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.

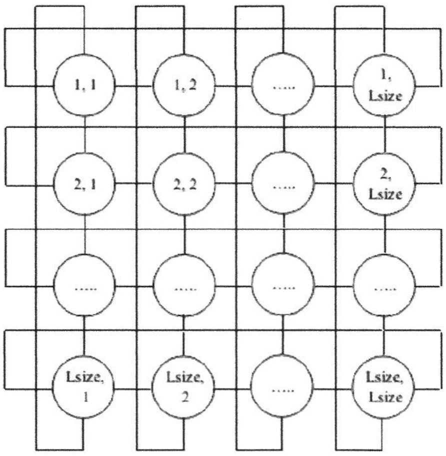

Figure 1: Lattice Environment

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:

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

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:

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

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:

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

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

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

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.

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

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.

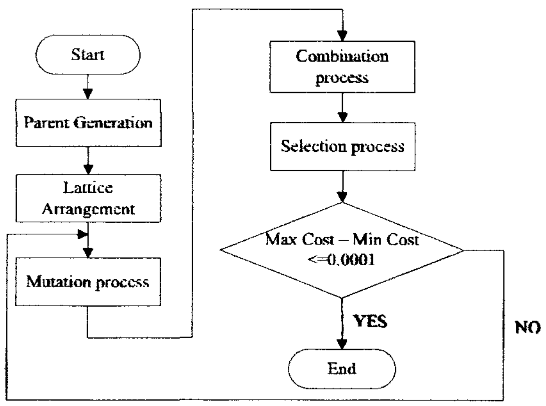

Figure 2: General Flow Chart of MAEP Program

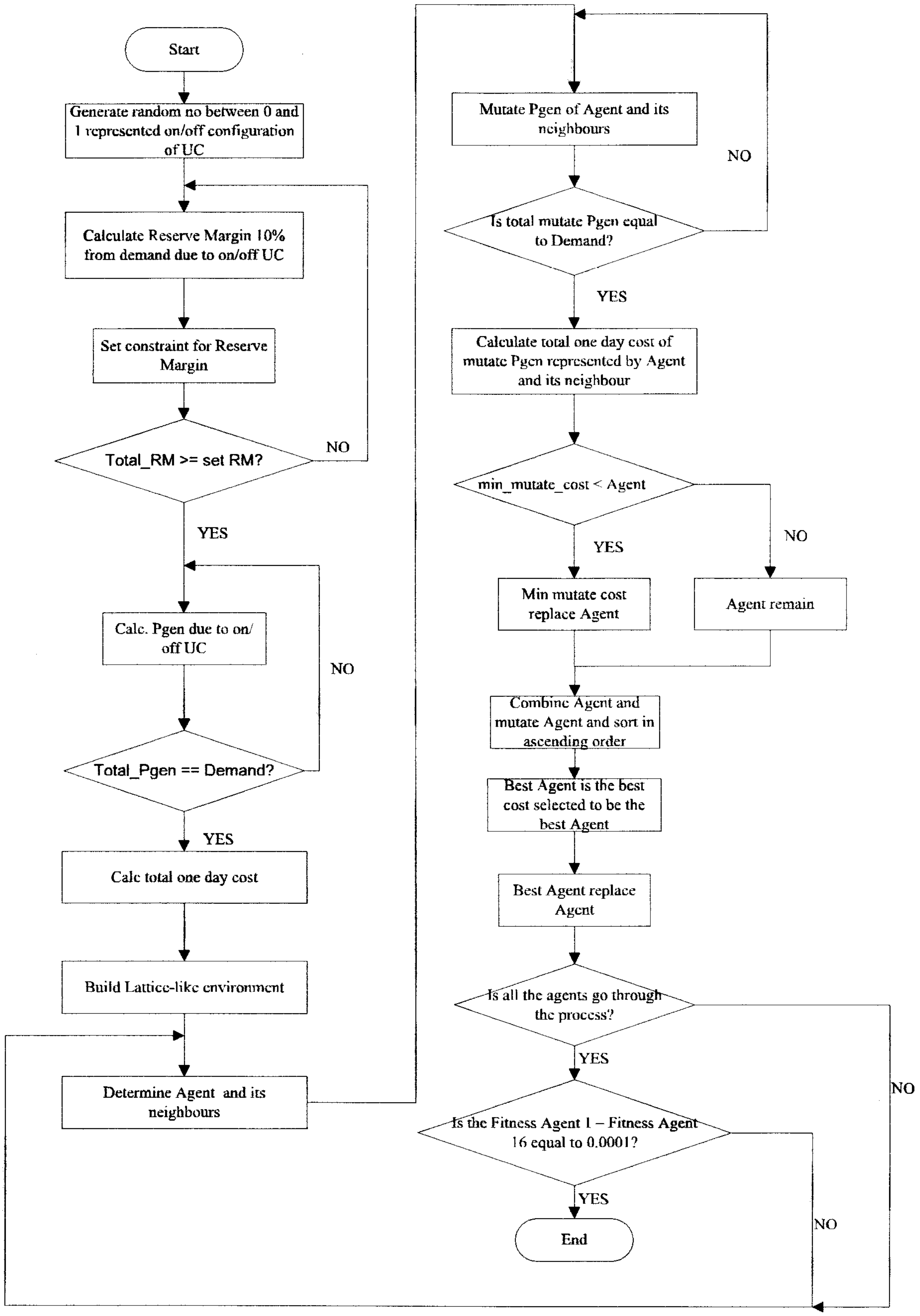

Figure 3: Full Flow Chart of MAEP Program

The detailed steps in developing MAEP program as follow:
Step 1: Generate randomly number between 0 and 1 to represent ON/OFF state of UC. (1 for ON state, 0 for OFF state).

Step 2: Calculate the reserve margin which is 10% from demand due to state of UC.

Step 3: Set the constraint for Reserve Margin (RM).

Step 4: Repeat the step 2 and three if the RM did not pass the constraint.

Step 5: Calculate Power generated (Pgen) due to on/off state of UC and its maximum and minimum allowable power.

Step 6: Set the demand constraint.

Step 7: Repeat step 5 if Pgen did not pass the demand constraint.

Step 8: Calculate the total operation cost for one day. The calculation is based on the formula stated in (3).

Step 9: The lattice-like environment is build based on the populations

Step 10: Determine the Agent and its neighbours. for 1 agent it should have 4 neighbours.

Step 11: Mutate agent and its neighbours which is represented by Pgen.

Step 12: Calculated the total mutate Pgen and set the Demand constraint.

Step 13: Repeated step 11 and 12 if total mutate Pgen did not meet the constraint set.

Step 14: Calculate total one day operation cost of mutate Pgen represented by an Agent and its neighbours.

