Solving Unit Commitment Problem with Solar Plant by Using Improved Evolutionary Programming

Mohamad Izazuddin bin Hassan

Faculty of Electrical Engineering
Universiti Teknologi MARA Malaysia
40450 Shah Alam, Selangor, Malaysia
e-mail: izzad89@yahoo.com

Abstract— **The aim of this paper is to solve the Unit Commitment Problem with Solar Plant using Improved Evolutionary Programming technique. The objective of this study is to search for minimum operational cost while satisfying the ranging load demand, to compare the performance of Improve Evolutionary Programming with Evolutionary Programming before installing Solar Plant and after the installation. The constraints considered in this research include spinning reserve margin, load demand, power and reserve limit, and also start-up cost. The improve technique is based on conventional technique where, the only difference is that in the initialization process instead of generating 20 population this Improve Evolutionary Programming generating 100 population to have wide range of data and from this it will select the best possible data combination. It also consist of three main steps, initialization, mutation, selection. The result obtain are shown in the result and the performance of Improve Evolutionary Programming are shown.[1, 2]**

Keywords— Evolutionary Programming, Unit Commitment, Solar Generator, power system operation planning

I. INTRODUCTION

Nowadays, the increase in load demand gives big problem for generation operation to meet the load demand. If the generation operation runs all the generators at maximum operation it will meet the demand, it will increase the cost of operation. Thus, an efficient Unit Commitment (UC) plays a significant role in short-term operation in the power system and in the economy.

This paper proposed Improve Evolutionary Programming (i-EP) technique to solve UC problem. This technique is based on conventional Evolutionary Programming (EP). This technique choose because of its simplicity and easy to develop and upgrading from conventional EP. Renewable Energy (RE) implementation is one of the way to improve/reduce the operating cost, since RE required less operational cost compare to other generation. They are many type of RE such as Solar, wind, wave, etc. for this research the Solar was choose to implement in this system.[3-5]

A. Unit Commitment

UC is defined as a process to determine the best combination which power plant or generator to turn on/off to meet the load demand in order to reduce the operating cost. UC has some parameter to be meet such as minimum up and down time, minimum operation point, also for economic consideration such as start-up and operation cost and for social element, which is the existing of work schemes and staff [6, 7].

The objective of UC is to minimize the production cost, startup cost, shutdown cost, transition cost and so on. Also, UC predicts the suitable set of units to run the generator that will provide the predicted load to the system[8].

B. Improve Evolutionary Programming

The EP is defined as optimization process. This method will optimize any fitness that can be represented using mathematical equations. The objective function of this method is either to minimize or maximize the fitness. This method it will predict and simulate the best result in order to solve the UC problem [3]. This technique was introduces by Lawrence j. Fogel at 1960, this method was used to simulate evolution to generate artificial intelligence (AI) for the learning purpose.

i-EP technique consist of three main steps which is initialization, mutation, and selection. However, the only difference i-EP and EP in the initialization process, instead of generated 20 population randomly in EP, the i-EP will generated 100 population randomly to have wide range of data. Based on wide range data it will select the best possible combination to get the lowest cost.

C. Solar Plant

Solar Plant (SP) is the current technology under RE that used nature resource to operate. This technology it will reduce the cost of operation. Since, SP required less cost of operation, last longer and need minimal maintenance, but the initial cost to install SP is high and the profit will show in long-term used. For this study purpose the data are based in Integrated Renewable Energy Park (IREP) in Pajam, Negeri Sembilan, Malaysia which is can produce 13MW of solar energy [9]. This SP will only operate for less than 7 hour continuously and also depend on weather in installation areas either it will be cloudy or not because cloud will act as shedding to the SP and it will not produce the power to it maximum.

