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A PSO Based Solution Methodology for Short Term Hybrid Generation Scheduling Problem

Shubham Tiwari[1], Bharti Dwivedi[2], M.P Dave[3]
Research Scholar[1], Professor[2], Institute of Engineering and Technology, Lucknow, U.P., India.
Professor[3], Shiv Nadar University, Dadri, U.P., India

Abstract: A multiple stage solution methodology involving Priority List method and Particle Swarm Optimization Technique with Time Varying Acceleration Coefficients has been proposed for solving short term generation scheduling problem having ten thermal generating units and one solar generating unit. The per day revenue saving in operational cost after inclusion of 300 MW solar plant is quantified. The proposed method is found reliable after executing the simulations several times.

Keywords: Unit Commitment Problem (UCP), Priority List Method (PLM), Particle Swarm Optimization with Time Varying Acceleration Coefficients (PSO_TVAC), Solar Energy Resources (SER), Economic Load Dispatch (ELD)

I. INTRODUCTION

Unit Commitment Problem (UCP) is an onerous non-linear optimization problem where load for a scheduled time frame is satisfied by generation with minimum cost undervarious constraints [1].The rising demand of energy warrants inclusion of Renewable Energy Resources (RES) as fossil fuel resources are becoming scarce. Today energy saving associated with environmental protection has become prudent. The inclusion of RES into mainstream power system is inexorable because it can not only reduce the overall operating cost but can also prove to be sustainable and eco-friendly in nature [2-3]. In wake of this, efforts have been done to include solar generation with conventional thermal generation [4-6].

Particle Swarm Optimization (PSO) technique is found to be one of the most effective techniques in obtaining solution for rigorous optimization problems like UCP and Economic Load Dispatch (ELD) [7-9].The advantages of PSO are that it is robust, its parameter tuning is easy and it can be hybridized with other techniques available in literature [10-12]. The adaptability of PSO allows hybridizing Priority List Method (PLM) which is an effective classical solution technique for providing better feasible solutions to the problem [13-15].

II. PROBLEM FORMULATION

There are two sub sections where the modeling of thermal generation [14], [16] and solar generation [5] have been carried out.

(a) Thermal Generation:

The cost functionCost$_N$ is given by Equation (1).

$$\mathrm{Cos}\,t_N = \sum_{i=1}^{N} [FC_i(P_{ih}) + STC_i(1 - U_{i(h-1)})]U_{ih} \tag{1}$$

$FC_i\ (P_{ih})$ is the fuel cost of ith unit with power output (P_{ih}) at the hth hour. FC is fuel cost function which is quadratic polynomial with coefficients a$_i$, b$_i$ and c$_i$.It is represented by Equation (2).

$$FC_i\ (P_{ih}) = a_i + b_i P_{ih} + c_i P^2{}_{ih} \tag{2}$$

If the downtime of ^{ith}unit is less than or equal to the summation of minimum down time (MD$_i$) and the Cold start up time (C$_s$), then the start-up cost of that unit (STC$_i$) is taken as Hot start-up cost (H$_{sc}$). Else it is taken as Cold start -up cost (C$_{sc}$) representedby Equation (3).

$$STC_i = Hsc_i$$

When, $X_i^{off} \le MD_i + Cs$ (3)

X_i^{off} is the duration in which the i$_{th}$ unit is continuously off. If the downtime of related unit is greater than the summation of minimum down time hours (MD$_i$) and cold start-up hours(Cs) then the cold start-up cost (C$_{sc}$) is considered.

This can be represented by Equation (4).

$$STC_i = \mathrm{Csc}_i$$

When, $X_i^{off} > MD_i + Cs$ (4)

Thus, the total cost ($Cost_{NH}$) for the complete schedule of the given time frame is given by Equation (5).

$$\mathrm{Cos}\,t_{NH} = \sum_{h=1}^{H}\sum_{i=1}^{N}[FC_i(P_{ih}) + STC_i(1-U_{i(h-1)})]U_{ih} \quad (5)$$

U_{ih} is the ON/OFF status of the i^{th} unit at h^{th} hour. Digit '1' represents ON, while '0' represents the OFF status.

The constraints of UCP (only thermal) considered here are as follows.