Step 15: Set the constraint for the minimum mutate cost < Agent.

Step 16: If the minimum mutate cost pass the constraint, replace old cost of Agent with mutate cost. If it did not pass the constraint, old cost of agent is remains.

Step 17: Set the constraint of the pool in lattice environment.

Step 18: Repeated step 11 until step 17 if pool in lattice in no meet the constraint set.

Step 19: Combine and sort all agent in ascending order to determine its minimum and maximum.

Step 20: Set the constraint for all agents (Agent 1 – Agent 16 <= 0.0001).

Step 21: Repeat step 11 until step 20 if the constraint set in step 20 did not meet.

IV. System Data

The data used in this research is taken from 10 unit base data [16] and wind power data is obtained from the study analysis performed by NREL United Stated [10]. Tables below show the data used in this research. The 10 unit generation data is commonly used in previous study [16]. Table I until Table III shows the unit data parameter which is used in this research for the 24 hours system. Since this research is only considered the operational cost, so the operational cost for wind energy is considered 0 (do not involved the operation cost at all) since the energy produce by wind is costless.

TABLE I. FORCASTED DEMAND FOR 24-HOURS PERIOD

Hour	Forecasted Demand (MW)	Hour	Forecasted Demand (MW)
1	700	13	1400
2	750	14	1300
3	850	15	1200
4	950	16	1050
5	1000	17	1000
6	1100	18	1100
7	1150	19	1200
8	1200	20	1400
9	1300	21	1300
10	1400	22	1100
11	1450	23	900
12	1500	24	800

TABLE II. FORCASTED WIND DATA FOR 24-HOURS PERIOD

Hours	Power(MW)	Hours	Power(MW)
1	62	13	35
2	35	14	42
3	28	15	42
4	16	16	65
5	38	17	42
6	25	18	28
7	35	19	42
8	28	20	78
9	56	21	84
10	48	22	82
11	36	23	84
12	52	24	72

TABLE III. OPERATIONAL COST AND POWER LIMITATION FOR 10 THERMAL GENERATING UNITS

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5
Pmax(MW)	455	455	130	130	162
Pmin(MW)	150	150	20	20	25
a $/MW²h)	1000	970	700	680	450
b ($/MWh)	16.19	17.26	16.60	16.50	19.70
c ($/h)	0.00048	0.00031	0.00200	0.00211	0.00398
ST	4500	5000	550	560	900