II. PROBLEM FORMULATION

A. Objective Function

The objective function of this research is to find the minimum cost of total operation to meet demand power, when subjected to several of constraints. The cost functions shows as below (1).[7, 10]

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

Where:-

a_i, b_i, c_i	cost parameter of unit i ($/MW²h, $/MWh , & $/h)
$F_{it}(P_{it})$	production cost of unit i at a time t ($/h)
P_{it}	output power from unit i at time t (MW)

The startup costs depends on the downtime of the unit, which will vary from a maximum value, when the unit i is started from cold state, to a much smaller value, if the unit i has been turned off recently. The startup costs calculation depends upon the treatment method for the thermal unit during downtime periods. The startup cost S_{it} is a function of the downtime of unit i as given in (2)[6, 10]

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

Where:-

ST_i unit i cold start-up cost ($)

Therefore, the total objective function of the UC problem is given in (3)

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

Where:-

U_{it}	unit i status at hour t=1 (if unit is ON), & t=0 (if unit is OFF)
V_{it}	unit i startup status at hour t=1 if the unit is started at hour t
S_{it}	startup cost of unit i at hour t ($)
F_T	total operating cost over the schedule horizon ($/h)

B. Constrains

In this UC problem is considered several constrains, such as load demand, spinning reserve margin, and power and reserve limit, etc.

1) Load Demand Constrain

The power generated must meet the load demand and satisfy the following equation given in (4)

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

Where:-

D_t Forecasted Demand at hour t (MW)

2) Spinning Reserve margin Constrain

The total power generated at maximum for all generator must meet the reserve demand and satisfy the following equation given in (5). This spinning reserve margin was set to 10% of demand

$$\sum_{i=1}^{N} Pmax_i U_{it} = R_t \quad (5)$$

Where:-

R_t Forecasted Reserve at hour t (MW)

3) Power and Reserve limit

The power generated and reserve must meet the factor in (6-8)

$$Pmin_i \leq P_i \geq Pmax_i \quad (6)$$

$$0 \leq R_i \geq Pmax_i - Pmin_i \quad (7)$$

$$R_i + P_i \leq Pmax_i \quad (8)$$

Where:-

i = 1,2,3,…,N

III. TEST SYSTEM DATA

A. 10 Unit Thermal Test System

In this paper, a ten-unit for 24-period system is used to solve this problem and the data are based on IEEE. Table 1 show the Forecasted Load Demand and reserve for 24-hour period. This load must be complying for each hour and at the same time take into consideration the spinning reserve margin and this spinning reserves margin was set to 10 % and the data are shown in table 2 below.[7]. This margin will be adding to load demand and this load must meet after the generator run to it maximum. This reserve is for contingency load.

Meanwhile, Table 2 show unit data for 10-unit test system consist of power maximum and minimum, cost in-term of a, b, c and start-up cost. This data is used to generate power and for costs calculation.

TABLE 1
FORECASTED DEMAND AND RESERVE FOR TEN-UNIT 24-PERIOD SYSTEM

Hour	Forecasted (MW)		Hour	Forecasted (MW)	
	load	Reserve		load	Reserve
1	700	70	13	1400	140
2	750	75	14	1300	130
3	850	85	15	1200	120
4	950	95	16	1050	105
5	1000	100	17	1000	100
6	1100	110	18	1100	110
7	1150	115	19	1200	120
8	1200	120	20	1400	140
9	1300	130	21	1300	130
10	1400	140	22	1100	110
11	1450	145	23	900	90
12	1500	150	24	800	80

TABLE 2
UNIT DATA (TEN-UNIT 24-PERIOD SYSTEM)

	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

	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 ($/MW²h)	370	480	660	665	670
b ($/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

B. 1 Unit Solar plant

For this study purpose, one-unit of SP was used for the second case which are implementation of SP. The data are based on Integrated Renewable Energy Park (IREP) in Pajam, Negeri Sembilan, Malaysia which is can produce 13MW of SP [9]. The addition of solar assume to be able to produce 12MW per-hour after consider 10% reserve margin for simplification of analysis

TABLE 3
UNIT DATA (ONE-UNIT OF SOLAR GENERATOR)

	Unit 1
Pmax (MW)	13

IV. APPLICATION OF IMPROVE EVOLUTIONARY PROGRAMMING

The goal of this study is to optimize the total operation cost that the demand is meet without violating any constraint.

i-EP technique involves three mains process which, is initialization process, mutation process and combination and selection process. This process will continue until the stopping criteria satisfied. A summary of this technique show in Figure 1 detailed descriptions of this technique in solving UCP are as follow.

