Economic Power Dispatch Problem using Artificial Immune System

R.Behera, B.B.Pati, B.P.Panigrahi

Abstract---- This paper presents the genetic algorithm approach to adaptive optimal economic dispatch of Electrical Power Systems. Artificial Immune System 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. Artificial immune system 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. The advantages of the artificial immune system algorithm approach in terms of problem reduction, flexibility and solution methodology are also discussed. The suitability of the proposed approach is described for the case of a six generator thirty bus IEEE system.

Index Terms----Antibody, Antigen, Cloning, Hypermutation, Optimization, Softcomputing

1 INTRODUCTION

THE definition of economic dispatch provided in EP Act section 1234 is: “The operation of generation facilities to produce energy at the lowest cost to reliably serve consumers, recognizing any operational limits of generation and transmission facilities”. Most electric power systems dispatch their own generating units and their own purchased power in a way that may be said to meet this definition. There are two fundamental components to economic dispatch:

I Planning for tomorrow’s dispatch
II Dispatching the power system today

I Planning for tomorrow’s dispatch

a. Scheduling generating units for each hour of the next day’s dispatch
b. Based on forecast load for the next day
c. Select generating units to be running and available for dispatch the next day (operating day)
d. Recognize each generating unit’s operating limit, including it’s:
Ramp rate (how quickly the generator’s output can be changed), Maximum and minimum generation levels,
Minimum amount of time the generator must run, Minimum amount of time the generator must stay off once turned off, Recognize generating unit characteristics
e. Cost of generation, which depends on its efficiency (heat rate), variable operating costs (fuel and non-fuel), variable cost of environmental compliance, start-up costs, next day scheduling is typically performed by a generation group or an independent market operator, reliability assessment.

Analyze forecasted load and transmission conditions in the area to ensure that scheduled generation dispatch can meet load reliability. If the scheduled dispatch is not feasible within the limits of the transmission system, revise it. The reliability assessment is typically performed by a transmission operations group.

II Dispatching the power system today

a) Monitor load, generation and interchange (imports/exports) to ensure balance of supply and load.
b) Monitor and maintain system frequency at 50/60 Hz during dispatch according to NERC standards, using Automatic Generation Control (AGC) to change generation dispatch as needed.
c) Monitor hourly dispatch schedules to ensure that dispatch for the next hour will be in balance.
d) Monitor flows on transmission system.

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e) Keep transmission flows within reliability limits.

f) Keep voltage levels within reliability ranges.

g) Take corrective action, when needed, by:

Limiting new power flow schedules, curtailing existing power flow schedules, changing the dispatch or shedding load.

h) This monitoring is typically performed by the transmission operator area factors limiting the effectiveness of dispatch in minimizing customer costs.

Geographic area included the size of the geographic region over which the dispatch occurs affects the level of costs: that is, which generation resources and which transmission facilities are considered in planning and economic dispatch. Generation resources included which generation resources in the area are included in the planning and economic dispatch, and whether they are included in the same manner, affects the level of costs. Transmission facilities included what transmission facilities are included in the planning and economic dispatch, and how the reliability security limits of the transmission facilities are incorporated into the economic dispatch. Implementation factors limiting effectiveness of dispatch in minimizing customer costs. Performing an economic dispatch more frequently (e.g., 5 or 15 minutes rather than each hour) affects the level of costs. Generation operators, transmission owners, and load serving entities must provide accurate and current information to those performing the planning and dispatch functions. Those performing planning and dispatch must provide accurate and current dispatch instructions to generation operators, transmission operators and load serving entities. Inadequate or incomplete communications affects the level of costs of the economic dispatch. Reliable and secure computer software is essential for rapidly responding to system changes to maintain power system reliability, while selecting the lowest cost generators to dispatch. Obsolete software affects the level of costs achieved by the economic dispatch.

Where there are multiple, independently performed, dispatches in a region, the effectiveness of coordination agreements and their implementation affect the level of costs of the economic dispatch.

Masashi Yoshimi Technical, Swamp, K. S. &Yoshio Izui [1] had presented the genetic algorithm approach to adaptive optimal economic dispatch of electrical power systems. The advantages of the genetic algorithmic approach in terms of problem reduction, flexibility and solution methodology are also discussed.

