Optimum Dispatch of Hybrid Solar Thermal (HSTP) Electric Power Plant Using Non-Smooth Cost Function and Emission Function for IEEE-30 Bus System

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***Abstract*—The basic objective of economic load dispatch (ELD) is to optimize the total fuel cost of hybrid solar thermal electric power plant (HSTP). In ELD problems the cost function for each generator has been approximated by a single quadratic cost equation. As cost of coal increases, it becomes even more important have a good model for the production cost of each generator for the solar thermal hybrid system. A more accurate formulation is obtained for the ELD problem by expressing the generation cost function as a piece wise quadratic cost function. However, the solution methods for ELD problem with piece wise quadratic cost function requires much complicated algorithms such as the hierarchical structure approach along with evolutionary computations (ECs). A test system comprising of 10 units with 29 different fuel [7] cost equations is considered in this paper. The applied genetic algorithm method will provide optimal solution for the given load demand.**

***Index Terms*—Economic Load Dispatch (ELD),Combined Cycle Plant(CCP),Genetic Algorithm(GA),Hybrid Solar Thermal Power Plant(HSTP), Evolutionary Computations(ECs),Multi-fuel Effects(MFE)**

I. INTRODUCTION

The basic theme of economic dispatch is to determine the optimal combination of power outputs of the generating units in electric power system so as to optimize the total fuel cost for a certain load demand satisfying operational constraints. The economic load dispatch (ELD) problem is analyzed basically through the input output characteristic or through the heat rate input output characteristic by taking real power output of ith generating unit (PGi) in the X axis and Fuel input in rupees per hour in the Y axis. Input-Output characteristic is approximated as a single quadratic variation curve which gives sub-optimal solutions. Usually the nature of Input-Output characteristics of modern generating units is non-linear because of multi-fuel effects (M F E) using combined cycle power plants (CCPP) and valve loading effects, which may lead to multiple local minimum points of cost functions. Hence it is more realistic to represent the Input-Output characteristic as a piece wise quadratic cost function to avoid huge revenue loss over time problems. This project develops algorithm approach for solving the economic dispatch problem for a test system of 10 plants having 29 fuel cost options. A salient feature of proposed approach is that solution time grows approximately linear with problem size. More over the inclusion of solar power plant in tandem with the thermal power plant reduces the emission level so as to maximize the power generation for solar plant leading to minimum utility of the solar generation. The quadratic cost function so chosen is minimized following the reduction in emission level of Sulphur dioxide (SO2), carbon monoxide (CO), nitrous oxide N2O and other greenhouse gasses. The quadratic programming approach so chosen for the hybrid solar thermal power system optimizes the cost of generation of solar thermal power plant and simulation time as well.

II. ECONOMIC LOAD DISPATCH

The ELD [3] problem is to determine the optimal combination of power outputs of all the generating units to minimize the total fuel cost while satisfying the load demand from the operational constraints. Minimum fuel costs are achieved by the economic load scheduling of different generating units. Here we mean to ascertain the generation of distinct generators so as to obtain the total fuel cost as minimum so that the load demand is met out by net generation.

A. Economic Load Dispatch Problem

However, economic load scheduling was not of relevance when there were small power generating plants for each locality, such as urban power system, but now with the growth in the power demand and at the same time guarantee regarding the continuity of power supply to the consumer under normal conditions have forced the power system engineers to develop grid system. For such system the economic dispatch problem has become increasingly important. The objective in the economic dispatch of power system is to minimize the cost of meeting the energy requirements of the system over some appropriate period of time and in a manner consistent with reliable service. The appropriate period may be as short as few minutes or as long as a year or more depending on the nature of the energy sources available to the system.

B. Problem Statement for ELD with Non-Smooth Cost Function

Let N be the number of units.

PG_i be the power supplied by the i_{th} unit.

PD be the load demand in MW

The generation cost objective function for the thermal power plant in proposed method can be represented by cost function [2] :

$$f_1(PG) = \sum_{i=1}^{NG} \begin{matrix} a_i PG_i^2 + b_i PG_i + c_i \\ + \lambda \left| ei \sin(PG_i \min - PG_i) \right| \end{matrix} Rs/h \quad (1)$$

Where, a_i , b_i *and* c_i *are generation cost coefficients for the* i_{th} *generating[4] unit subjected to condition*

$$\sum PGi = P_D + P_L \; Where \; i = 1,2,3.......n \quad (2)$$

$$P_L = \sum_{m=1}^{n} \sum_{n=1}^{n} PG_m PG_n B_{mn} \quad (3)$$

$$\sum B_{mn} = \frac{\cos(\sigma_m - \sigma_n) Mp_m \times Mp_n \times P_L}{|V_m| \times |V_n| \cos\phi_m \times \cos\phi_n} \quad (4)$$

:

Neglecting valve point loading [3] and incorporating transmission loss using conventional method the cost of thermal generation is expressed as

$$\left. \begin{aligned} F(PG) &= \sum a_i PG_i^2 + b_i PG_i + c_i + \lambda(P_D + P_L - \sum PG_i) \\ f_2(P_i) &= \sum_{i=1}^{NG} \alpha_i PG_i^2 + \beta_i PG_i + \gamma_i + \eta_i \exp(-k_i PG_s) Rs/h \end{aligned} \right\} \quad (5)$$

$$Subject\ to\ condition\ \mathrm{PGi}(\min) \le PGi \le \mathrm{PGi}(\max)$$

C. Cost Criteria for Economic Load Dispatch Problem

Using Lagrangian multiplier method fuel cost and emission cost functions incorporating transmission loss were expressed in equation (1) and equation (2) respectively.