The detail process for i-EP as describe below.

Step 1 : Produce UC at random
The power produce from each generating unit which turn on without violating any constraint and satisfy the load demand. This population generation process occur at random.

Step 2 : Test generated population with system requirement
Power produce will be verify wither it comply or not. If any generated violated the requirement the process will return to step 1.

Step 3 : Store the obtain data in parent pool
If all requirement satisfy, the UC and generated power will be store in parent pool.

Step 4 : Store the obtain data in parent pool
If the population size not equal to 100, the process will back to step 1.

Step 5 : Cost calculation and selection
From the data store in parent pool it will be used to calculate the unit cost, fuel cost, start-up cost and total cost. After complete the cost calculation it will sort the total cost in ascending order and will select the best cost for mutation process, P. This, P will be varies.

Step 6 : Perform mutation process to produce Offspring pool
The mutation process will be perform to each parent pool to produce Offspring pool with the same size as parent.

Step 7 : Combination of Parent pool and Offspring pool

Step 8 : selection process
The combine pool will be sort ascending order and the P lowest cost will be selected as new population.

Step 9 : Convergent test
Compare the best fitness to the worst fitness and if the difference is zero, the solution is said to be converge and the process ended. Otherwise step 6 to 8 will be repeated again.

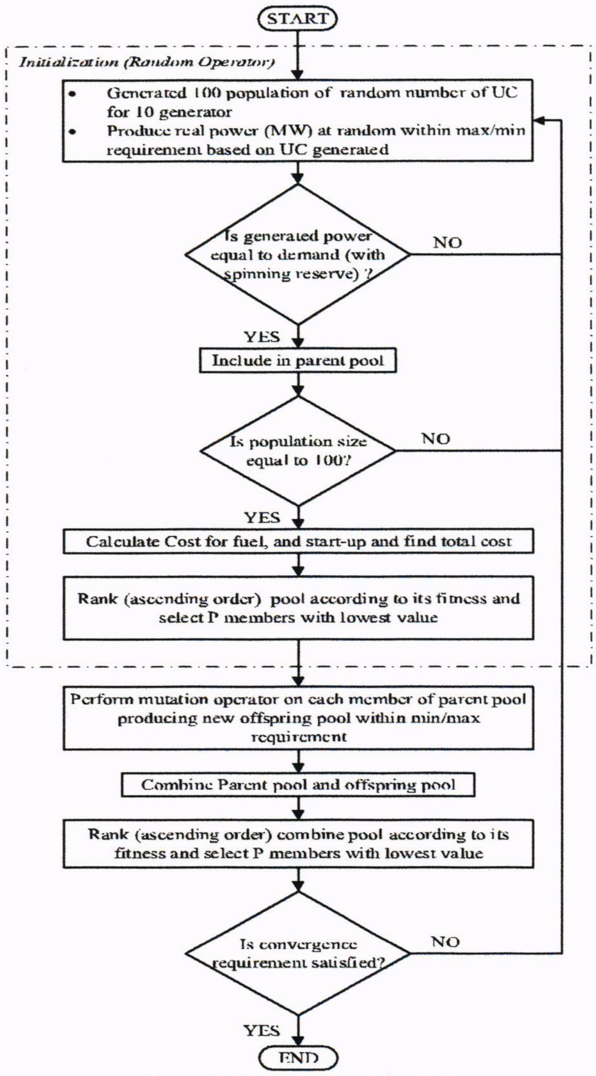

Figure 1 i-EP Process in solving UCP

A. Initialization

1) Evolutionary Programming

The first step of EP is to generate random number for the selected control variables. As for UC problem, the process of random number generation applied for both cases since the purpose of this case is to investigate the original cost without SP and with SP. In this case, there are constraint that need to be comply which is UC, power reserve limit, spinning reserve margin, load demand. The ranges of random numbers generated are between 0 to 1 only since it will indicate either the generator turn ON/OFF only.