TABLE IV. OPERATIONAL COST AND POWER LIMITATION FOR 10 THERMAL GENERATING UNITS

	Unit 6	Unit 7	Unit 8	Unit 9	Unit 10
Pmax(MW)	80	85	55	55	55
Pmin(MW)	20	25	10	10	10
a ($\$/MW^2h$)	370	480	660	665	670
b ($/MWh)	22.26	27.74	25.92	27.27	27.79
c ($/h)	0.00712	0.00079	0.00413	0.00222	0.00173
ST	170	260	30	30	30

V. RESULTS AND DISCUSSION

There are two cases considered in this testing system. The proposed technique is tested on 10 unit base problem to see how much the percentage can be saved using this technique. The associated of wind data also tested to see the effect of wind power in the operating cost. Case 1 is to determine the operation cost for a day using 10 thermal generation units. For Case 2, the study is to determine the operational day cost using 10 thermal generations and 1 wind power turbine. In Case 2, it is decided that the wind power is always on due to its capability to generate power for the whole day. This study also decided to turn off one of the thermal generator which generator unit no. 10 whenever wind turbine is operated.

A. Determination of Number of Trials

First off all, the analysis is to find the best trial for the system is said to be converge. The simulation is all done through 10 trials on 4 populations (Pops). The fitness here as know is the operating cost for a day. Three ranges of cost have been taken into considerations which are best cost, average and worst cost. Table V shows the recorded result for the trial analysis. To know on what trial the system said to be converged, the data in Table V is transformed into the graph plotted shows in Figure 4. From 10 trials, based on the graph shown in Figure 4, the system is said to be converge when it is done with 5 trials. From Figure 4, the value of cost is start to maintained when the 5 trials is performed. So that, the system is said to reach it convergence value is in 5 trials. Therefore, the number of trials is chosen for entire analysis is 5.

TABLE V. OPERATION COST FOR 24-HOURS PERIOD FOR 10 THERMAL GENERATING UNITS FOR 4 POPULATIONS USING MAEP TECHNIQUE

Trial	Pops	Cost ($) Best	Average	Worst	Elapse Time (H)
1	4	612183.18	612183.18	612183.18	0.38
5		592722.16	593145.07	595093.35	3.31
10		589167.37	591134.43	593237.18	5.35

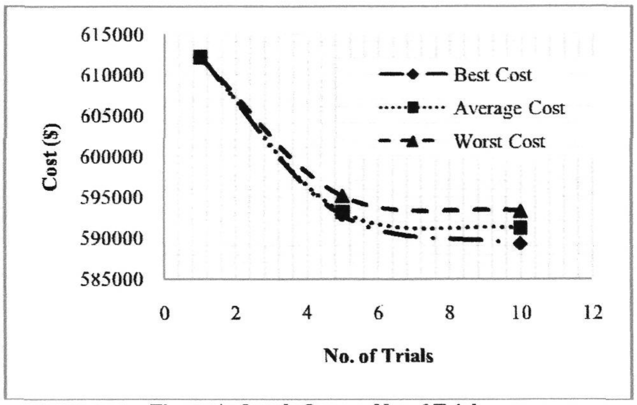

Figure 4: Graph Cost vs. No. of Trials

B. Determination of Number of Populations

This analysis is about to decide the best population's numbers to set to proceed to next analysis. Theoretically, it is said that the higher number of populations, the better cost is produced. The analysis is decided to go through 3 different population numbers which are 4, 9 and 16 population numbers. From these 3 population numbers, the ones who produce lowest result will be determined as best population and this population will be used for the next analysis. These populations are decided based on the optimization technique used in the analysis. Since the method involves MAS, the population size is determined by lattice size which is Lsize x Lsize. Therefore the population used is decided to be 4, 9 and 16. The analysis is done on 10 thermal based generating units. All these three population is gone through 5 trials and the result is recorded in Table VI. Table V and VI show the total operation cost for a day without wind power (Case 1).