1) Power Balance Constraint

$$\sum_{i=1}^{N} P_{ih}U_{ih} = LD_h \quad (6)$$

P_{ih} is the generation in MW of i^{th}unit in h^{th} hour, U_{ih} is the ON/OFF status of i^{th} unit and LD_h is the load demand at h^{th} hour.

2) Spinning Reserve Constraint

$$\sum_{i=1}^{N} P_{i(\max)}U_{ih} \geq LD_h + SR_h \quad (7)$$

$Pi_{(max)}$ is the maximum generation in MW of i^{th} unit and SR_h is the spinning reserve at h^{th} hour. In this paper for ten thermal generating units the spinning reserve is taken as 5% of total load.

3) Generation Limit Constraint

$$P_{i(\min)} \leq P_{ih} \leq P_{i(\max)} \quad (8)$$

4) Minimum up time constraints

$$X_i^{on}(t) \geq MU_i \quad (9)$$

5) Minimum down time constraint

$$X_i^{off}(t) \geq MD_i \quad (10)$$

6) Initial Status

It is the initial down time status that is required to be considered in the first hour of scheduling. The data regarding thermal generating units and load profile is given in Appendix I and II respectively.

(b) Solar Generation System

The power balance constraint under the lights of solar generation is given as

$$\sum_{i=1}^{N}[P_i(t)+]U_{ih} + P_{solar}(t) = LD_h \quad (11)$$

Where, $P_{solar}(t)$ is the hourly solar power output.The total availability of hourly solar power is calculated by using following equations [17].

$$P_{solar}(s(t)) = P_{sn}\frac{s(t)}{s_{stand.} * R_s}; 0 \leq s(t) \leq R_s \quad (12)$$

$$P_{solar}(s(t)) = P_{sn}\frac{s(t)^2}{s_{stand.}}; s(t) \geq R_s \quad (13)$$

Where, s(t) is forecasted solar radiation at hour t, $S_{stand}$is solar radiation in standard environment taken as 1000 W/m^2 and R_s is the cut-in radiation point set as 150W/m^2 [17]. $P_{sn}$is maximum generation capability of solar system taken as 300 MW. The data regarding radiation is provided in Appendix III.

III. SOLUTION METHODOLOGY

A two stage solution methodology involving Priority Listing Method (PLM) and Particle Swarm Optimization with Time Varying Acceleration Coefficients (PSO_TVAC) is proposed for the solution of problem. The ON/OFF schedule in the first stage is determined by PLM and economic allocation of load among thermal generating units is done by PSO_TVAC.

(a) Stage One-

The priority vector is obtained by using equation (26) [14, 16].

$$priorityvector = \frac{P_{(\max),vec}}{\max.\left[P_{(\max),vec}\right]} + \frac{MD_{vec}}{\max.\left[MD_{vec}\right]} \quad (14)$$

This priority vector is updated with the help of a pseudo code [14, 16] given below.

```
% H:    hour (1 to 24)
% hrs:  time frame of one day (1to 24)
% i_hrs: initial status vector (changes every hour)
% MD:   minimum down time vector
% MU:   minimum up time vector
% dem:  demand vector

 for H=1:hrs
commit units with (0<i_hrs_MU)

while sum(capacity of Committed generating units)<1.1* dem (H)
   commit all generating units with (i_hrs>MU)in accordance to
priority vector
end

while sum(capacity of Committed generating units)<1.1*dem(H)
   commit all generating units with (i_hrs<=-MD) in accordance to
priority vector
end

for unchanged units thus far obtain reverse order of priority vector

   if i_hrs(generating unit)>=MU(generating unit)
      if sum(capacity of Committed generating units)> = 1.1dem(H)
&(20-H>MD(generating unit)
         put the generating unit OFF
      else
         put the generating unit ON
      end

   elseif i_hrs(generating unit)<=-MU(generating unit)
      if sum(capacity of Committed generating units)>=1.1dem(H)
         put the generating unit OFF
      else
         put the generating unit ON
      end

   elseif i_hrs(generating unit)<0

      put the generating unit OFF

 end %i_hrs

end %unchanged units

end %for H
```