2) Improve Evolutionary Programming

To get the better result the initialization process was improved instead generated 20 populations for EP this i-EP will generate 100 population.

In initialization, the parent is generated from random number. This parent consists of 100 population. From this it will calculate the power generated without violating any constraint. After that it will calculate the cost of operation and from this cost it will select of the best cost which, is the lowest cost.

B. Mutation

Mutation operator is used to generate the off-springs (P_n') of the parents (P_n)., the previous generated data will be mutating into an acceptable range. This is given in equation (8)

$$P_n' = P_n + \alpha.\beta_n \tag{8}$$

Where:-

$$\alpha = \eta.\exp(\tau'.\beta_o + \tau.\beta_n) \tag{9}$$

$$\beta = N(\mu, \sigma^2) \tag{10}$$

and,

$$\tau = \frac{1}{\sqrt{2(\sqrt{m})}} \tag{11}$$

$$\tau' = \frac{1}{\sqrt{2m}} \tag{12}$$

α mutation factor of n-th individual

β Gaussian random variable

$N(\mu,\sigma^2)$ with mean, μ and variance, σ^2 which are equal to 0 and 1 respectively

β_o initial random variable of each individual of the test system

β_n denotes the n-th individual component of Gaussian random variable

η strategic parameter for mutation of Parents, P_n, which generated randomly with mutation scale $0<\eta\leq 1$.

m number of decision variable in an individual.

This new mutated data is so-called as the off-springs. Then, the off-spring will be used to replace the old data to compute the new cost in the system. In this paper, the mutation process is used to compute the new cost values.

C. Combination and Selection

Combination operator is the combination of random generated data and the off-springs. Then, it is sorted in ascending or descending order. In this paper, the data are arranged in ascending order since it was purposed to minimize the cost. Then, the selection process is implemented. Selection process is determined by the user itself.

D. Convergence test

Convergence test is used to determine the stopping criterion. Once the system reached the stopping criterion, the result of convergence test will be displayed. The system is said to be converge when the control variable is the same for all population. As for this paper, the system is said converged when the cost of operation is the same after the i-EP process.

V. SIMULATION RESULT

Simulations are carried out using two case. The first case is UC problem without SP and the second case is the UC problem with SP. All data are available in the Test System Data. Simulations are classified into two parts. In the first part, the effect of cost without using SP are simulated using a ten-unit thermal generator system. In the second part, a nine-unit thermal generator system is used with additional one-unit of SP. All simulation results are tabulated and plotted.

A. Analysis to determine no. of trial and population size

1) Determination of no. of Trial

This analysis is to determine no. of trial to be used to get the best result. In table 4 and 5 below it shows the total operation cost based on multiple number of trial and the time taken to complete each trial. Based on table below, it shows 20 trial produce best result. Since it produce lowest cost $584707.20 and take 10.56 hour to complete. Second lowest is 10 trial $587778.83 follow by 5 trial $592265.27 and lastly 1 trial $618327.53. Therefore, the number of trial that will be chosen are 5 to get the best result of total cost for both cases since there are not much difference between 10 and 20 trial and the value are the beginning of saturated based on figure 2. Apart from that, time taken to complete trial is acceptable (3.46 hour) since it much faster than 10 trial (5.65 hour) and 20 trial (10.5.6 hour). Besides that, for analysis of choose no. of population, also will be using this chosen number of trial. Figure 2, show the tabulated result in in-term of graph figure.

