Solving Unit Commitment Problem with Wind Energy using Multi Agent Evolutionary Programming Optimization Technique

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***Abstract*—This paper presents an approach to search for an optimal solution for Unit Commitment Problem with wind power generation. The objectives of this research are to find the optimal cost of generation and to review the effect of the presence of renewable energy which is the wind energy in the conventional Unit Commitment problem. Unit commitment involves the scheduling of start-up and shutdown of generating units, an indirect determines the optimum power should be generated by each unit committed over a period of time to meet the required load demand at minimum possible cost. In this study, Multi Agent Evolutionary Programming has been used to solve the optimal unit commitment for 24 hour periods. Multi Agent Evolutionary Programming is a combination of two Artificial Intelligent techniques which are Multi Agent System and Evolutionary Programming. In this research, the Multi Agent Evolutionary Programming technique has been applied with 10 thermal based generator data along with wind power data. The 10 thermal generator data are collected from previous research paper while the data for wind power is collected from power forecasting report by National Renewable Energy Laboratory (NREL). This research has considered a few constraints that go along with Unit Commitment problem such as load demand constraint, generator limit, and 10% reserve margin. The comparison of the result obtained is to observe the performance of Multi Agent Evolutionary Programming technique against conventional Evolutionary Programming technique.**

***Keywords*—Unit Commitment, Multi Agent System, Evolutionary Programming, Wind Power**

I. Introduction

An electric power system network is electrical components network used to supply and transmit and use electric power either in DC or AC. Three major parts in power system consist of Generation, Transmission and Distribution. Power system planning consists of operation planning, improvement, expansion and optimization of the power system. Unit Commitment (UC) problem is about of having enough supply to the demand of consumer in optimal operational cost [1]. This is the most crucial part in electrical power system operation and planning.

Problems such as variations in load demand, increase in population size, number and type of generating facilities are the problem faced by power generation system operator. The unit commitment problem is a problem of selecting the right generating unit from the generating facilities to meet the consumer demand in a reliable and an economical way [2]. The objective of unit commitment study is to reduce the operational cost in power system planning hence help the country in improving the economy. In order to find the optimal unit commitment, there are few constraints that need to be taken into consideration such as load demand constraint, generator limit, spinning reserve, ramp-up constraint etc [3].

source since the world's fuel crisis has got out government attentions. This research is conducted as an effort to provide an analysis toward conventional system with the objectives to reduce the operational cost of electricity supply without affecting the power produced to consumer and to see the effect of using renewable energy (wind in this case) to the operational cost.

A. Unit Commitment

The power system unit commitment problem is the problem to decide which electric generating units should be running or turn on in each period to satisfy a predicted demand for electricity [4].

The electric consumption varies accordingly with its usage and the demand for electricity usually shows a major difference between peak hours and off-peak hours [5]. As a result, the existence of peak hours and off-peak hours makes all generating units at its maximum capacity and to leave them online continuously to meet the maximum demand are very uneconomical and costly. The unnecessary generating units might be turn off in order to save an operating system cost. The previous research shown many artificial intelligent techniques have been developed to solve UC problem with various constraint consideration [6]. The previous techniques such as improve particle swarm optimization (PSO) [7], EP based Tabu search method [8], hybrid Lagrange EP method [9] shown the successful in finding the optimal solution for UC with various constraint.

B. Wind Power

Renewable energy nowadays has been a reliable source in supplying the electricity power to grid system in the world including Malaysia because of its potential in generates electricity and as an alternative way to reduce the environmental pollution. This research introduces the wind power usage in the generation line as an objective to reduce the operating cost of power electricity supply to consumers. NREL United State has done with the analysis of wind power behavior. This research has used the wind data from the long-term analysis which conducted by NREL US to completing this research. NREL's wind power plant monitoring project has collected the data from seven different locations to see the capability of wind energy [10].

In Malaysia, the research show that the hybrid wind power installed at Perhentian Island show the potential of wind power source. Two main weather seasons had been experienced in Malaysia which is southwest monsoon which usually occurs in May to September and northeast monsoon which usually occurs between Novembers until March [11].

Wind speed is often below 7m/s during the southwest monsoon, but in the east coast of Peninsular Malaysia, wind speed could

Malaysia. For the purpose of study, this research has decided to use the wind energy data provided by NREL as an alternative to see the effect of the wind energy presence.

