GENETIC ALGORITHM SOLUTION FOR ECONOMIC DISPATCH AT KHARTOUM NORTH POWER STATION

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ABSTRACT- in this paper, genetic algorithm (GA) solution to the economic dispatch problem at Khartoum North Power Station is presented. The study uses GA to perfectly fix the fuel consumption problem. GA is a highly nominated way to solve such complicated system. The fuel-cost equations for each generator in the station have been formulated to satisfy specific constrains. The implementation of the algorithm involves two modules: knowledge module; holds decision making elements and genetic module, holds the optimization components such as selection, crossover, mutation and number of generation. The algorithm works through designed procedure from which the global optima solution reached. The results of the study revealed that the fuel cost reduced by 64005.12 €/year compared with those obtained from the station.

المستخلص- في هذه الورقة تم استخدام الخوارزمية الجينية للوصول لافضل تشغيل لمحطة بحري الحرارية, لان الخوارزمية الجينية لها المقدره علي حل كثير من السائل المعقدة. تم وضع المعادلات الخاصة بالاستهلاك لكل مولد علي حده. في هذه الخوارزمية تم استخدام وحدتين هما وحدة المعرفه وتحوي عنصر اتخاذ القرار, و وحدة الجين و تحوي عناصر التحسين مثل الانتخاب, العبور, الطفره و عدد الاجيال. تم التوصل الي الحل الامثل العام و كانت نتيجة الدراسه تخفيض التكلفه بمبلغ 64005.12 يورو لكل عام مقارنه مع التقديرات المستنبطه بواسطة المحطة.

Keywords: *economic dispatch, genetic algorithm, fuel cost, power generation.*

INTRODUCTION

Economic load dispatch is the important task in power system, and the main functions electrical power management system [1]. The objective of economic dispatch problem is to find the optimal power generation from different power generating units in given time period to minimize the cost of fuel consumption, while satisfying the required equality and inequality constraints.

Many traditional solution methods presented to solve the economic dispatch problem such as, linear programming [2], nonlinear programming [3, 4], quadratic programming [5], and Lagrangian method. The obtained solution of these methods may be local optima. Recently, many stochastic methods solution have been presented to solve the economic dispatch problem. The stochastic methods considered as global optima solution in contrast to traditional solution. The stochastic methods are: simulated annealing [6], particles swam optimization [7], genetic algorithms [8, 9], and ant colony optimization [10].

In this paper two objectives considered are optimizing power generation and minimizing fuel consumption costs by using genetic algorithm.

LITERATURE REVIEW

The economic dispatch problem, which is used to minimize the cost of production of real power generation, can generally be stated as follows [11].

$$F_t = \sum_{i=1}^{N} F_i = \sum_{i=1}^{N} A_i + B_i P_i + C_i P_i^2 \qquad (1)$$

Subject to: The equality constraints:

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

The inequality constraints:

$$Pi,\min \le Pi \le Pi,\max \qquad (3)$$

Where:

F_t: total production cost ($/h)

F_I: production cost of ith plant ($/h).

P_I: real power output of generator i (MW).
A_i, B_i, C_i : cost coefficient for generator i.
D_T: total demand (MW).
$P_{i,min}$, $P_{i,max}$: operating limits of unit i (MW).
N: total number of units on economic dispatch.

Genetic algorithm (GA) form a class of adaptive heuristics based on principles derived from the dynamics of natural population genetics. The searching process simulates the natural evaluation of biological creatures and turns out to be an intelligent exploitation of a random search. A candidate solution (chromosome) is represented by an appropriate sequence of numbers. The quality of its fitness function, which evaluates a chromosome with respect to the objective function of the optimization problem [12].

Generally, there are three operators in GA: selection, crossover and mutation [13, 14]. "Selection" means that two individuals from the whole population of individuals are selected as "parents". "Crossover" serves to exchange the segments of selected parents between each other according to a probability. The operation "Mutation" consists in randomly altering the value of each element of the chromosome according to a probability which is called the mutation probability.