TABLE 4
TOTAL OPERATING COST USING i-EP BASED ON MULTIPLE NUMBER OF TRIAL WITHOUT CONSIDER SP

No. of Trial	Pop. Size	Cost ($)			Mean Time (Hour)
		Best	Average	Worst	
1	4	618327.53			0.50
5		592265.27	594539.65	599346.13	3.46
10		587778.83	591617.60	592528.01	5.65
20		584705.20	585933.86	586156.64	10.56

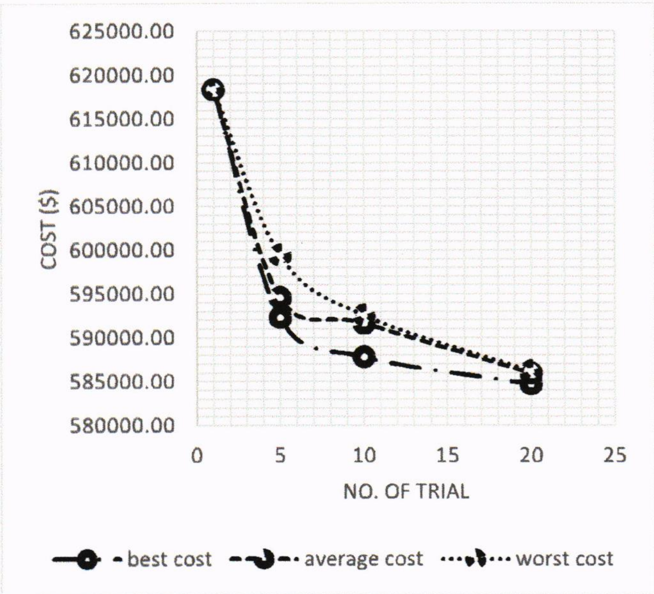

Figure 2 Graph of Cost VS No. of Trial

2) Determination of no. of population

TABLE 5
TOTAL OPERATING COST USING i-EP BASED ON MULTIPLE POPULATION SIZE WITHOUT CONSIDER SP

No. of Trial	Pop. Size	Cost ($)			Mean Time (Hour)
		Best	Average	Worst	
5	2	599306.60	609433.19	621057.04	3.33
	4	592265.27	594539.65	599346.13	5.65
	6	588564.12	592742.12	595339.41	6.49
	10	587778.83	591617.60	592528.01	7.59

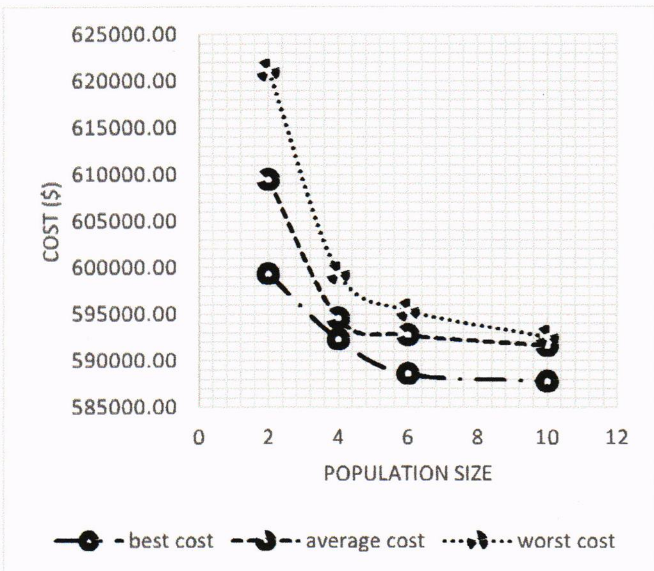

Figure 3 Graph of Cost VS Population Size

Table 5 above, shows the tabulated result of total operating cost using i-EP with multiple population size without implementation of SP. At first, 100 population generated to have a wide range of data. Then, the no of population selected to be consider for the next mutation process were varies from 2,4,6, and 10 to search the best no of population to be consider for entire analysis and the result was tabulated as shown above. This analysis was run 5 consecutive time. Since it is optimize based previous analysis.

The purpose of this analysis is to determine which population to be used to solve UCP. Theoretically, the increase in population size will make the total cost of production reduced. Based on result obtain, it is proven that, theoretically and actual analysis is same as shown in table 5 and Figure 3, show the tabulated result in in-term of graph figure..

