent implementation limitations. For example, Many of the techniques such as gradient-based, Lambda-iterative and Lagrange relaxation methods are not applicable to some classes of objective functions with non-smooth cost functions, as they fail to get optimal solutions, with a possibility of being stuck in local optima. For effective implementation of lambda-iterative method, the problem formulation needs to be continuous. Other problems encountered by these methods include: Long execution time, poor computation efficiency, and *curse of dimensionality* (a process whereby the dimensions of the problem becomes too large that it requires massive computational effort). Hence, solutions of Economic Load Dispatch problems through mathematical computation methods have minimal applications.

Despite the successes from mathematical optimization methods to solving power system problems, the enumerated challenges have pushed developments of Economic Load Dispatch in the recent decades from the traditional iterative methods to random variable search methods, as there are still some classes of problems whose complete solutions could not be achieved in a conventional setting.

Advancements in Computer Science and Engineering have led to greater need for more specialized Artificial Intelligence (AI) approaches to overcome the above limitations. Modern optimization techniques based on this Artificial Intelligence approach to solving Economic Load Dispatch problems include: Evolutionary Algorithms

(EAs), Fuzzy Logic, Artificial Neural Networks (ANN), Expert Systems and Swarm Intelligence. These methods have the ability of searching the global optimal solutions to power systems; however, most of them suffer from long computation time, with huge number of problem-specific parameters.
Evolutionary Algorithms (EAs) have the ability to produce optimal or near-optimal solutions in reasonable time, and are highly flexible and adaptable to different problems.
There are many varieties of Evolutionary Algorithms such as, Genetic Algorithms (GA), Genetic Programming (GP), Evolutionary Programming (EP), Evolution Strategies (ES), Estimation of Distribution Algorithms (EDA), Differential Evolution (DE) etc, each tending to be associated with particular candidate solution representations. For example, real numbers Differential Evolution, discrete variables Genetic Algorithms, or function trees Genetic Programming and using distinct types of operations.

6.0 BRIEF REVIEW ON GENETIC ALGORITHM (GA) APPROACH BASED ECONOMIC DISPATCH

The power engineering community has been studying the feasibility and application of Artificial Intelligence tools for efficient solution of complex power system problems.
AI tools such as:

- Artificial Neural Network (ANN)
- Expert Systems
- Evolutionary Computation and
- Fuzzy Logic have been developed to formulate and solve the convex and non-convex

Economic Dispatch problem. Genetic Algorithm (GA) is one of the most popular paradigms of evolutionary computation. It has been used to solve the economic dispatch problem
independently and in conjunction with other AI tools and optimization approaches. It has the superior global searching capability in a complex searching surface using little information of searching space, such as derivative, continuity thus providing potential tool for real Economic
Dispatch problem.
Genetic Algorithm has inherent ability to reach the global minimum region of search space in a short or affordable time. But it has the following disadvantages:

- Long computational time
- Convergence speed near the global optimum becomes slow
- Provide near optimal solution or non-convergence to global solution.

There are several ways by which the performance of GA can be enhanced. Hybrid approach is one of the methodologies used efficiently for producing quality results. The objective of hybridization is to overcome the weakness of one approach during its application with the strengths of other by appropriately integrating them. The brief review on GA based approaches has been presented below:
(Yoshimi, et al. 1993) mapped Economic Dispatch problem in binary coded Genetic Algorithm (GA) environment using typical reproduction operator crossover and mutation. 15-machine test system has been used for performance evaluation of GA in terms of objective function and equality constraints satisfaction for four

different case studies and established the fact that GA performs function optimization in an adaptive manner so as to schedule the power generation in order to minimize objective function.

(Walters, et al. 1993) has used Simple Genetic Algorithm (SGA) with two different encoding schemes for solving the Economic Dispatch problem including valve point effect. The SGA has been tested for Economic Dispatch problem with and without losses for smooth and non-smooth cost curves using three machine test system for five different cases by comparing the results obtained from dynamic programming technique. He made useful observations regarding the GA parameters during analysis and concluded that GA has the ability to handle any type of unit characteristics.