By differentiating the above equations we get:

$$\frac{dF(PG)}{dPG_i} = 0 \quad (6)$$

$$\Rightarrow 2a_i PG_i + b_i + \lambda * \left(\frac{\partial P_L}{\partial PG_i} - 1 \right) = 0 \quad \& \; (7)$$

$$\frac{\partial F(PG)}{\partial \lambda} = P_L - \sum PG_i + P_D \quad (8)$$

$$\sum PG_i = (P_D + P_L)$$

$$Dividing\ equation\ (7)\ by\ 2a_i$$

$$PG_i + \frac{bi}{2a_i} + \lambda \left[\frac{\frac{\partial P_L}{\partial PG_i} - 1}{2a_i} \right] = 0 \quad (9)$$

$$\Rightarrow PG_i + \frac{b_i}{2a_i} = \frac{\lambda}{2a_i} \left(1 - \frac{\partial P_L}{\partial PG_i} \right) \quad (10)$$

$$\Rightarrow \sum PG_i + \frac{\sum b_i}{2a_i} = \lambda \sum \frac{1}{2a_i} \left(1 - \frac{\partial P_L}{\partial PG_i} \right)$$

$$\Rightarrow PG_i = \frac{\lambda \left(1 - \frac{\partial P_L}{\partial PG_i} \right) - b_i}{2a_i} \quad (11)$$

III. SOLAR THERMAL HYBRID PLANT

$$f_2(P_i) = \sum_{i=1}^{NG} \alpha_i PG_i^2 + \beta_i PG_i + \gamma_i + \eta_i \exp(-k_i PG_s) Rs/h \quad (12)$$

Where, α_i , β_i γ_i *and* η_i are generation cost coefficients for the i_{th} generating unit subjected to condition

$$f_1(PG) = \sum_{i=1}^{NG} a_i PG_i^2 + b_i PG_i + c_i + \lambda \times f_2(P_i) \left| ei \sin(PG_{i\min} - PG_i) \right| Rs/h \quad (13)$$

IV. GENETIC ALGORITHM

Genetic algorithm (GA), was first propounded by John Holland in early seventies, is a flagship among various techniques of function optimization. Genetic algorithm criss-crosses all the above limitations of conventional algorithms by using the basic building blocks that are distinct from those of conventional algorithms. The following differential aspects are as follows:

1. GA works with a coding of the parameters set and not the parameters themselves.
2. GA searches from a population of points and not from a single point like conventional algorithm.
3. GA uses objective function information, not derivative or other auxiliary data.
4. GA uses probabilistic transition rules by stochastic operands, not by deterministic rules.

The initial step of GA [8] is the random selection of initial search points from the total search space. Each and every point in the search space corresponds to one set of values for the parameters of the problem. Each parameter is coded with a string of bits. The individual bit is called "gene". The content of each gene is called "allele". The total string of such genes of all parameters written in a sequence is called a "chromosome". So there exists a chromosome for each point in the search space. The sea of search points selected and used for processing is called a population. That means population is a set of chromosomes. The no of chromosomes in population is called "population size" and the total number of genes in a string is called "string length". The population is processed and evaluated through various operators of GA to generate a new population and this process is carried out till global optimum point is reached. The two parts of the process are called “generation and evaluation”.

For the evaluation of GA we define a fitness function and evaluate the fitness for each chromosome of a population. This fitness is an indication of the suitability of the values of the parameters, as represented by that chromosome and acts as a solution of the optimization problem [9] under consideration. This fitness is used as bias for selecting the parents and generating a new population from the existing one.

V. RESULT AND PERFORMANCE CHARACTERISTIC

The various program specific arguments for the optimization of cost and emission function of hybrid

Solar thermal power plant were tabulated in the tables-1,2 and 3.

The increment in solar generation is accompanied by decrement in emission level in the thermal power plant thereby optimizing the cost of generation of the thermal power plant as shown in Fig-1.

Average cost of generation incorporating cost of fuel for solar thermal power plant for various units of thermal power plant and various generating modules of solar power plant with respect to number of units of the hybrid plant decreases with number of units initially and rises further with further increment of number of units as shown in Fig-2.

TABLE I.

Power generation (PGi)	ai	bi	ci	Power demand (PD)	ei	Power loss (PL)
404.40	0.05	2.33	39.79	1870	134.21	12.51
285.93	0.01	0.09	13.97	1900	153.95	39.74
255.66	0.01	0.08	13.92	1930	155.98	73.89
243.33	0.01	0.31	39.79	1960	157.23	49.68
297.72	0.01	0.13	18.95	1990	161.63	61.18
162.79	0.01	0.01	14.23	2020	240.01	125.95

TABLE II.