Fig.1. Pseudo code for obtaining ON/OFF Schedule

(b) Stage two-

The ON/OFF status obtained from stage one serves as an input to stage two where the load is distributed among thermal generating units economically. PSO_TVAC [17, 18] is proposed to solve non-linear UCP. The equations are as follows

$$v_{id}^{(k+1)} = [W * v_{id}^{k} + c_1 * Rand_1() * \left(P_{bestid} - x_{id}^{k}\right) + c_2 * Rand_2() * \left(G_{best\ gd} - x_{id}^{k}\right)] \quad (15)$$

$$x_{id}^{(k+1)} = x_{id}^{k} + v_{id}^{k+1} \quad (16)$$

Where, ‘W’ is the inertia weight parameter which controls the global and local exploration capabilities of the particle. The linearly varying ‘W’ is given as

$$w = w_{\max} - \left(\frac{w_{\max} - w_{\min}}{iter_{\max}}\right) * iter \quad (17)$$

'c_1' and 'c_2' are acceleration coefficients, to deal with the high non-linear nature of UCP some modifications are done in classical PSO algorithm, in this paper PSO with Time Varying Acceleration Coefficients (TVAC) is used, the values of 'c_1' and 'c_2' can be given as

$$c_1 = \left(c_{1f} - c_{1i}\right) * \frac{iter.}{iter_{\max}} * c_{1i} \quad (18)$$

$$c_2 = \left(c_{2f} - c_{2i}\right) * \frac{iter.}{iter_{\max}} * c_{2i} \quad (19)$$

Where, c_{1i}, c_{1f}, c_{2i}, c_{2f} are initial and final values of cognitive and social acceleration factors respectively. The values considered for acceleration coefficients are-

c_{1f} =0.5, c_{1i} =2.5, c_{2f} =2.5, c_{2i} =0.5.

The bounds for velocity are set to make sure that the solution does not fly away. These bounds are set as explained below.

If, $V_{id}^{(k+1)} > V_d^{max}$, then , $V_{id}^{(k+1)} = v_d^{max}$

If, $V_{id}^{(k+1)} < V_d^{min}$, then, $V_{id}^{(k+1)} = v_d^{min}$

Where, $V_d^{min} = -0.5\ Pg^{min}$, $V_d^{max} = +0.5\ P_g^{max}$ (20)

IV. SIMULATION AND RESULTS

Case (a) Thermal Generation

The ON/OFF schedule obtained by Stage One is given in Table 1.

Table1-ON/OFF Schedule for *Case (a)*

Hrs.	**Unit No**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
H1	1	1	0	0	0	0	0	0	0	0
H2	1	1	0	0	0	0	0	0	0	0
H3	1	1	0	0	0	0	0	0	0	0
H4	1	1	0	0	1	0	0	0	0	0
H5	1	1	0	0	1	0	0	0	0	0
H6	1	1	0	1	1	0	0	0	0	0
H7	1	1	1	1	1	0	0	0	0	0
H8	1	1	1	1	1	0	0	0	0	0
H9	1	1	1	1	1	1	0	0	0	0
H10	1	1	1	1	1	1	1	0	0	0
H11	1	1	1	1	1	1	1	1	0	0
H12	1	1	1	1	1	1	1	1	1	0
H13	1	1	1	1	1	1	1	0	0	0
H14	1	1	1	1	1	1	0	0	0	0
H15	1	1	1	1	1	0	0	0	0	0
H16	1	1	1	1	1	0	0	0	0	0
H17	1	1	1	1	1	0	0	0	0	0
H18	1	1	1	1	1	0	0	0	0	0
H19	1	1	1	1	1	0	0	0	0	0
H20	1	1	1	1	1	1	1	0	0	0
H21	1	1	0	1	1	1	1	0	0	0
H22	1	1	0	0	1	1	1	0	0	0
H23	1	1	0	0	0	1	0	0	0	0
H24	1	1	0	0	0	0	0	0	0	0

The economic allocation of load obtained by Stage Two is given in Table 2.