(H. Ma, et al. 1994) presented Genetic Algorithm based solution for ill structured and multimodal economic dispatch problem including transmission loss considering compensating generation plan provided in the Clean Air Act 1990. The proposed algorithm has been tested on 9-units system (including 2 hydro units with fixed outputs).

(Bakirtzis, et al. 1994) presented two Genetic Algorithms GA–I and GA–II for the solutions of the economic dispatch problem. Test results with systems of up to 72 generating units with non-convex cost functions show that both genetic algorithms outperform the dynamic programming solution to the economic dispatch problem. However, the solution time of GA-II is system dependent and increases linearly with the size of system.

(Po-Hung, et al. 1995) presented genetic algorithm based approach for large-scale economic dispatch subject to the network losses, ramp rate limits and prohibited zone avoidance. He has selected the encoding scheme such that chromosome contains only an encoding of the normalized system incremental cost thus making chromosome size independent of number of units. This feature has been exploited as an edge for large-scale economic dispatch. The two test systems: 3 machines system and 40 units Tai power systems have been used for demonstration of the approach. The comparison of results with lambda –iteration method proved that proposed approach is fast, robust in large systems.

(Sheble, et al.1995) presented genetic algorithm based solution for economic dispatch with a view to get around the problems in classical optimization theory. He proposed the techniques such as mutation prediction, elitism, interval approximation and penalty factors to enhance the program efficiency and accuracy. Three units test system has been test for Economic dispatch solution using proposed algorithm.

(P. Y. Wang, et al. 1996) presented fuzzy logic controlled genetic algorithm for economic dispatch problem. Two fuzzy logic controllers for adoptively adjustment GA parameters (crossover rate and mutation rate) have been proposed. Six generators system has been solved for economic dispatch using the proposed algorithm and compared the results with conventional GA.

(Orero, et al. 1996) has developed the genetic algorithm solution for non-convex economic dispatch problem taking into account the prohibited operating zones of the generators. Two different implementations of genetic algorithms: Standard Genetic Algorithm and Deterministic Crowding Genetic Algorithm have been presented with a view to improve the performance (robustness and few parameter settings) of genetic algorithm. 15 generators practical power system with 4 of the units up to three prohibited operating zones system has been tested on the proposed approaches.

(Li, et al. 1997) investigated the capability of genetic algorithms on the ramping rate constrained DED problem on 25 generators practical power supply system --- Northern Ireland Supply (NIE). It has been established that the ramping rate constraint not only put no additional burden on the genetic search, but also forced the search to move within the operating feasible region, and gives smoother and more economical operational strategy for the whole dispatch period. However, a too strict ramping rate constraint will prevent a GA from obtaining an economic, feasible solution within a reasonable time. An investigation into choice of appropriate ramping rates for the generator units in a power system can be time consuming, but highly rewarding.

(Song, et al. 1997) presented the application of a fuzzy logic controlled genetic algorithm (FCGA) to environmental/economic dispatch. Two fuzzy controllers have been designed to adaptively adjust the crossover probability and mutation rate during the optimization process based on some heuristics. For the demonstration of algorithm six machines system has been solved for economic load dispatch problem. The results have been compared with conventional GA and Newton-Raphson Method for the performance evaluation of proposed approach. It has also been recommended that this algorithm can be applied to wide range of optimization problems.

(Song, et al. 1997) proposed an advanced engineered-conditioning genetic algorithm (AEC-GA) with a view to improve the performance of GA. This approach uses combination strategy using local search algorithms and genetic algorithms. In addition to this elite policy, adaptive mutation prediction, non-linear fitness mapping and different crossover techniques have also been explored. The proposed algorithm has been demonstrated by solving the power economic dispatch problem. The six units test system results have been for its validation.