α_i	β_i	γ_i	η_i	k_i
0.025	1.35	22.983	0.5035	0.02075
0.027	1.24	137.370	0.5773	0.02446
0.015	0.80	363.704	0.4968	0.02270
0.017	0.70	720.450	0.5634	0.03033
0.007	0.60	1428.43	0.5244	0.03356
0.009	0.50	2856.22	0.5978	0.0367

TABLE III.

Fuel Cost in MR/hr for Proposed Method	Fuel Cost in MR/hr for Conventional Method	Deviation
0.759	3.225	-0.764
0.656	0.6988	-0.061
0.126	0.1519	-0.170
0.143	0.1951	-0.267
0.121	0.206	-0.412
0.0348	0.150	-0.0076

Following the increased generation level of solar power plant the generation [1] cost of thermal power plant decreases. As a result of this deviation between cost of generation incorporating valve point loading for cost and emission function in the proposed method and the conventional method without valve point loading with respect to various power demands undergoes a change as reflected in Fig-3.

The IEEE 30 bus test case system used for the Present dissertation is shown in Fig-4.

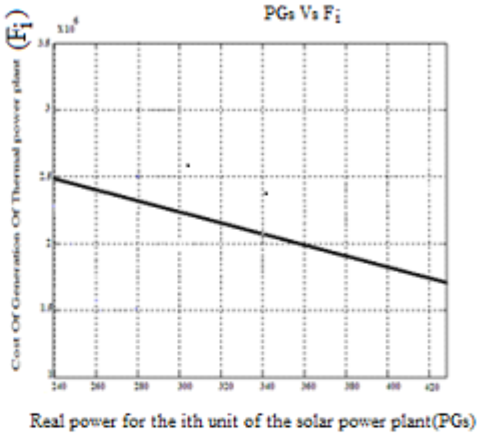

Figure 1. Variation of real power of Solar power plant versus Cost of generation of thermal power plant

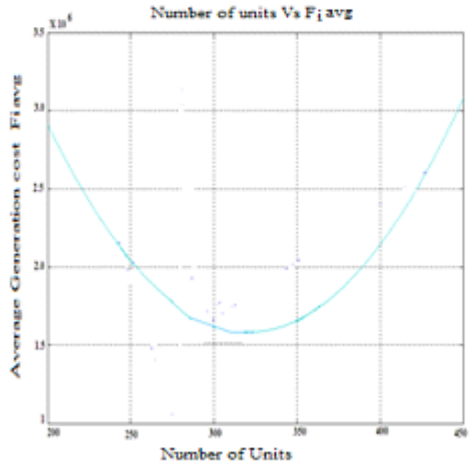

Figure 2. Number of units versus average generation cost

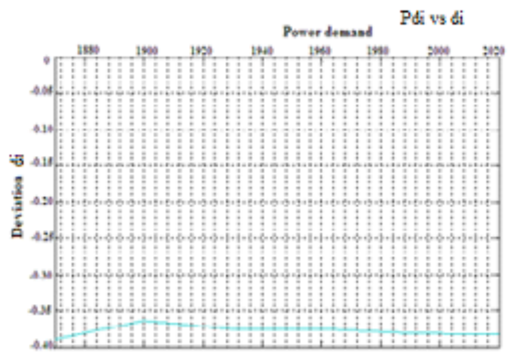

Figure 3. Power demand versus deviation

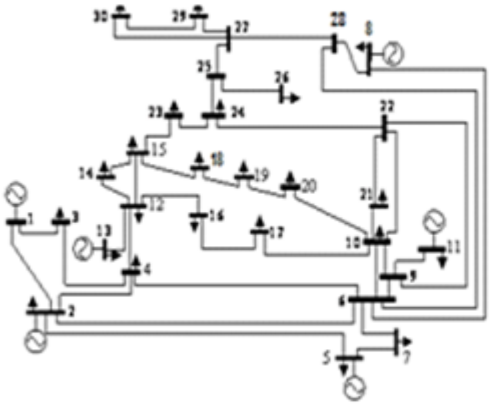

Figure 4. IEEE 30 bus test case system

VI. CONCLUSION

Various soft computing methods like neural network, fuzzy logic etc. were used for optimal dispatch for optimizing the cost of generation of thermal power plant with multi-objectives[5] wherein the computation time for simulation and convergence of the result became cumbersome and sluggish. So at its favor the concept of hybrid solar thermal power plant (HSTP) owning quadratic programming [6] method, an emerging evolutionary programming technique that was involved in the current dissertation, found useful in regulating greenhouse gasses optimizing the emission level so as to maximize the real power generation by reducing the global warming level. The use of multi-objective generation dispatch incorporating the cost of generation and emission as well with non-smooth cost and emission function with valve point loading and quadratic programming approach can be incorporated for reduction in emission level of SO2, CO, N2O and other greenhouse gasses so as to maximize real power generation level for yielding the optimum cost of generation.

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