From Table 5, show that the total cost of production in term of best, worst and average for 5 trial and multiple population size. For this problem, population 10 ($587778.83) get the lowest value compare to other population size. Meanwhile, population 4 ($592265.27) is the middle between population 2 and 10. Therefore, for this UCP population 4 and 10 was chosen to solve this problem and compare the result. Besides that the meantime is for population 4 (5.65hour) and 10 (7.59).

B. Best UC Schedule for i-EP with and without SP

Table 6 show the UC schedule without SP using i-EP and Table 7 show the UC schedule with SP using i-EP both case the population size set to 4.

In Table 6, shows the UC schedule using all ten-unit of thermal generator without using SP. This table contain the data for 10-unit of generator for 24-hours' time period. In this table the '0' to indicate that the generator is in OFF state and others number than '0' shows in ON state.

The total operating cost for one day are the summations of Day Cost added up with total start-up cost. The Day Cost is a summation of fuel cost for each hour, while the start-up cost is the cost associated with interchange of any state from '0' to number other than '0'. For example, unit 2 for hour 2 to 3 there is startup cost since it change from 0 to 422. For detail equation on Unit cost and start-up show as shown in Problem Formulation.

In Table 7, it shows UC schedule using only nine-unit of thermal generator and one-unit will turn OFF with using SP.

For this case, SP does not have start-up cost and also day cost since it is from nature. Therefore, it only needs to consider how long it will be available in the system and the maximum generated power so the SP is the priority for this case. The total costs calculation is the same in the case without SP since it has thermal generation only, but it not run all 10-unit since 1-unit will be OFF.

TABLE 6
UC SCHEDULE WITHOUT SOLAR PLANT USING IMPROVE EP

Unit	Power (MW)																							
	Hour																							
	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	260	453	305	436	347	243	397	440	384	437	407	450	385	426	445	319	399	295	443	454	428	352	450	356
2	347	0	422	297	365	430	424	413	418	428	435	412	444	384	451	450	342	438	417	437	437	409	355	301
3	0	92	0	0	124	40	76	0	107	115	122	126	113	99	80	0	0	105	98	100	92	0	0	46
4	0	125	0	126	32	107	107	107	75	93	122	129	117	99	57	0	74	79	0	79	59	124	0	0
5	0	0	0	0	0	128	0	128	88	153	144	139	155	118	127	155	130	113	149	126	125	154	0	0
6	0	29	0	48	58	49	75	79	70	72	60	79	61	49	0	78	55	0	0	51	50	0	0	0
7	0	0	52	0	74	52	0	0	84	0	65	65	34	0	0	0	0	0	0	81	0	31	54	79
8	13	0	19	0	0	0	0	0	0	39	0	11	29	43	40	0	0	0	0	0	28	0	0	0
9	34	0	0	0	0	40	52	0	33	37	47	53	32	33	0	0	0	22	52	52	29	30	0	18
10	46	51	52	43	0	11	19	33	41	26	48	36	30	49	0	48	0	48	41	20	52	0	41	0
TOTAL LOAD	700	750	850	950	1000	1100	1150	1200	1300	1400	1450	1500	1400	1300	1200	1050	1000	1100	1200	1400	1300	1100	900	800