(Chira, et al. 1998) has developed genetic algorithm based economic dispatch solution for eastern region of Electricity Generating Authority of Thailand (EGAT) system by using piecewise model of cost characteristics for the combined cycle and the cogeneration power plants in the system. Conventional & parallel micro genetic algorithms have been used for the solution with result that parallel micro genetic algorithm offers faster convergence.

(Angela, et al. 2000) developed framework “GAFrame” for constructing genetic algorithms based on object oriented programming methodology. GAFrame includes features: GUI, ease of use, code reusability, continuous and integer optimization problem solution, flexible, and extensible. The two optimization problems: economic dispatch and distribution system expansion planning has been solved by this framework for validation of its features.

(Yalcinoz T., et al. 2001) proposed real coded genetic algorithm for the solution of economic dispatch problem. Elitism, arithmetic crossover and mutation have been used to generate solutions in successive generations. The approach has been tested on 6 machine and 20 machine systems and results have been compared with an Improved Hopfield NN approach (IHN), a fuzzy logic controlled genetic algorithm (FLCGA), an advance engineered-conditioning genetic approach (AECGA) and an advance Hopfield NN approach (AHNN) and established the fact that the proposed technique improves the quality of the solution.

(Yalcinoz, T., et al. 2002) presented the environmental economic dispatch problem using modified GA, which based on arithmetic crossover operator. The objective function consists of three terms, which are the production cost and emissions functions. The proposed algorithm has been tested on 3-unit system and a 10-unit system and results compared with the taboo search (TS), the Hopfield NN and an improved Hopfield NN approach.

(Ying-Yi, et al. 2002) solved using binary coded GA for optimal dispatch among multi-plant (cogeneration systems) with multicogenerators, which transmit MW to designated buyers (load buses) via wheeling subject to the operation constraints in the cogeneration systems and security constraints in the third party (transmission system owner). Varying weighting coefficients for penalty functions (constraint handling) and determination of gene variables for GA has been adopted. The algorithm has been tested on IEEE 30 and 118-bus systems. From the test results, it has been shown that the computational time required strongly depends on the number of the gene variables (Lagrange multipliers) instead of the system size. Also, the proposed method can efficiently obtain the global optimum with the concept of equal Lagrange multiplier.

(Jarurote, et al. 2002) proposed an algorithm based on parallel micro genetic algorithm for the solution of ramp rate constrained economic dispatch neglecting the transmission loss for generating units with non-monotonic and monotonic incremental cost functions. The proposed algorithm was programmed on thirty-two-processor Beowulf cluster subject to schedule processors, computational loads, and synchronization overhead for the best performance. The speedup upper bounds and the synchronization overheads on the Beowulf cluster for different system sizes and different migration frequencies have been shown. Claim has been made that PMGA is viable to the online implementation of the constrained ED due to substantial generator fuel cost savings and high speed up upper bounds.

(Patricia, et al. 2002) presented GA based solution for the operational planning of hydro-thermal power systems to get around the deficiencies in non-linear programming based approaches. The paper presents an adaptation of the technique and an actual application on the optimization of the operation planning for a cascaded system composed by interconnected hydroelectric plants. The fact has been established that by using GA approach, for each additional problem constraint, only the equation used to define each individual performance needs to be modified and proposed approaches can be an efficient alternative or complementary technique for the planning of Hydrothermal power system operation.

(Ioannis, et al. 2003) developed real coded GA for the solution of network constrained Power economic Dispatch for minimizing the dispatch cost subject to branch power flow limits.

52 buses Greek island of Crete system has been tested with convex cost functions and non-convex cost functions for proposed algorithm to establish that the algorithm retained the advantages of the GAs over the traditional ED methods but also eliminated the main disadvantage of the binary coded GAs (long execution time) and thus providing an efficient generic ED solution method.