STRUCTURE OF GENETIC ALGORITHMS SOLUTION

This work, carried out in Khartoum North Power Station. The power station included two generators: unit 1 and unit 2. The implementation of the work involves two main steps: formulation of economic dispatch problem and developing of genetic algorithm solution.

Formulation of Production Function

Characteristic values and coefficients of production function (A, B, C) of the units were evaluated from heat rate curve of the power station are given in Table 1 [15].

The fuel consumption cost of these units is given by following equations:

$$F_1 = 1.826 + 5.770 + P_1 - 0.023 P_1^2 \qquad (4)$$

$$F2 = 1.847 + 4.838 P1 - 0.008 P2^2 \qquad (5)$$

Subject to:
The equality constraints

$$\sum_{i=1}^{2} P_i = P_1 + P_2 = D_T \qquad (6)$$

The inequality constraints are:

$$30 \le P1 \le 57 \qquad (7)$$

$$15 \le P2 \le 30 \qquad (8)$$

The total fuel consumption cost:

$$Min.\left[\sum_{i=1}^{2} Fi\right] = F_1 + F_2 \qquad (9)$$

The Genetic Algorithm Solution

This genetic algorithm is developed which aimed to optimize the power generated and minimize the cost of fuel consumption in the station. The genetic algorithm was built from two modules and implemented on XpertRule Knowledge Builder software.

a. Knowledge module

A knowledge module is term for a collection of knowledge objects such as attributes, variables, reports, procedure as shown in Figure 1. The attributes inside this module consist of two types: list attributes, they have predefined string such as total demand. The second is numeric attributes was used as decision making elements like power generated cost. Variables are collective terms used to describe non attributes data, these attributes were designed as numeric string, numeric array and string array like units, cost coefficient. Dialog object was designed to query the user about the total load demand and represent a run time user.

b. Genetic Module

This module holds the optimization components for optimizing the economic dispatch problem. The module includes of three main parts: Selection of chromosomes, selection of genetic operators, procedures calculations and decision tree.

c. Selection of Chromosomes

A variable chromosome type with two genes for unit 1 and unit 2 were represented in a single array [1; 1] and [1; 2]. These arrays are called tied of genes. The inequality constraints for unit 1 and unit 2 represent the minimum and maximum genes values. The genes values for these units were specified in Table 2 and set in the knowledge builder as shown in Figure 2.

d. Genetic Algorithm Operators:

The genetic algorithm has a number of operators that were selected. These operators include: direction, number of generation, number of individuals crossover probability, mutation probability and cost gradient. The values of these operators were specified in Table 2 and set in the builder window as shown in Figure 3. The number of generations, 10, 20, 30 and 40 were used to test that the optimum variables are improving with advancing generations.

e. Procedures Calculations

The procedure was designed as the search space which the genetic algorithm can work and search for the optimum solution. This procedure was built of three procedures elements: initialization, generation cost, and setup report. Initialization holds all the constant values used in the calculation cost .Generation cost holds all sequences of calculations of the costs. Setup report procedure used to calculate the value of some variables no need to put them in the main procedure and need to see them in the report. The procedure consists of the following algorithms:

- Algorithm is used to describe the power balance constraints
- Algorithm is used to initialize the variables
- Algorithm is used to calculate production cost by using while loop commands.

The procedure is written in Xpert knowledge builder script commands as shown in Figure 4.

f. Decision Tree

Decision tree was built to offer a graphical view of the knowledge and held the solution decision elements as shown in Figure 5

RESULTS AND ANALYSIS

The proposed program tested on the power station to assess the suitability and validity of algorithms. In this station, the required power to be delivered to load demand side is 70 MW and the available power-generating machine is unit1 and unit 2. The optimum condition obtained from the genetic algorithm is shown in Table 3, while the best average cost is shown Figure 6. When the same load demand was applied to the optimization method that used in the station, the optimum condition obtained is shown in Table 4.