Table 2-Economic Load Dispatch Case (a)

Hrs	Unit No.										Tot. Gen. (MW)
	1	2	3	4	5	6	7	8	9	10	
H1	455	245	0	0	0	0	0	0	0	0	**700**
H2	455	295	0	0	0	0	0	0	0	0	**750**
H3	455	395	0	0	0	0	0	0	0	0	**850**
H4	455	455	0	0	40	0	0	0	0	0	**950**
H5	455	455	0	0	90	0	0	0	0	0	**1000**
H6	455	455	0	130	60	0	0	0	0	0	**1100**
H7	455	410	130	130	25	0	0	0	0	0	**1150**
H8	455	455	130	130	30	0	0	0	0	0	**1200**
H9	455	455	130	130	110	20	0	0	0	0	**1300**
H10	455	455	130	130	162	43	25	0	0	0	**1400**
H11	455	455	130	130	162	80	25	13	0	0	**1450**
H12	455	455	130	130	162	80	25	53	10	0	**1500**
H13	455	455	130	130	162	43	25	0	0	0	**1400**
H14	455	455	130	130	110	20	0	0	0	0	**1300**
H15	455	455	130	130	30	0	0	0	0	0	**1200**
H16	455	310	130	130	25	0	0	0	0	0	**1050**
H17	455	260	130	130	25	0	0	0	0	0	**1000**
H18	455	360	130	130	25	0	0	0	0	0	**1100**
H19	455	455	130	130	30	0	0	0	0	0	**1200**
H20	455	455	130	130	162	43	25	0	0	0	**1400**
H21	455	455	0	130	162	73	25	0	0	0	**1300**
H22	455	455	0	0	145	20	25	0	0	0	**1100**
H23	455	425	0	0	0	20	0	0	0	0	**900**
H24	455	345	0	0	0	0	0	0	0	0	**800**

The generation in MWh and operating costs details (fuel cost and start-up costs)are given in Table3.

Table 3-Operating Cost for Individual Generators for 24 hours for *Case (a)*

Unit No.	Gen. (MWh)	Fuel Cost ($)	Start-up Cost ($)
1	10920	203180	0
2	9870	194928.7	0
3	1820	40485.2	1100
4	2080	45770.54	1120
5	1717	43255.23	900
6	442	13718.89	510
7	175	8249.063	1040
8	66	3043.019	60
9	10	937.922	60
10	0	0	0
Total	**27100**	**553569**	**4790**

The convergence of the proposed method is shown in Fig.2.

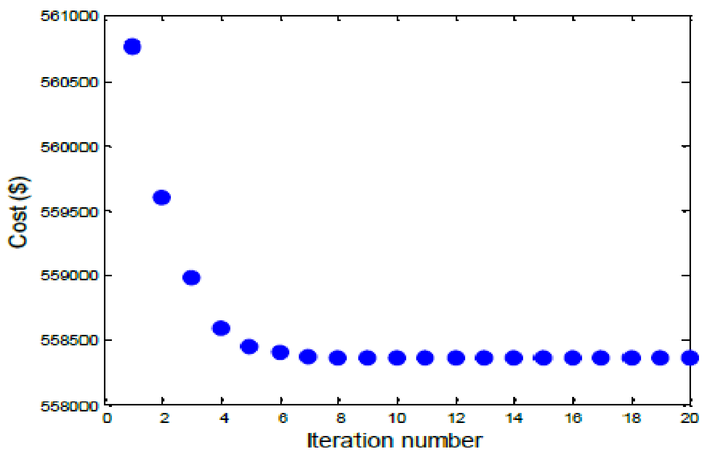

Fig.2. Convergence for *Case (a)*

The total operating cost for *Case (a)* is **558359$.**

Case (b) Solar Integrated Thermal Generation

The hourly generation from solar plant is shown in Fig.3.