TABLE VI. OPERATION COST FOR 24-HOURS PERIOD FOR 10 THERMAL GENERATING UNITS USING MAEP TECHNIQUE

	Pops	Cost ($) Best	Average	Worst	Time Elapse (H)
5 Trials	4	589210.17	591360.34	600691.74	3.12
	9	586672.23	591170.05	600517.16	10.22
	16	582950.44	590004.61	600361.31	18.24

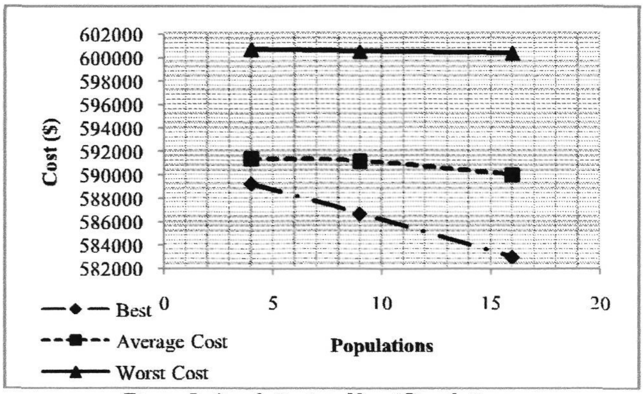

Figure 5: Graph Cost vs. No. of Populations

Based on graph in Figure 5, it is shown that the analysis at 16 populations produced the lowest cost among these three different populations. Thus, 16 population numbers are chosen for entire analysis

C. Comparison of Performance between EP and MAEP

As a benchmarking, EP technique is used against the MAEP technique. This analysis is conducted to see and compare the performance of the proposed technique against conventional EP technique. Using the data of trials and population numbers in previous analysis, the data of 5 trials and 16 population numbers is proceeded to test the reliability and performance of the proposed technique against the conventional EP technique. In this section, along the comparison between these two techniques, the wind data also being implemented to see the effect after installation of wind power generator. The result obtained from the simulation is recorded in Table VII and Table VIII for 10 thermal based generating units and 10 thermal based generating units integrated with 1 wind generator unit respectively.

TABLE VII. COMPARISON OF OPERATIONAL COST BETWEEN EP AND MAEP TECHNIQUE FOR 10 THERMAL GENERATORS WITH WIND ENERGY

			Technique	
	Cost ($)	**Populations**	**MAEP**	**EP**
5 Trials	**Best**	16	561440.02	581269.12
	Average		565562.22	594900.17
	Worst		570694.13	601331.75
Time Elapse (H)			18.31	22.24

TABLE VIII. COMPARISON OF OPERATIONAL COST BETWEEN EP AND MAEP TECHNIQUE FOR 10 THERMAL GENERATORS WITHOUT WIND ENERGY

			Technique	
	Cost ($)	**Populations**	**MAEP**	**EP**
5 Trials	**Best**	16	582953.00	610054.19
	Average		592172.23	620244.65
	Worst		600365.05	623370.04
Time Elapse (H)			20.11	25.61

As the previous analysis, the operational cost produced through the simulation result is divided into 3 categories which are best cost, average and worst cost. Based on Table VII, it can be seen MAEP technique produce lower cost than using conventional EP technique. Based on Table VII, using EP technique, the best and operational cost produce are $ 610,054.19 and $ 623,370.04 respectively, while using MAEP technique, the best and worst operational cost produce are $582,953.00 and $ 600,365.05 respectively. Averagely, using MAEP technique, it can reduce the operational cost around 4.4% in a day or $ 27, 000 in a day. As for Table 8, it is shows the operational cost using 10 thermal generators without using wind power generator. Based on Table 8, using EP technique, the best and operational cost produce are $ 581,269.12 and $ 601,331.75 respectively, while using MAEP technique, the best and worst operational cost produce are $ 561,440.02 and $ 570, 694.13 respectively. By comparing the result obtained in both Table VII and VII, using wind power in the generation system can reduce the operational cost about 3.8% per day or $ 21, 000. This is due the wind which is did not require any operational cost to produce energy.

D. Best UC Scheduling with the use of Wind Energy using MAEP Technique

From the analysis of 16 population numbers with 5 trials, the best power generated and the total operation cost is shown in Table IX and X for using 10 thermal generators only and using 10 thermal generators associated with wind power turbine respectively. The sample of best power generated is taken from the best cost produced in both Table VII and VIII. From the best cost obtained in both cases, its generated power is recorded in Table IX and X. The data contained the power generated for 24-hours by 10 thermal based generator and 1 wind power generator. The Total Demand shows in Table IX and X are the summation of power generated for every one hour. It can be seen the amount of Total Demand is same with forecasted demand show in Table 1 in system data section. The total cost of power generated is calculated using the formula in (3) under Problem Formulation section and it is shown below the both Table IX and X. The Total Cost $ 582, 953.00 and $ 561440.02 shows under the both Table IX and X are the total cost calculated for the power generated in both table and represents the best cost using MAEP technique for 16 population numbers with 5 trials. From table IX and X, it can be seen that most power generated from generator unit 1 and unit 2. This is because those two generators have a cheaper value in cost.