Mehrdad Salami and Greg Cain [2] 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 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.

Leandro Nunes de Castro & Fernando J. Von Zuben [3] had presented The clonal selection algorithm is used by the natural immune system to define the basic features of an immune response to an antigenic stimulus. It establishes the idea that only those cells that recognize the antigens are selected to proliferate. The selected cells are subject to an affinity maturation process, which improves their affinity to the selective antigens. In this paper, we propose a powerful computational implementation of the clonal selection principle that explicitly takes into account the affinity maturation of the immune response. The algorithm is shown to be an evolutionary strategy capable of solving complex machine learning tasks, like pattern recognition and multimodal optimization.

Leandro Nunes de Castro [4] had presented review the general algorithms of immune, swarm and evolutionary systems.

Leandro N. de Castro and Fernando J. Von Zuben [5] had presented the clonal selection principle used to explain the basic features of an adaptive immune response to an antigenic stimulus.

K Selvi, Dr N Ramaraj, & S P Umayal [6] had presented a genetic algorithm (GA) based effective method for the optimal scheduling of thermal generation incorporating the uncertainties in the system production cost data. The algorithm gives fairly accurate results. The effectiveness of the method has been demonstrated by analyzing sample systems and the results are presented.

Titik Khawa Abdul Rahman, Zuhaila Mal Yasin arid Wan Norani W.Abdullah [7] had presented Artificial Immune System based optimization approach for solving the economic dispatch problem in a power system. Economic Dispatch determines the electrical power to be generated by the committed generating units in a power system so that the generation cost is minimized, while satisfying the load demand simultaneously. The developed Artificial Immune System optimization technique used the total generation cost as the objective function and represented as the affinity measure. Though genetic evolution, the antibodies with high affinity measure are produced and become the solution .The simulation result reveal that the developed technique is easy to implement and converged within an acceptable execution time and highly optimal solution for economic dispatch with minimum generation cost can be achieved .The result also confirms that AIS based optimization technique can be a useful tool for solving optimization solution in economic dispatch problem ,which involves a large number of generating units and at the same time to comply with a large number of constraints

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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 Kcalories 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

$C_i(P_{Gi})$ 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

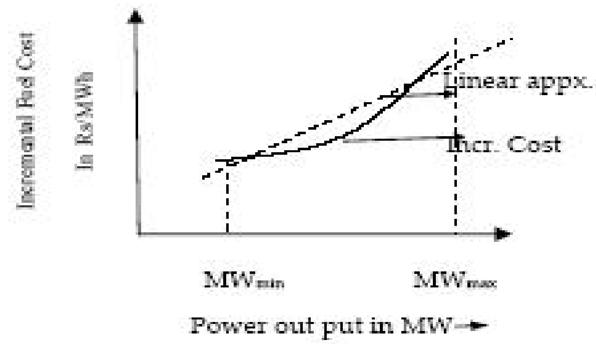

Fig. 1

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

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

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

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.

$P_{Gi,min} \leq P_{Gi} \leq P_{Gi,max}, i=1,2,3,\ldots,k$ (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

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

(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

$$P_L=\sum_{m=1}^{k} \sum_{n=1}^{k} P_{Gm} {*} B_{mn} {*} P_{Gn}$$

(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 ALGORITHIM(GA)

Genetic algorithms, first introduced by John Holland in the early seventies, are becoming an important tool in machine learning and function optimization. The metaphor underlying GA is natural selection. To solve a learning task, a design, or an optimization problem, the GA maintains a population of 'chromosomes' or 'bit strings' and probabilistically modifies the population seeking a near-optimal solution to the given task. Beneficial changes to the parents are combined in their offspring. The GA adapts itself to the problem being solved through syntactic operations on the bit strings. GA has been tried on NP-hard combinatorial optimization problems and may provide a more advantageous approach to machine learning problems than neuromorphic networks and simulated annealing. The genetic algorithm consists of a string representation of nodes in the search space, a set of genetic operators for generating new search nodes, a fitness function to evaluate the search nodes and a stochastic assignment to control the genetic operators. The stepwise procedure of GA for the optimization of generation cost can be outlined as follows:

i. Initialization; Random generation of the initial population of the search nodes.