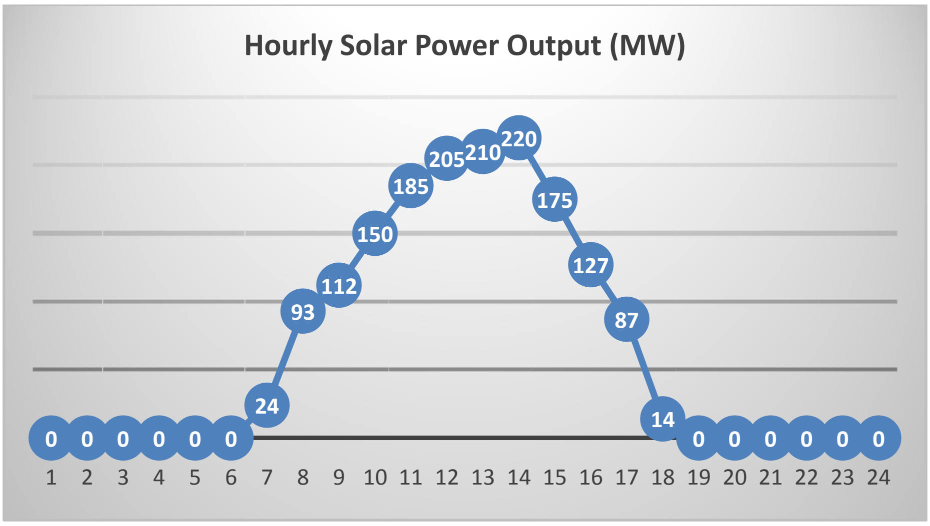

Fig.3. 24 hours Generation from Solar Plant

After calculating the generation from a 300 MW Solar power plant the demand is further updated by subtracting the hourly solar power from the demand. This updated load demand is fed to Stage One to obtain the ON/OFF schedule.

The ON/OFF schedule, Economic allocation of load, operational cost for generation and convergence of the proposed method for *Case (b)* is given in Table 4, Table 5, Table 6 and Fig.4 respectively.

Table4-ON/OFF Schedule for *Case (b)*

Hrs.	**Unit No.**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	1	1	0	0	0	0	0	0	0	0
2	1	1	0	0	0	0	0	0	0	0
3	1	1	0	0	0	0	0	0	0	0
4	1	1	0	0	1	0	0	0	0	0
5	1	1	0	1	1	0	0	0	0	0
6	1	1	0	1	1	0	0	0	0	0
7	1	1	0	1	1	0	0	0	0	0
8	1	1	0	1	1	0	0	0	0	0
9	1	1	1	1	1	0	0	0	0	0
10	1	1	1	1	1	0	0	0	0	0
11	1	1	1	1	1	0	0	0	0	0
12	1	1	1	1	1	1	0	0	0	0
13	1	1	1	0	1	1	0	0	0	0
14	1	1	0	0	1	1	0	0	0	0
15	1	1	0	0	1	1	0	0	0	0
16	1	1	0	0	1	0	0	0	0	0
17	1	1	0	0	1	0	0	0	0	0
18	1	1	0	1	1	0	0	0	0	0
19	1	1	1	1	1	1	0	0	0	0
20	1	1	1	1	1	1	0	1	1	0
21	1	1	1	1	1	1	0	0	0	0
22	1	1	1	1	0	0	0	0	0	0
23	1	1	1	0	0	0	0	0	0	0
24	1	1	0	0	0	0	0	0	0	0

Table 5-Economic Load Dispatch *Case (b)*

Hrs.	**Unit No.**											**Tot. Gen. (MW)**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**P_{solar}**	
1	455	245	0	0	0	0	0	0	0	0	0	**700**
2	455	295	0	0	0	0	0	0	0	0	0	**750**
3	455	395	0	0	0	0	0	0	0	0	0	**850**
4	455	455	0	0	40	0	0	0	0	0	0	**950**
5	455	390	0	130	25	0	0	0	0	0	0	**1000**
6	455	455	0	130	60	0	0	0	0	0	0	**1100**
7	455	455	0	130	86	0	0	0	0	0	24	**1150**
8	455	455	0	130	67	0	0	0	0	0	93	**1200**
9	455	448	130	130	25	0	0	0	0	0	112	**1300**
10	455	455	130	130	80	0	0	0	0	0	150	**1400**
11	455	455	130	130	95	0	0	0	0	0	185	**1450**
12	455	455	130	130	105	20	0	0	0	0	205	**1500**
13	455	455	130	0	130	20	0	0	0	0	210	**1400**
14	455	455	0	0	150	20	0	0	0	0	220	**1300**
15	455	455	0	0	95	20	0	0	0	0	175	**1200**
16	455	443	0	0	25	0	0	0	0	0	127	**1050**
17	455	433	0	0	25	0	0	0	0	0	87	**1000**
18	455	455	0	130	46	0	0	0	0	0	14	**1100**

19	455	440	130	130	25	20	0	0	0	0	0	**1200**
20	455	455	130	130	162	48	0	10	10	0	0	**1400**
21	455	455	130	130	110	20	0	0	0	0	0	**1300**
22	455	385	130	130	0	0	0	0	0	0	0	**1100**
23	455	315	130	0	0	0	0	0	0	0	0	**900**
24	455	345	0	0	0	0	0	0	0	0	0	**800**