C. Evolutionary Programming

Evolutionary Programming (EP) is a one of Evolutionary Computation (EC) technique in AI hierarchy. It has been use as optimization problems tools in recent years [13], [14], [17]. Evolutionary Programming is a technique for optimization based on mutation process used to optimize any fitness which can be represented using mathematical equation [14]. EP algorithms based on initialization, fitness computation, mutation, combination, selection and new generation definition. General equation of mutation process is given by:

$$P'_n = P_n + \alpha.\beta_n \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where:
P'_n = offspring
$\alpha.\beta_n$ = mutation step size

EP can be divided into three types which are Classical EP, Meta EP and Adaptive EP. For this research, EP has been used as based concept of optimizing unit commitment problem. The concept of EP technique is based on competition of the fitness. In general, EP algorithm consists of three major parts or steps [15], [16], [17]:

i. Initialization
Initialization process is where the initial populations are being generated randomly based on its limitation. This generated population is then used to calculate the fitness based on its objective function ($f(x)$).

ii. Mutation
Mutation process is to generate the offspring from its parents. Then from the offspring, new fitness is calculated to perform optimization to the system.

iii. Combination and Selection
Combination process is the stage where the parent and its offspring is combined together to determine the fitness one. After that, the selection process comes through. The combination of parent and its offspring is whether in ascending order or descending order based on the fitness owned by the parents and offspring [13], [14].

D. Multi Agent System

Multi Agent System (MAS) is where Individual agents will interact with others to compete and trying to search for optimal performance and every agent has its sphere of influence. An agent is anything that can sense its surroundings with sensor and acts on those surroundings via actuators [15]. Individual agents will interact with others to compete and trying to search for optimal performance and every agent has its sphere of influence [16]. Each agent has its self-interact which is they do not share same goal. Multi Agent System is complex designed using these agents and these agents share common interest to achieve the same goal set by human. An agent can be whether autonomous, social, reactive and proactive depends on how the agents interact. Each agent has its self-interact which is they do not share same goal. The agent generally has the characteristics as follow [14]:

1. Able to live and act in its environment called global environment.
2. Able to interact and sense its own local environment.
3. It is driven by the certain purposed.
4. Able to respond to the change that happened using its learning ability.

E. Definition of the Global Environment

Figure 1 shows the lattice like configuration called the global environment. Every single agent in MAS is arrange together in matrix form or lattice-like environment. This is where the global environment, L is defined and the size of L is Lsize x Lsize, where Lsize is an integer [14]. Every agent in global environment will share together the information received by an agent through competition and corporation process in local environment.

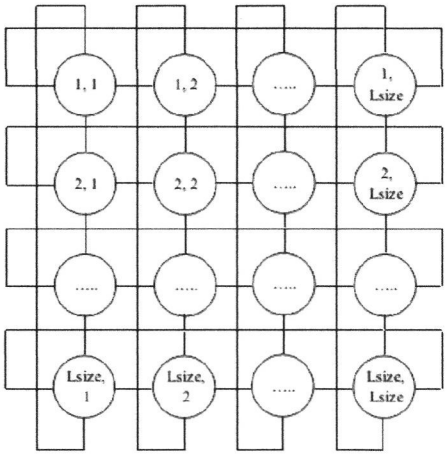

Figure 1: Lattice Environment

In Figure 1, an agent is represented by the circle it is hold its own coordinate in the lattice configuration. Every agent has its certain fitness value and control variables generated during the initialization process for the optimization problem.

F. Definition of the Local Environment

Local environment is where an agent is only able to interact, compete and cooperative with its own neighbourhood or namely local environment. Neighbours of an agent are chosen as they are located next to the agent [14]. For example, if an agent located at (i, j) is represented as $L_{i,j}$ where i,j = 1,2,....,Lsize [17]. The neighbours are coordinated as follow:

$$N_{i,j} = \{L_{i',j}, L_{i,j'}, L_{i'',j}, L_{i,j''}\}$$

Where:

$$i' = \begin{cases} i-1 & i \neq 1 \\ Lsize & i = 1 \end{cases} \qquad j' = \begin{cases} j-1 & j \neq 1 \\ Lsize & j = 1 \end{cases}$$

$$i'' = \begin{cases} i+1 & i \neq Lsize \\ 1 & i = Lsize \end{cases} \qquad j'' = \begin{cases} j+1 & j \neq Lsize \\ 1 & j = Lsize \end{cases}$$

So, each agent has only four neighbors and this local environment can sense the information that speared around its environment before the information is speared into the global environment.