ii. Evaluation: Calculation of the fitness value of each node according to fitness function.

iii. Evaluation: Evaluation of strings or chromosomes of a population.

iv. Selection: Selection of reproducing sets from the population based on relative fitness values.

v. Reproduction: Generation of new strings from each reproducing set using various reproductive strategies. Replacing some or all of the original

vi. Population with new strings. The possible reproductive strategies are combinations of

vii. Reproduction: Generation of identical copies of some or all of the strings in the reproduction set.

viii. Mating: Construction of a new string by concatenating substrings chosen from members of the reproductive set.

ix. Mutation: Substitution of new symbols for selected positions in the new string.

4 ARTIFICIAL IMMUNE SYSTEM(AIS)

The immune system (IS) is a complex of cells, molecules and organs that represent an identification mechanism capable of perceiving and combating dysfunction from our own cells (infectious self) and the action of exogenous infectious microorganisms (infectious nonself). The interaction among the IS and several other systems and organs allows the regulation of the body, guaranteeing its stable functioning. Without the immune system, death from infection would be inevitable. Its cells and molecules maintain constant surveillance for infecting organisms. They recognize an almost limitless variety of infectious foreign cells and substances, known as nonself elements, distinguishing them from those native noninfectious cells, known as self molecules .When a pathogen (infectious foreign element) enters the body, it is detected and mobilized for elimination.

The AIS can be defined as a computational system based upon metaphors of the biological immune system. The immune engineering (IE) is a meta-synthesis process that uses the information contained in the problem itself to define the solution tool to a given problem, and then apply it to obtain the problem solution. It is not our intention to pose a strict limit between the AIS and the IE. Instead, we intend to make use of all immunological inspired phenomena and algorithm in order to solve complex problems. The topics involved in the definition and development of the artificial immune systems cover mainly:

a) Hybrid structures and algorithms that take into account immune-like mechanisms.
b) Computational algorithms based on immunological principles, like distributed processing, clonal selection algorithms, and immune network theory.
c) Immunity-based optimization, learning, self-organization, artificial life, cognitive models, multi-agent systems, design and scheduling, pattern recognition and anomaly detection.
d) Immune engineering tools.

Potential applications of the artificial immune systems can be listed (but are not limited to):

Pattern recognition, function approximation and optimization, anomaly detection, computer and network security, generation of diversity and noise tolerance.

The stepwise procedure of AIS for the optimization of generation cost can be outlined as follows:

i. Read the data which includes a_i, b_i,c_i, maximum and minimum limits of generation of power of each generator and population size etc.
ii. Generate random binary string
iii. Decode them to actual value
iv. Insert them in population pool
v. Check for the satisfaction of constraints of the objective function if 'yes' go to (vi) else go to (i).
vi. Evaluate fitness of each set of generation to meet the demand using

$$F = K \div \left(1 + \alpha\left(\frac{\epsilon}{P_D}\right)\right)$$

Where $\epsilon = \left|P_D + P_L - \sum_{i=1}^{n} P_i\right|$, n = number of generators.
vii. Select the antigen and antibody from the fitness values
viii. Calculate the Euclidean distance between antibody and antigen using

$$D = \sqrt{\sum_{i=1}^{L}(ab_i - ag_i)^2}$$

ix. If D is more select them for hyper mutation else simple mutation by cloning the antibody.
x. Enter the cloned population in new population pool.
xi. Check for the satisfaction of constraints of the objective function.
xii. Check for the convergence else go to clonal proliferation.

5 RESULTS AND DISCUSSION

IEEE data of 6 generators 30 bus system

Table-I (Generator Data)

Generator	a	b	c	P_{max}	P_{min}
G_1	0.0037	2.0000	0	200	50
G_2	0.0175	1.7500	0	80	20
G_3	0.0625	1.0000	0	50	15
G_4	0.0083	3.2500	0	35	10
G_5	0.0250	3.0000	0	30	10
G_6	0.0250	3.0000	0	40	12

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