Table 6-Operating Cost for Individual Generators for 24 hours for *Case (b)*

Unit No.	Gen. (MWh)	Fuel Cost ($)	Start-up Cost ($)
1	10920	203180	0
2	10049	198056	0
3	1300	28918	1650
4	1690	37188.6	1120
5	1351	35254.2	900
6	168	6363.17	510
7	0	0	0
8	10	919.613	60
9	10	937.922	60
10	0	0	0
Total	**25498**	**510818**	**4300**

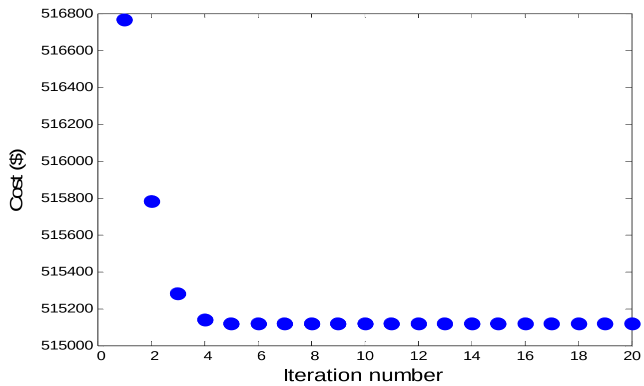

Fig.4. Convergence for *Case (b)*

The total operating cost for *Case (a)* is **515118 $.**

V. CONCLUSION

It can be concluded from this work that after properly scheduling renewable energy resources with conventional thermal generation the fuel cost of thermal generation can be significantly reduced. In this case after inclusion of a 300 MW Solar generation plant the total saving in fuel cost is **43241$ per day.** The hybridization of Priority List Method (PLM) with Particle Swarm Optimization Technique with Time Varying Acceleration Coefficients (PSO_TVAC) gives satisfactory results for a non-linear, complex and constraints based problem like UCP. The convergence of the proposed method remains unaltered even after inclusion of renewable generation.

APPENDICES

Appendix I (Thermal Units Detail)[5, 14]

Unit No.	1	2	3	4	6	7	8	9	10
P_{max}	455	455	130	130	80	85	55	55	55
P_{min}	150	150	20	20	20	25	10	10	10
a($/h)	1000	970	700	680	370	480	660	665	670
b($/MWh)	16.19	17.26	16.60	16.50	22.26	27.74	25.92	27.27	27.79
c($/MW^{2}h)	0.00048	0.00031	0.002	0.00211	0.0072	0.00079	0.00413	0.0022	0.00173
MD(h)	8	8	5	5	3	3	1	1	1
MU(h)	8	8	5	5	3	3	1	1	1
HSc($/h)	4500	5000	550	560	170	260	30	30	30
CSc($/h)	9000	10000	1100	1120	340	520	60	60	60
Cs(h)	5	5	4	4	2	2	0	0	0
Initial Status	8	8	-5	-5	-3	-3	-1	-1	-1

Appendix II (Load Profile for 24 Hours)[5, 14]

Hour	H1	H2	H3	H4	H5	H6
Load (MW)	700	750	850	950	1000	1100
Hour	H7	H8	H9	H10	H11	H12
Load (MW)	1150	1200	1300	1400	1450	1500
Hour	H13	H14	H15	H16	H17	H18
Load (MW)	1400	1300	1200	1050	1000	1100
Hour	H19	H20	H21	H22	H23	H24
Load (MW)	1200	1400	1300	1100	900	800

Appendix III (Solar Radiation Data for 24 Hours)[5]

Hour	1	2	3	4	5	6
SR(W/m^2)	0	0	0	0	0	0
Hour	7	8	9	10	11	12
SR(W/m^2)	111	311	375	503	617	686
Hour	13	14	15	16	17	18
SR(W/m^2)	703	736	586	425	291	86
Hour	19	20	21	22	23	24
SR(W/m^2)	0	0	0	0	0	0

REFERENCES

[1] Wood A. J. and Wollenberg B. F, “Power generation, operation and control”, John Wiley & sons, New York, 3rd Edition.