G. Purpose of Agents

In the proposed technique, the purpose of each agent is to find the optimal point of unit commitment in order to give the minimum cost at required demand.

H. Agents' Behavior

i. Competition and Cooperation Operator
Each Agent will cooperate and compete with each other and who ever win will hold the place. A located agent will compete with its neighbours and who ever win will remain in located agent place [14].

ii. EP Operator
In order to compete with each other, the EP operation which mutation stage is act as the main process to obtain the best agent between its neighbours. The Agent and its four neighbours will go through the mutation process and who ever pass the constraint will be the winner [14].

II. PROBLEM FORMULATION

A. Unit Commitment's Objective Function

The objective function in this research is the total operation cost for one day. The total operation cost for one day is based on the cost generated by 10 thermal generators and its startup cost. The power production cost formulation is given by:

$$F_{it}(P_{it}) = a_i + b_i P_{it} + c_i P^2_{it} \dots\dots\dots\dots (1)$$

Where:
a_i, b_i, c_i = Cost parameter of unit i ($/MW^{2}h, $/MWh, $/h)
P_{it} = Output power of unit i at t time (MW)

The startup cost in this research is based on the hot start-up cost which is the generator unit is assumed to be turn off recently and still in warm condition. The formulation for the start-up cost is given as:

$$S_{it} = ST_i \dots\dots\dots\dots\dots\dots (2)$$

Where:
ST_i = Hot start-up cost for Unit I ($)

So, the total operation cost is the summation of production cost and start-up cost and given by:

$$F_T = \sum_{t=1}^{T} \sum_{i=1}^{N} (F_{it}(P_{it})U_{it} + S_{it}V_{it}) \dots\dots\dots\dots (3)$$

Where:
U_{it}= Status of unit i (t=1 for on state, t=0 for off state)
S_{it}= Start-up cost of unit i at t hour ($)
V_{it}= startup status of unit i at hour t

B. Unit Commitment's Constrains Consideration

There are a few constraints in unit commitment that have been taken into consideration in conducting this project:

1. Load Demand
To satisfy the consumer's load demand for 24 hours periods, the real power (MW) produced by generating units shall be truly sufficient [5]. The constraint condition is given by

$$\sum_{i=1}^{N} P_{it}U_{it} = PD_t \dots\dots\dots\dots (4)$$

Where,
PD_t = The system peak demand at hour t (MW)
N = Number of available generating units

2. Generator Limit
Generator thermal units of temperature and pressure must be synchronized before initiating to online since they vary rapidly. The factor like maximum and minimum allowable power generated by each generator considered as generator limit in this research [17].

3. Spinning Reserve
Spinning reserve is the present load and the losses minus by the total real power generation generated from all the synchronized units. The 10% reserve margin at the estimated peak demand is assumed to be reserve. Furthermore, it must be truly sufficient to cover up the loss for the most heavily loaded condition in the power system [17]. The given equation below need to be satisfies.

$$\sum_{i=1}^{N} Pmax_i U_{it} \geq (PD_t + R_t); 1 \leq t \leq T \dots\dots\dots\dots (5)$$

Where,
$Pmax_i$ = Maximum generation limit of unit I
R_t = Spinning reserve time t (MW)
T = Time horizon schedule (24 h)

III. METHODOLOGY

Generally, this research is done by using combination of two artificial intelligent methods which are Evolutionary Programming and Multi Agent System. The basic operations of Multi Agent Evolutionary Programming (MAEP) consist of 6 major steps as show in Figure 2 below. The different between MAEP optimization technique with conventional EP is the arrangement of the agents. The conventional EP technique does not have an arrangement of the agents. General flow chart for the whole simulation program is shown in Figure 2. EP is used to the populations (initialization process), mutation, combination, selection and convergence test while multi agent system is used to arrange the agents in a lattice environment and the interaction among an agent and its neighbours is considered. The neighbours of an agent are live around the agent itself. One agent can only have four neighbours and these neighbours defined themselves as the local environment. This is where the interaction between agent and its neighbours occurred. The detailed flow chart can be seen in Figure 3.