Result shows that performance of the genetic algorithm solution is better than the optimization method is used in the power station. Fuel cost obtained by the proposed algorithm is 327.265 €/h, while fuel cost of the station is 335.06 €/h. When comparing the two results our proposed genetic algorithm leads to save 64005.12 €/year. Computing time taken by the proposed system is 4 seconds; this may be considered as real time solution.

CONCLUSION

Genetic Algorithm model has been developed to solve the economic dispatch problem for Khartoum North Power Station. The problem formulated and the cost production function of two generators was determined considering both equality and none equality constraints. The Genetic algorithm is capable to find the best solution among the search space, using operator like selection of chromosome genes, crossover and mutation.

In summary, the numerical outputs indicate that the proposed algorithm can be used to determine the best power generation plan with minimum fuel cost. In this study, factors as fuel consumption cost variable were considered. Therefore, further work can be extended to include: transmission line losses and costs of capital.

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Table 1: Units limits and coefficients of the power station

Unit No.	**P_{min} (KW)**	**P_{max} (KW)**	**A**	**B**	**C**
Unit1	30	57	1.826	5.77	-0.023
Unit2	15	30	1.847	4.838	-0.008

Table 2: Values for genes and optimization operators

Power units	**Number of generation**	**Gene tied**	**Min gene value**	**Max gene value**	**No of individual**	**Crossover probability**	**Mutation probability**	**Cost gradient**
Unit1	10, 20,30, 40	Units[1,1]	30	57	50	0.2	0.05	2
Unit2	10,20,30,40	Units[1,2]	15	30	50	0.2	0.05	2

Table 3: Optimum condition obtained from the GA

Generation No.	**Unit Type**	**P Optimal (MW)**	**Available capacity (MW)**	**Used capacity (MW)**	**Exceed capacity (MW)**	**Fuel Cost (€/h)**	**Compute time (S)**
10	Unit 1	55	57	55	0	327.267	1
	Unit 2	15	30	15	0		
	Total	70	87	70	0		
20	Unit 1	55	57	55	0	327.266	2
	Unit 2	15	30	15	0		
	Total	70	87	70	0		
30	Unit 1	55	57	55	0	327.265	3
	Unit 2	15	30	15	0		
	Total	70	87	70	0		
40	Unit 1	55	57	55	0	327.265	4
	Unit 2	15	30	15	0		
	Total	70	87	70	0		

Table 4: Optimum condition obtained from the optimization method

No of Generation	Unit Type	P Optimal (MW)	Available capacity (MW)	Used capacity (MW)	exceed Capacity (MW)	Fuel Cost (€/h)	Compute time (S)
Not available	Unit 1	45	57	45	0	335.06	Not available
	Unit 2	25	30	25	0		