*Best Cost = $ 588265.27

TABLE7
UC SCHEDULE WITH SOLAR GPLANT USING IMPROVE EP

Unit	Power (MW)																							
	Hour																							
	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	398	342	287	392	430	417	407	414	409	416	415	451	436	436	447	446	389	428	378	444	423	447	407	351
2	290	320	346	372	447	407	353	427	435	437	455	436	451	440	447	327	432	385	433	440	429	434	352	405
3	0	0	0	0	123	76	0	101	120	120	120	116	108	128	0	55	0	102	98	130	94	0	0	44
4	0	0	65	122	0	121	75	69	117	127	128	119	98	0	128	0	0	0	112	124	97	59	65	0
5	0	0	152	0	0	0	125	137	156	112	152	160	151	140	132	114	0	0	52	158	139	106	0	0
6	0	51	0	0	0	0	75	0	0	76	56	68	0	40	0	0	77	78	72	0	0	54	76	0
7	0	0	0	64	0	79	77	0	0	60	76	63	84	69	46	72	65	70	0	51	79	0	0	0
8	0	0	0	0	0	0	0	0	51	0	48	38	29	0	0	0	0	0	38	53	39	0	0	0
9	12	37	0	0	0	0	38	52	0	40	0	49	43	47	0	36	37	37	17	0	0	0	0	0
10	OFF																							
11 (SP)	0	0	0	0	0	0	0	0	12	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL LOAD	700	750	850	950	1000	1100	1150	1200	1300	1400	1450	1500	1400	1300	1200	1050	1000	1100	1200	1400	1300	1100	900	800

*Best Cost = $ 567127.69

C. *Result of Total Operating Cost*

TABLE 8
TABULATED RESULT OF TOTAL OPERATING COST

Optimization Method of EP	**No. of Trial**	**Pop Size**	**Case**	**Cost ($)**			**Mean Time (Hour)**
				Best	**Average**	**Worst**	
Standard	5	4	1 (without SP)	595441.34	615508.04	614274.60	3.33
			2 (with SP)	573825.42	599261.69	612297.16	2.28
			reduction (%)	3.63	2.64	0.32	-
		10	1 (without SP)	590442.59	609643.18	610339.39	7.59
			2 (with SP)	570216.57	591495.34	607338.20	3.18
			reduction (%)	3.43	1.36	0.49	-
Improve		4	1 (without SP)	592265.27	594539.65	599346.13	11.18
			2 (with SP)	567127.69	578713.50	593792.93	9.08
			reduction (%)	4.24	2.66	0.93	-
		10	1 (without SP)	587778.83	591617.60	592528.01	11.37
			2 (with SP)	564996.04	570270.04	588229.65	7.04
			reduction (%)	3.88	3.61	0.73	-

TABLE 9
COMPARISON OF COST BETWEEN POPULATION SIZE AND BETWEEN CASE

No. of Trial	**Pop Size**	**Case**	**Cost (%)**		
			Best	**Average**	**Worst**
5	4	1 (without SP)	0.53	3.41	2.43
		2 (with SP)	1.17	3.43	3.02
		Improvement (%)	0.63	0.02	0.59
	10	1 (without SP)	0.45	2.96	2.92
		2 (with SP)	0.92	3.59	3.15
		Improvement (%)	0.46	0.63	0.23

In Table 8 it show the tabulated result of total operation cost. From this table, it shows two difference type of optimization method which are standard EP and improve EP at the same time this method used two population size, which is four and ten populations. Besides that the operation cost is in-term of best, worst, and average. To get this cost the system was run 10 consecutive times. For improve and standard EP the increase in population size will get the lowest value for both 3 cost and the meantime also will increase. Furthermore, by implemented SP in the system the total cost reduce significantly.

In this Table show that the cost for improves EP method will reduce when the system implemented SP. For example, the best cost for population size set to 4 show that before implemented SP the cost is $592265.27 and after implementation of SP the cost is $567127.69 reduction by 4.24%. Also, the best cost for population size set to 10 show that before implemented SP the cost is $587778.83 and after implementation of SP the cost is $564996.04 reduction by 3.88%.

Table 9, show the comparison of cost reduction between Improve EP and Standard EP method for the same case and also improvement of implemented by reduction of cost before and after implemented SP. For comparison both optimization method for case 1 and case 2 at population size set to 4, it show that the best total operating cost will reduce significantly about 0.53% for case 1 without SP and about 1.17% for case 2 with implemented SP. The improvement by implemented SP are 0.63%. meanwhile for population size set to 10,it shows that the best total operating cost will reduce significantly about 0.45% for case 1 without SP and about 0.92% for case 2 with implemented SP. The improvement by implemented SP are 0.46%.