(Liladhur, et al. 2004) presented economic dispatch solution considering valve point loading effect using Simple Genetic Algorithm (SGA), SGA with generation- apart elitism, SGA with atavism and Atavistic Genetic Algorithm (AGA). These three concepts have been compared on three test systems: 3-generator system, 13-generator system and the standard IEEE 30-bus test system. It has been established that when valve-point loading and ramping characteristics of the generators are taken into account, AGA outperforms SGA, SGA with generation-apart elitism, SGA with atavism, Tabu search and conventional Lagrangian multiplier method.

(Hosseini, et al. 2004) discusses the centralized economic dispatch in deregulated environment. Power economic dispatch problem has been using genetic algorithm subject to the constraints such as are minimum and maximum power generation of units, capacity of transmission lines and ramp rate limits. IEEE 30- bus system has been tested for the proposed algorithm for its validation.

(Bakare, et al. 2005) has made comparative investigation of both Conventional GA (CGA) and micro-GA (μGA) for Power economic dispatch problem using 6-bus IEEE test system and 31-bus Nigerian grid Systems. The results obtained are satisfactory for both approaches, but it is shown that the μGA performed better than CGA with reference to the economic and computational time (average of 62% time reduction) for Nigerian system.

(Chao-Lung Chiang, et al. 2005) presented genetic algorithm solution for economic dispatch taking into account the valve point effect and multiple fuels simultaneously with multiplier update (IGA - MU). Basically this algorithm is the integration of the Improved Genetic Algorithm (IGA) and the multiplier updating (MU). The proposed algorithm has been demonstrated by applying separately on: 13 units test system considering valve-point effects only, 10 units considering multiple fuels only, and ten units addressing both valve-point effects and multiple fuels. By comparison of results of proposed algorithm with conventional genetic algorithm with multiplier update, it has been established the fact that IGA - MU is more effective and can apply to the real world problems.

(Wong, et al. in 2007) presented Simulated Annealing (SA) based Economic Dispatch Algorithm. The algorithm was demonstrated on three generating units system only. In comparison with Zoom Dynamic Programming (ZDP) method Economic Dispatch results obtained for the test system are more economical. Subsequently in four algorithms (two GA based algorithms, Basic Genetic Algorithms (BGA) and Incremental Genetic Algorithm (IGA), two Genetic simulated annealing based algorithms GGA and GAA2) have been presented to determine the optimal or near optimum solution of the ED problem. By modifying step 3 of four steps BGA algorithm, an IGA algorithm has been derived which can find global optimum solution earlier in the solution process than BGA. To avoid premature convergence in IGA, hybrid algorithm GAA is developed by combining IGA and simulated annealing. Further GAA2 is developed to deal with the memory requirement by reducing the population size to 2.

13 Machine real life systems have been tested and established the fact that GAA2 is superior to other algorithms.

(Ongsakul, et al. 2002) proposed the micro genetic algorithm based on migration and Merit Order Loading solutions (MGAM-MOL) for solving the constrained ED with linear decreasing and decreasing staircase Incremental Cost (IC) functions. MGAM-MOL used a Merit Order

Loading (MOL) solution as a base solution to reduce the search effort to the optimal solutions. The MGAM-MOL solutions were less expensive than those obtained from Simple Genetic Algorithm (SGA), Micro Genetic Algorithm (MGA), and MOL.

(Ongsakul, et al. 2001) presented a Genetic Algorithm based on Simulated Annealing solutions (GA-SA) to solve ramp rate constrained Dynamic Economic Dispatch

(DED) problems for generating units with non-monotonically and monotonically increasing IC functions. As the transmission line losses are incorporated, GA-SA is tested on the 10 generating unit systems and compared to the Zoom Brute Force (ZBF), ZDP, SA, local search (LS), Genetic Algorithm based on MOL solutions (GA-MOL), and MOL methods. To illustrate the quality of GA-SA solutions on larger generating unit systems, the algorithm has also been tested and compared to the others on the 20 and 40 generating unit systems.