[2] Vine E, “Breaking down the silos: the integration of energy efficiency, renewable energy, demand response and climate changes”, Energy efficiency, 1:49-63, 2008.

[3] Juan M. Morales, Antonio J. Conejo, Henrik Madsen, Pierre Pinson and Marco Zugno, “Integrating Renewables in Electricity Markets: operational problems”, International series in Operational Research& Management Science, Springer, 2014.

[4] Anup Shukla and S.N Singh, “PSO for solving Unit Commitment Problem including Renewable Energy Resources”, Electrical India, Vol. 54, No. 12, pp. 100-105, Dec. 2014.

[5] Shantanu C.,Senjyu T.,Saber A.Y.,Yona A. and Funabashi T., “Optimal Thermal Unit Commitment Integrated with Renewable Energy Sources Using Advanced Particle Swarm Optimization”, IEEJ Trans.4,pp.609-617, 2009.

[6] Anup Shukla, S.N Singh, “Multi-objective Unit Commitment with Renewable Energy using GSA Algorithm”, Springer, INAE Letters,vol.1,issue 1,pp.21-27,2016.

[7] Anup Shukla, S. N. Singh, "Multi-objective Unit Commitment Using Search Space Based Crazy PSO and Normal Boundary Intersection Technique", IET, Generation,Transmission and Distribution, Vol. 10, Issue 5, pp. 1222-1231, Apr. 2016.

[8] Shubham Tiwari, Ankit Kumar, G.S. Chaurasia, G.S. Sirohi, “Economic Load Dispatch Using Particle Swarm Optimization”, IJAIEM, Vol. 2, Issue 4, pp 476-485, 2013.

[9] Pappala VS and Erlich I., “A new approach for solving Unit Commitment Problem by adaptive particle swarm optimization”, Power and Energy Society general meeting-conversion and delivery of electrical energy in the 21st century, USA:IEEE ,pp.1-6., 2008.

[10] Sayeed Salem, “Unit Commitment Solution Methods”,World Academy of Science, Engineering and Technology, pp.320-325, 2007

[11] Shubham Tiwari, Bharti Dwivedi and M.P Dave, “Advancements in Unit Commitment Strategy”, In: proceedings of IEEE International Conference on Emerging Trends in Electrical, Electronics & Sustainable Energy Systems (ICETEESES-16) ,Vol.1,Issue 1, pp.259-262,11-12 March,2016.

[12] Yun-Won Jeong, Jong-Bae Park, Se-Hwan Jang, and Kwang Y. Lee, “A New Quantum-Inspired Binary PSO: Application to Unit Commitment Problems for Power Systems”, IEEE Transactions On Power Systems, Vol. 25, No. 3, Aug. 2010,pp.1486-95.

[13] Anup Shukla, S.N. Singh, “Advanced three stage pseudo inspired weight improved crazy particle swarm optimization for Unit Commitment Problem”,Elseveir, Energy, Vol.96, pp.23-36, Feb. 2016.

[14] Shubham Tiwari, Bharti Dwivedi, M.P Dave, “ A Two stage solution methodology for Deterministic Unit Commitment problem”, In:Proceedings of 3rd IEEE International Conference on Electrical, Computer and Electronics(UPCON-2016),09-11 Dec., 2016,p.p.317-322.

[15] Archana Yadav, Shubham Tiwari and Bharti Dwivedi, “A hybrid PSO based technique for Unit Commitment problem”, In:Proceedings of IEEE International Conference on Computing, Communication and Control Technology (IC^{4}T-2016), Vol.1,Issue 1,pp.191-195,Nov. 2016.

[16] Khanmohammadi S., Amiri M. and Tarafdar Haque M., “A new three stage method for solving unit commitment method”, Elsevier Energy 35(2010),3072-3080

[17] K.T Chaturvedi, Manjaree Pandit, Laxmi Srivastava,“Self-Organizing Hierarchical Particle Swarm Optimization for Non-Convex Economic Dispatch”; IEEE Transactions on Power Systems,August2008,vol.23,pp.1079-1087.

[18] Shubham Tiwari, Abhishek Maurya, “Particle Swarm Optimization Technique with Time Varying Acceleration coefficients for load Dispatch Problem”, IJRITCC, Vol. 3, Issue 6, Jun. 2015, pp. 3878-3885.