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ECONOMIC DISPATCH AT THE AMBARLI POWER PLANT USING GENETIC ALGORITHM

AMBARLI SANTRALINDA GENETÝK ALGORÝTMA ÝLE EKONOMÝK YÜK DAÐITIMI

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ABSTRACT

In this paper we consider the important problem of economic operation of power systems: how to operate a power system to supply all loads at minimum cost. Here we assume that we have some flexibility in adjusting the power delivered by each generator. Of course, if we have a "peak" demand for power that is so large that all the available generator capacity must be used, there are no options. But usually the total load is less than the available generator capacity and there are many possible generation assignments.

In this work, genetic algorithm (GA) solution to economic dispatch problem of Ambarlý Power Plant is presented. An advantage of the GA solutions is that they do not impose any convexity restrictions. Another advantage is that GAs can be very effectively coded to work on parallel machines.

Key Words: *Economic Dispatch, Genetic Algorithms*

ÖZET

Bu makalede güç sistemindeki bütün yüklerin minimum maliyetle beslenebilmesini gerçekleyen ekonomik iþletme problemi incelenecektir. Çalýþmada herbir generatör tarafýndan gücün ayarlanabildiði kabul edilmiþtir. Eðer, çekilen maksimum yük toplam generatör kapasitesinin üzerinde ise ekonomik yük daðýtýmýndan söz etmek mümkün degildir. Ancak genellikle toplam yük mevcut generatör kapasitelerinin altinda olduðundan generatörler arasýnda ekonomik yük daðýtýmý yapýlmasý sözkonusu olabilir.

Yapýlan çalýþmada, Ambarlý santralýnda gruplar arasýnda ekonomik yük daðýtýmý yapabilmek için genetic algoritma (GA) yöntemi kullanýlmýþtýr. GA 'nýn herhangibir konveks sýnýrlama içermemesi çözüm de üstünlük saðlamaktadýr. Ayrýca GA paralel çalýþan makinalar da verimli olarak programlanabilmektedir.

Anahtar Kelimeler: *Ekonomik yük daðýtýmý, Genetik algoritma*

1. INTRODUCTION

The basic purpose of the economic dispatch function is to schedule the outputs of the online fossil-fuel generating units so as to meet the system load at least cost. The annual fossil-fuel costs are of the order of several billions of dolars and even a small improvement in the economic dispatch function can lead to significiant cost savings.

The factors influencing power generation at minimum cost are operating efficiencies of generators, fuel cost, and transmission losses. The most efficient generator in the system does not gurantee minimum cost as it may be located in an area where fuel cost is high. Also, if the plant is located far from the load center, transmission losses may be considerably higher and hence the plant may be overly uneconomical. Hence, the problem is to determine the generation of different plants such that the total operating cost is minimum.
In analyzing the problems associated with the controlled operation of power systems, there are many possible parameters of interest. Fundamental to the economic operating problem is the set of input-output characteristics of thermal power generation unit. In defining the chracteristics of steam turbine units, the following term will be used. .
H: Kcal per hour heat input to the unit
F: Fuel cost times H is the $ per hour.

The input to the thermal plant is generally measured in kcal/h (or Btu/h), and the output is measured in MW. A simplified input-output curve of a thermal unit known as heat- rate curve is given in Fig. 1 [1].

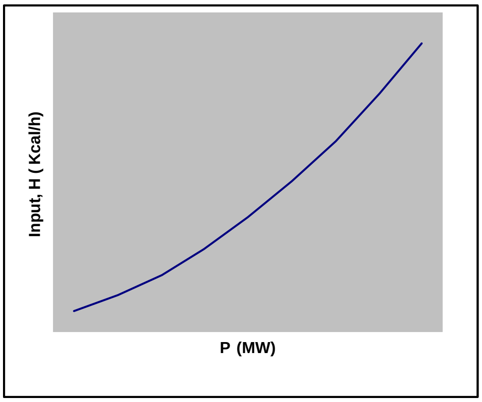

Fig.1 Heat-rate curve

Fig.2 shows the configuration that will be studied in this paper. This system consists of N thermal generating units connected to a single bus bar serving a received electrical load P_R.