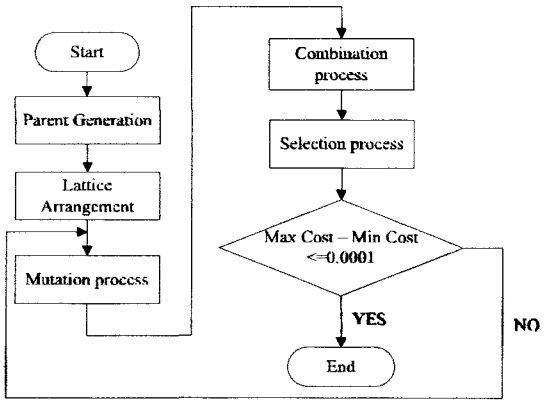

Figure 2: General Flow Chart of MAEP Program

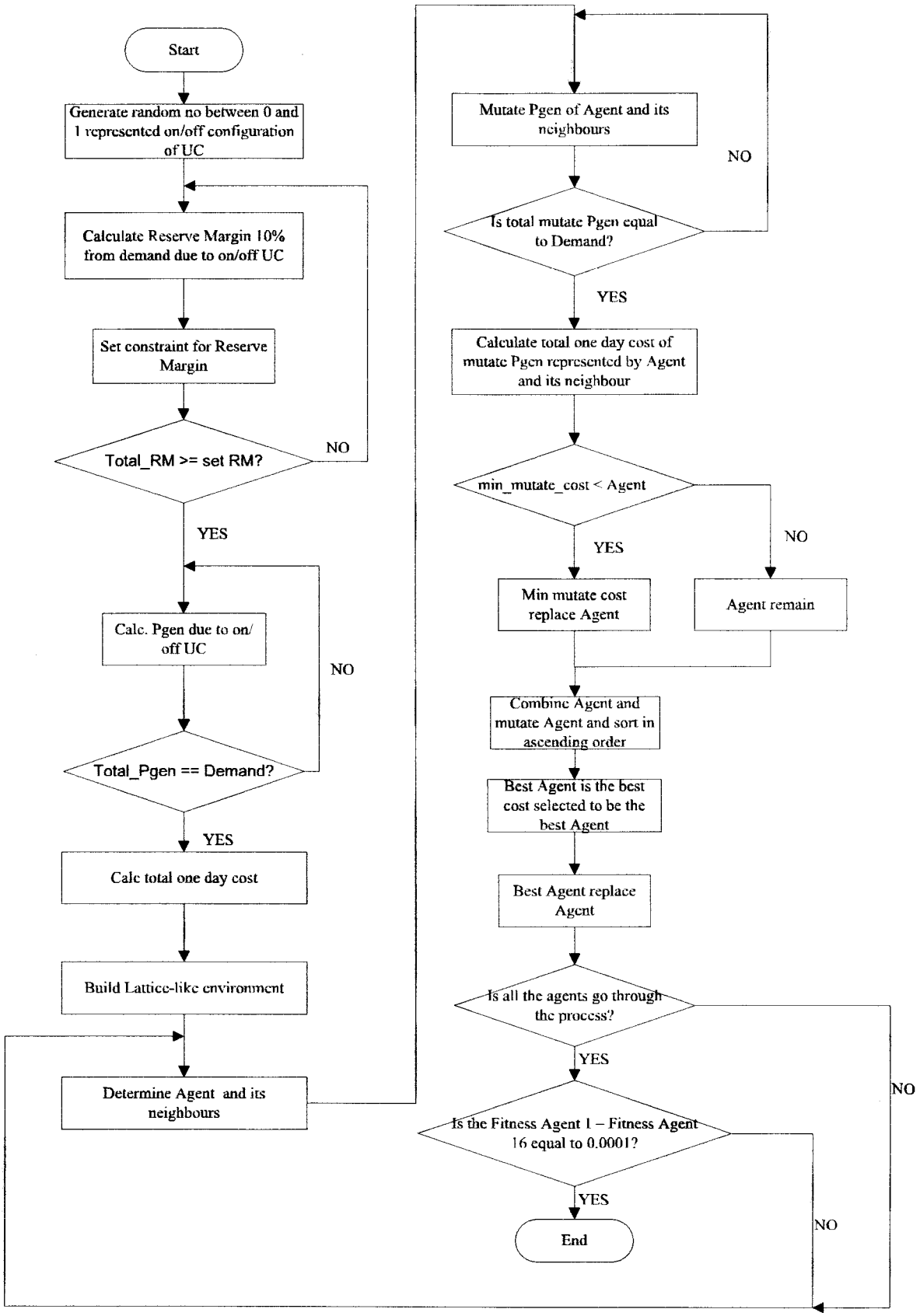

Figure 3: Full Flow Chart of MAEP Program