From Table 8 and Table 9 it show that Improve EP is the best since the total operating cost is much lower compare to standard EP. Furthermore, the initialization was set to generate more population and from this it will get the lowest cost compare to the standard EP that the initialization generated only 20 populations.

VI. CONCLUSION

This paper presents Improve Evolutionary Programming (i-EP) technique to solving UC problem with Solar Plant attached. The purposes of this study are to, to solve the UC problem with minimum cost while satisfying the load demand, power and reserve limit, spinning reserve. Also, the performance of i-EP before installing SP and after the installation also being compared. Based on result obtain , i-EP is able to solve UC problem with the cost $587778.83 which is better than the cost $590442.59 using EP technique. The percentage of reduction is 0.45% using 10 population size. After, implementing SP the operating cost further reduce. For i-EP the cost $564996.04 and for EP the cost $570216.57 with percentage of reduction is 0.92%. from this it show that by implement SP it will improve the operating cost by 0.46%.

For future development, this i-EP technique can be integrated with other techniques such as Priority Listing (PL), Multi Agent (MA), and Particle Swan Optimization (PSO). Other than that, this system also can be integrated with other source of energy such as wind, wave, biomass. Also, by increasing the population size to a bigger number such as 20, 40, or 100. This future development is for preparation of a bigger system in the future. This, new development will produce better outcome in term of operating cost.

VII. ACKNOWLEDGMENT

I would like to thank to the Almighty Allah, who in his infinite mercy for the strength, health, endurance and foresight to undertake this project and complete it to the satisfaction of Universiti Technology MARA. I would like to acknowledge most especially, the contribution of En. Muhammad Nazree bin Che Othman for his guidance in the process of completing this project. Also, my appreciation to all of my colleague for assisting with relevant materials. Finally, I thank all those who in one way or the other, have contributed to the successful completion of this work, may God bless Amin.

VIII. REFERENCES

[1] Y. Xu, Z. Wang, W. Sun, S. Chen, Y. Wu, and B. Zhao, "Unit commitment model considering nuclear power plant load following," in *Advanced Power System Automation and Protection (APAP), 2011 International Conference on*, 2011, pp. 1828-1832.

[2] R. H. Liang and F. C. Kang, "Thermal generating unit commitment using an extended mean field annealing neural network," *Generation, Transmission and Distribution, IEE Proceedings-*, vol. 147, pp. 164-170, 2000.

[3] C. Christober and R. Asir, "An evolutionary programming based simulated annealing method for unit commitment problem with cooling-banking constraints," in *India Annual Conference, 2004. Proceedings of the IEEE INDICON 2004. First*, 2004, pp. 435-440.

[4] K. A. De Jong, *Evolutionary computation: a unified approach*, 2006.

[5] S. S. Kumar and V. Palanisamy, "A New Dynamic Programming Based Hopfield Neural Network to Unit Commitment and Economic Dispatch," in *Industrial Technology, 2006. ICIT 2006. IEEE International Conference on*, 2006, pp. 887-892.

[6] P. Attaviriyanupap, H. Kita, E. Tanaka, and J. Hasegawa, "A Hybrid LR-EP for Solving New Profit-Based UC Problem under Competitive Environment," *Power Engineering Review, IEEE*, vol. 22, pp. 62-62, 2002.

[7] P. Attaviriyanupap, H. Kita, E. Tanaka, and J. Hasegawa, "A hybrid LR-EP for solving new profit-based UC problem under competitive environment," *Power Systems, IEEE Transactions on*, vol. 18, pp. 229-237, 2003.

[8] C. C. A. Rajan and M. R. Mohan, "An evolutionary programming method for solving the unit commitment problem," in *Power Engineering Society General Meeting, 2004. IEEE*, 2004, p. 1149 Vol.1.

[9] S. H. Zakaria, "Cypark aims for RM45m revenue from solar power," in *The Edge Financial Daily*, ed, 2012.

[10] C. C. Asir Rajan, "An evolutionary programming based tabu search method for unit commitment problem with cooling-banking constraints," in *Power India Conference, 2006 IEEE*, 2006, p. 8 pp.