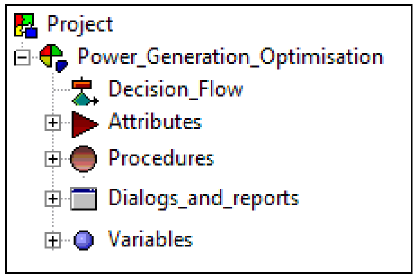

Figure 1: The main elements of knowledge module

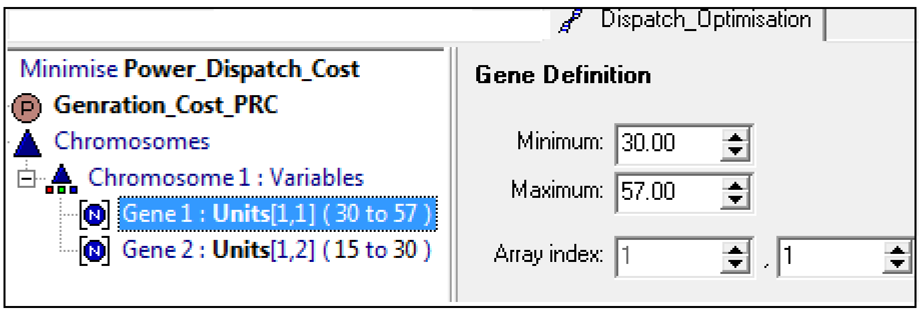

Figure 2: GA with chromosomes and genes

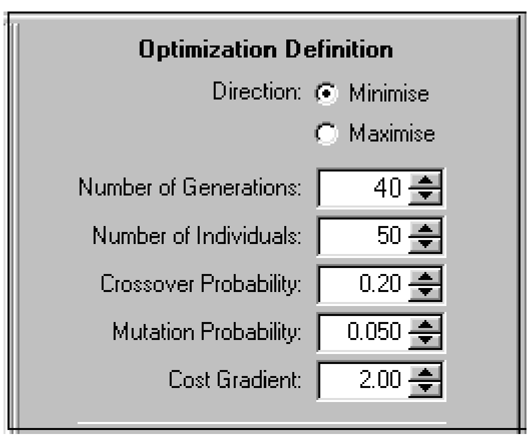

Figure 3: Optimization operator's definition

```
@ Remeber power balance constraints
@ Assign Unit[1,2]=DT-Unit[1,]
@ Remember initilise optimization cost variable
@ Assign production cost=0
@ Assign penality cost=0
@ Assign power dispatch cost=0
@ Remember initialise machine machine used capacity variable
@ Assign capacity used [1]=0
@ Assign capacity used [2]=0
@ Remember assign production cost
@ Assign operation =1
@ Remember process operation (1)
@ While operation<2
@ Assign machine=1
@ Remeber process machine (A,B)
@ While machine<3
@ Assign production cost=(A1+A2+capcity used[1]*B1+Capacity
  used[1]^2*C1+capacity used[2]*B2+capcityused[2]^2*C2
@ Assign  capacity used[1]=unit[1,1]
@ Assign capacity used [2]=Unit[1,2]
@ Assign machine=Machine+1
@ End
@ Assign operation=operation+1
```

Figure 4: Part of the algorithm of calculation cost procedure

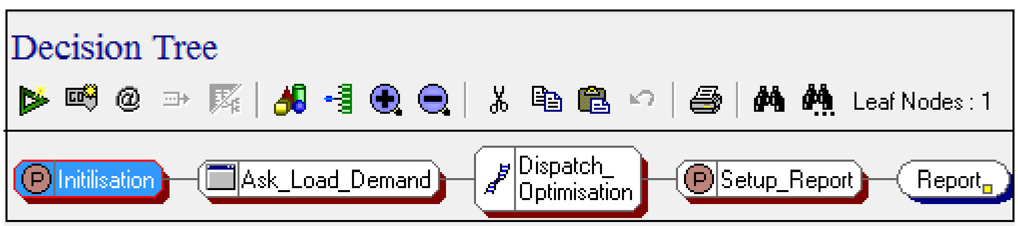

Figure 5: Decision tree elements

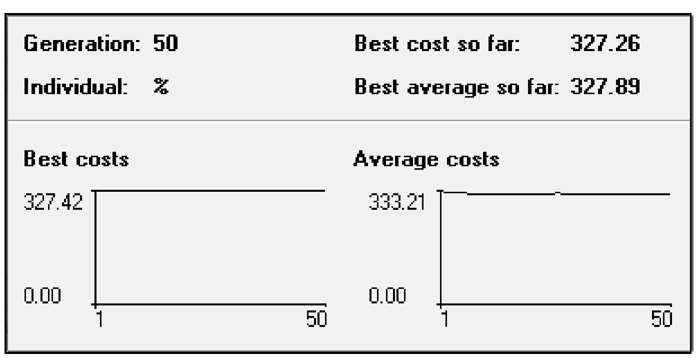

Figure 6: Best and average costs.