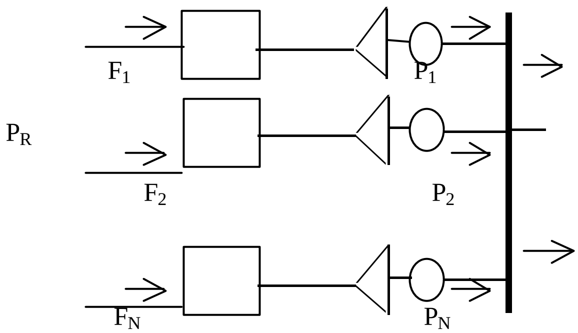

Fig. 2. N thermal units committed to serve a load of P_R.

The input to each unit, shown as F_i, represents the cost rate of the unit. The output of each unit P_i, is the electrical power generated by that particular unit. The total cost rate of this system is, of course, the sum of the heats of each of the individual units.
In reality, unit incremental heat rate curves do not exhibit the monotonically increasings shape required by traditional dispatch algorithms. Since traditional dispatch algorithms cannot handle nonmomotonically increasing heat rate curves, approximations have been introduced during the estimation of the unit heat rate curves, so that the resulting heat rate curves are monotonically increasing.

Today, the most general solution to the economic dispatch problem is based on dynamic programming. Unlike traditional solution, the dynamic programming solution to the economic dispatch problem imp oses no restrictions on the generating unit chracteristics. However, it suffers from the curse of dimensionality: as the number of generators to be dispatched increases and higher solution accuary is sought, the storage requirements and the execution time of the dynamic programming algorithm increase dramatically.

In this paper, a genetic algorithm (GA) is used for the solution of the economic dispatch problem. GAs have been applied to many diverse areas such as function optimisation, system identification and control, image processing, combinatorial problems, artificial neural network topology, determination, artificial neural network training and rule based systems.

2. ECONOMIC DISPATCH NEGLECTING LOSSES INCLUDING GENERATOR LIMITS

The problem is to find the real power generation for each unit such that the objective function (i.e. total production cost) as defined by the equation

$$F_t = \sum_{i=1}^{N} F_i = \sum_{i=1}^{N} (\boldsymbol{a}_i + \boldsymbol{b}_i P_i + \boldsymbol{g} P_i^2) \qquad (1)$$

is minimum subject to constraints [2]

$$\sum_{i=1}^{N} P_i = P_R \qquad (2)$$

$$P_{i,\min} \le P_i \le P_{i,\max} \qquad (3)$$

where

F_t : total production cost ($/h)
F_I : production cost of ith plant ($/h),
P_I : real power output of generator i (MW)
P_R :total demand (MW)
Pi,min , Pi,max : operating limits of unit i (MW)
N : total number of units on economic dispatch.

The well known solution to this problem using Kuhn-Tucker conditions is

$$\frac{dF_i}{dP_i} = \boldsymbol{l} \quad for\ P_{i(\min)} \angle P_i \angle P_{i(\max)}$$

$$\frac{dF_i}{dP_i} \le \boldsymbol{l} \quad for\ P_i = P_{i(\max)} \qquad (4)$$

$$\frac{dF_i}{dP_i} \ge \boldsymbol{l} \quad for\ P_i = P_{i(\min)}$$

3. GENETIC ALGORITHM SOLUTION

Genetic algorithms are conceptually based on natural genetic and evolution mechanisms working on populations of solutions in contrast to other search techniques that work on a single one. Searching not on the real parameter solution space but on bit string encoding of it, they mimic the natural chromosome genetics by applying genetics-like operators in search for the global optimum.The most interesting aspect of GAs is that although they do not require any prior knowledge and they do not require any space limitations such as smoothness, convexity or unimodality of the function to be optimised, they exhibit very good performance on the majority of the problems applied . They only require an evaluation function to assign a quality value to every solution produced. Another interesting feature is thet they are inherently parallel, therefore their implemention on parallel machines reduces significantly the CPU time required.