(Yalcinoze, 2001) presented Hybrid Genetic Algorithm (HGA) for solving the Economic Dispatch problem. The algorithm incorporates the solution produced by an improved Hopfield Neural Network (NN) as a part of its initial population. Elitism, arithmetic crossover, and mutation are used in the GAs to generate successive sets of possible operating policies. The technique improves the quality of the solution and reduces the computation time, and is compared with the classical optimization technique, an improved Hopfield NN approach (IHN), a Fuzzy Logic Controlled GA (FLCGA), and an Improved GA (IGA).

(Attaviriyanupap, et al. 2002) proposed hybrid methodology for solving DED. The proposed method has been developed in such a way that a simple Evolutionary Programming (EP) has been applied as a based level search, which can give a good direction to the optimal global region, and a local search Sequential Quadratic Programming (SQP) has been used as a fine tuning to determine the optimal solution at the final. A ten-unit test system with non-smooth fuel cost function has been used to illustrate the effectiveness of the proposed method compared with those obtained from EP and SQP alone.

(Kumarappan, 2003) presented Neuro hybrid Genetic Algorithm (GA) to solve an economic dispatch problem. The algorithm has been proposed for minimum cost of operating units. Working philosophy of algorithm is as:

- Real Coded GA has been used for global search.
- Fine tunings by Tabu Search (TS) to direct the search towards the optimal region and local optimization.
- For loss calculation Fast Decoupled Load Flow (FDLF) conducted to find the losses by substituting the generation values to the respective PV buses.

Then the loss has been participated among all generating units using participation factor method. Artificial Neural Networks (ANN) has been applied to the Hybrid GA. The algorithm is tested on IEEE 6-bus system and 66-bus utility system.

7.0 CONCLUSION

The expected output of this discussion paper is to solve the multi criteria based economic dispatch problems. This discussion paper concludes that the evolutionary algorithms can help very effectively in solving the multi criteria optimization problems associated with the economic dispatch of power system. The developed algorithm would consider all the constraints associated with economic dispatch and should be computationally efficient and robust, which would help to reduce the per unit cost of electricity generated, improve the reliability and security of power system network, reduce the environmental degradation, reduce the technical losses, enhance the power system capacity and improve the power quality of supply. To develop such an algorithm and making an allowance for multi criteria optimization to solve economic dispatch complications for sustainable grid-connected power system such algorithm needs to be designed simple, efficient, effective, time convergent, reliable, secure and stable. Such attributes would help power system engineer to make the optimal decision regarding economic dispatch under constrained condition.

Thus power system network would be able to be operated, controlled and planned efficiently. Another advantage would be for especially those countries which are suffering from power crisis like Nigeria where supply demand gap is very high. In that scenario to better manage the supply demand gap, power system engineers would have chance to manage the load shedding effectively.

REFERENCES

1. **www.wikipedia** .com

2. Sttot, B. and Marinho, J. L.," Linear programming for power system network security applications." IEEE Trans. On Power Systems, vol. PAS-98, no. 3, May/June 1979, p. 837-848.

3. Goldberg, D. E. (1989). Genetic Algorithms in Search, Optimisation and Machine Learning. Addison Wesley, Reading.

4. Momoh, J. A. (2001). Electrical Power System: Applications of Optimizations. Marcel Dekker Inc.

5. Bakare,G.A., Aliyu,U.O, Venayagamoorthy,G.K, Shu'aibu,Y.K "Genetic Algorithm Based Economic Dispatch with Application to Coordination of Nigerian Thermal Power Plants.", IEEE, (2005)

6. Bakare, G.A., Aliyu, U. O., Venayagamoorthy, G. K. and Shu'aibu, Y. K. (2005) Genetic Algorithm Based Economic Dispatch with Application to Coordination of Nigerian Thermal Power Plants. DOI: 10.1109/PES.2005.1489725.

7. Yan.G, Hongbin, S, "The Economic Operation of the Interconnect Electric Power System Based on the Genetic Algorithm", IEEE, (2010)