TABLE IX. BEST POWER GENERATED FOR 16 POPULATION FOR 10 THERMAL GENERATOR USING MAEP TECHNIQUE

Units	Power (MW) Hours																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	451	444	415	294	355	426	415	439	453	410	437	438	450	355	449	421	349	443	407	454	455	387	254	343
2	0	0	0	357	422	374	426	371	445	439	441	452	450	436	419	401	442	265	413	385	432	438	447	314
3	105	122	119	128	79	127	119	114	100	118	56	107	108	101	113	102	102	128	116	105	114	130	107	110
4	67	0	0	129	0	0	0	0	0	107	115	130	84	97	86	0	0	62	62	127	98	0	0	0
5	0	66	159	0	28	85	141	80	101	77	147	154	99	125	0	27	107	151	75	130	105	83	0	0
6	0	73	73	0	76	45	0	76	77	65	74	79	78	63	0	0	0	0	0	54	76	0	0	0
7	0	0	69	0	0	0	0	85	54	71	78	37	77	0	41	0	0	0	50	41	0	62	63	0
8	0	45	15	42	15	0	34	0	51	40	52	37	0	38	40	49	0	31	34	50	0	0	0	0
9	23	0	0	0	0	0	15	0	19	42	34	28	54	47	25	50	0	20	0	24	20	0	0	33
10	54	0	0	0	25	43	0	35	0	31	16	38	0	38	27	0	0	0	43	30	0	0	29	0
Total Demand	**700**	**750**	**850**	**950**	**1000**	**1100**	**1150**	**1200**	**1300**	**1400**	**1450**	**1500**	**1400**	**1300**	**1200**	**1050**	**1000**	**1100**	**1200**	**1400**	**1300**	**1100**	**900**	**800**

Total Cost = $ 582,953.00

TABLE X. BEST POWER GENERATED FOR 16 POPULATION FOR 10 THERMAL GENERATOR AND 1 WIND POWER TURBINE USING MAEP TECHNIQUE

Units	Power (MW) Hours																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	428	452	444	438	441	407	447	346	445	440	444	442	432	454	407	333	438	353	453	372	365	412	418	435
2	0	0	0	324	406	437	351	443	416	418	450	439	438	354	425	419	386	449	429	432	439	403	310	0
3	121	99	94	93	23	91	48	101	122	125	123	117	122	89	109	60	58	69	89	112	123	125	96	120
4	0	0	104	0	0	28	66	95	113	103	97	127	122	88	83	127	80	89	0	126	91	33	0	0
5	76	50	133	0	0	78	60	137	94	81	101	149	134	157	0	0	0	0	93	161	74	0	0	37
6	0	0	50	45	46	0	66	0	26	69	51	62	29	60	0	0	0	72	44	49	74	53	0	77
7	0	70	0	0	0	0	80	0	0	39	74	37	48	60	81	52	0	0	0	63	0	0	0	66
8	0	0	0	0	50	36	0	0	0	46	27	28	43	0	25	0	0	0	45	15	11	0	0	0
9	19	47	0	36	0	0	0	53	34	36	51	52	0	0	32	0	0	43	0	0	47	0	0	0
10	off																							
wind	56	32	25	14	34	23	32	25	50	43	32	47	32	38	38	59	38	25	47	70	76	74	76	65
Total Demand	**700**	**750**	**850**	**950**	**1000**	**1100**	**1150**	**1200**	**1300**	**1400**	**1450**	**1500**	**1400**	**1300**	**1200**	**1050**	**1000**	**1100**	**1200**	**1400**	**1300**	**1100**	**900**	**800**

Total Cost = $ 561,440.02

VI. CONCLUSION & RECOMMENDATION

The proposed MAEP technique successfully solved the UC problem with the cost reduction of \$ 27, 000 as compared to conventional EP technique. With the implementation of wind energy, the total operational cost is further reduced as much as \$ 21, 000 or around 3.8% for a day as compared to without implementing the wind energy. From the results obtained, MAEP technique is a good technique to be implemented to the power system planning to help the economy of the country. Also, the implementation of renewable energy in power system planning is a great way to improve the national economy. From the analysis done, it is important to find the optimal solution for unit commitment in order to help the country in improving the economic.

As recommendation, the research can be further extended with improving the proposed technique by combining others artificial intelligent methods as an effort to get a better result and more reliable system. It is also possible to integrate other power source to the system such as solar, wave power, nuclear, and etc.

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