The outputs of the N generators are determined so as to minimise the total operating cost (eqn. 1) subject to the power balance constraint (eqn.2) and the generator limits (eqn.3). The outputs of the n=N-1 'free generators' can be chosen arbitrarily within limits while output of the 'reference generator' is constrained by the power balance equation (eqn.2) . It is assumed that the N th generator is reference generator. For arbitrary outputs P_i, i=1,…,n, the output of reference generator (eqn.2) is

$$P_{ref} = P_N = P_R - \sum_{i=1}^{N-1} P_i \qquad (5)$$

GAs do not work on the real generator outputs themselves, but on bit string encodings of them. The output of each one of the free generators is encoded in a 10 bit string (an unsigned 10 bit integer), which gives a resolution of $2^{10} = 1024$ discrete power values in the range ($P_{i,min}$, $P_{i,max}$).

These n strings are concatenated to form a consolidated solution bit string of 10n bits called genotype. Each genotype is decoded uniqely to an n-dimesional generator power output vector called the phenotype which is a real solution of the problem. The resulting genotype spaces are vast.

According to the GA principles a population of m genotypes must be initially generated at random. After their generation the m genotypes are evaluated by the following procedure:

Each genotype is decoded to a power output vector $[P_1,\ldots P_N]$. The output of reference generator P_N is computed using eqn.5. The total production cost is finally computed as the sum of the individual unit's costs (eqn.1). The total production cost is fitness value of the particular genotype and must be minimised.

Finally, the GA is terminated when the population converges so that it does not produce better solution over a given number of generations [3,4].

4. ECONOMIC DISPATCH AT THE AMBARLI POWER PLANT

Characteristic values of the Ambarlý Power plant are given in the Table 1.

Table 1. Unit Limits of the Ambarlý Power Plant

Unit No.	*Rated Power (MW)*	$P_{i,min}$ *(MW)*	$P_{i,max}$ *(MW)*
1	130	55	130
2	110	55	130
3	110	55	130
4	150	75	160
5	150	75	160

The heat-rate functions for these units are given by following equations.

$$H_1(kcal/h) = -226000000000+2524717\,P_1+4023{,}639\,P_1^2 \quad (6)$$

$$H_2(kcal/h) = -23900000000+4092{,}312P_2+3910{,}007\,P_2^2 \quad (7)$$

$$H_3(kcal/h) = 9{,}12\ 10^{10}+929529{,}9P_3+14{,}97\,P_3^2 \quad (8)$$

$$H_4(kcal/h) = 1{,}63\ 10^{11}-567447\,P_4+25849{,}55\,P_4^2 \quad (9)$$

$$H_5(kcal/h) = 2{,}39\ 10^{13}-223376P_5+21{,}04\,P_5^2 \quad (10)$$

where H_1, H_2, H_3, H_4, H_5 are heat rates of five units.

Heat rate curves of five units are shown in Fig.3, Fig.4, Fig. 5, and Fig. 6. And Fig. 7 respectively.

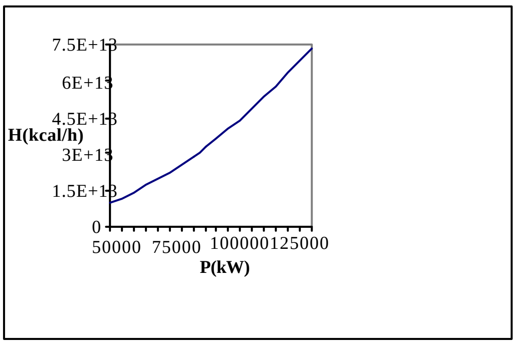

Fig. 3. Input-Output curve for first unit

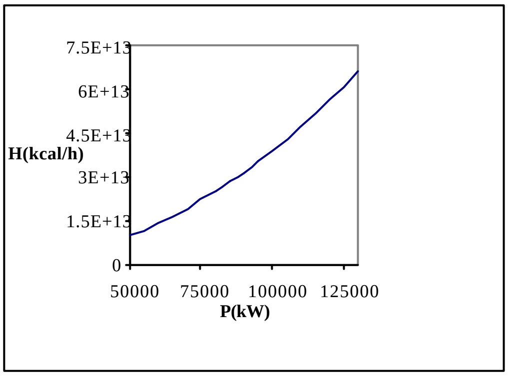

Fig. 4. Input-Output curve for second unit

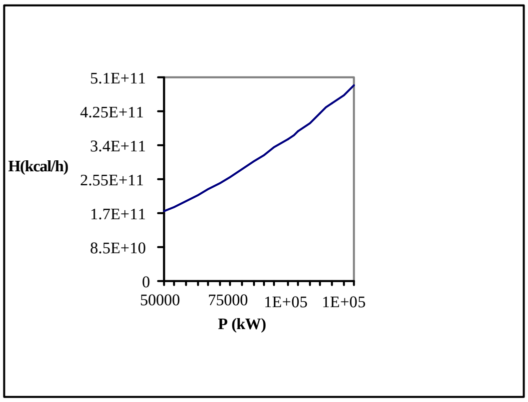

Fig. 5. Input-Output curve for third unit

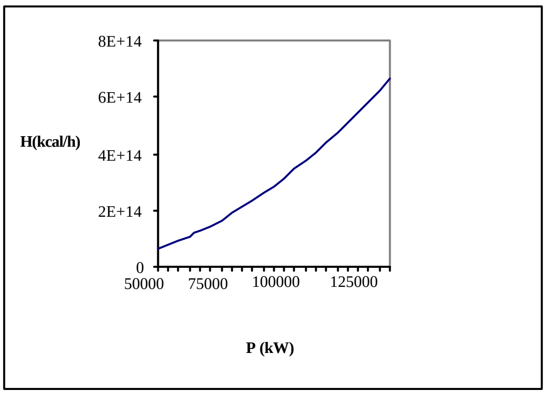

Fig 6. Input-Output curve for fourth unit

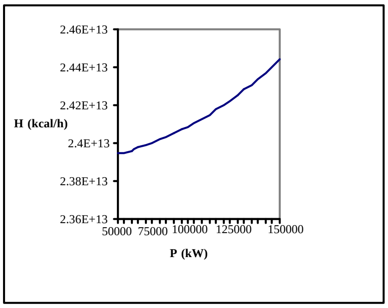

Fig 7. Input-Output curve for fifth unit

The problem is minimize the objective function

$$H = -226000000000 + 2524717P_1 + 4023.639P_1^2$$
$$- 23900000000 + 4092{,}312P_2 + 3910{,}007\ P_2^2$$
$$+ 9{,}12\ 1010 + 929529{,}9P_3 + 14.97P_3^2 \qquad (11)$$
$$+ 1{,}631011 - 567447\ P_4 + 25849{,}55\ P_4^2$$
$$+ 2{,}39\,1013 - 223376P_5 + 21{,}04\ P_5^2$$

Subject to constraints

$$;\ P_1 + P_2 + P_3 + P_4 + P_5 = 500\ MW \qquad (12)$$

$$55\ MW \le P_1 \le 130\ MW$$
$$55\ MW \le P_2 \le 130\ MW$$
$$55\ MW \le P_3 \le 130\ MW \qquad (13)$$
$$75\ MW \le P_4 \le 160\ MW$$
$$75\ MW \le P_5 \le 160\ MW$$

In Table 2, economic dispatch results when five generators supply a load of 500 MW are shown. The GA is a stochastic algorithm and although it theoretically converges to the global optimum.

Table 2. Optimum dispatch of five -units system

Unit i	1	2	3	4	5
P_i (MW)	88	92	100	110	110

4. CONCLUSIONS

GA solution to the economic dispatch problem of the Ambarlý Power Plant have been presented. Although genetic algorithms are generally considered to be offline optimisation algorithms, owing to the large amount of CPU time thet neeed to converge to an optimal solution, they can exhibit very good online performance, when a suitable combination of operators is employed.

The basic advantage of GAs is that they can be very effectively coded to work on parallel machines.Potential applications of GAs include unit commitment and optimal power flow. With the recent advances in parallel computing, the on line solution of optimal power flow with nonconvex generator cost functions may soon be possible.

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