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Single Area Unit Commitment Problem by Modern Soft Computing Techniques

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Abstract: Electricity generating companies and power systems have the problem of deciding how best to meet the varying demand for electricity, which has a daily and weekly cycle. The short-term optimization problem is how to schedule generation to minimize the total fuel cost or to maximize the total profit over a study period of typically a day, subject to a large number of constraints that must be satisfied. If the electricity company has responsibility for satisfying the demand for electricity, then the most important constraint is that the total generation must equal the half-hourly forecast demands. This research paper aims to present the solution of single area unit commitment problem comprises of 10-units for 24-hours load demand by the use of modern soft computing. The results presented in this paper are compiled by the use of Mi-Power software to analyze the critical unit commitment problem by priority list method.

Keywords: ***Average Full Load Cost (AFLC), Mi-power, Priority List, Unit Commitment.***

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INTRODUCTION

The Unit Commitment Problem is to determine a minimal cost turn-on and turn-off schedule of a set of electrical power generating units to meet a load demand while satisfying a set of operational constraints. The production cost includes fuel, startup, shutdown, and no-load costs. Some of the operational constraints that must be taken into account include, 1. The total power generated must meet the load demand plus system losses. 2.There must be enough spinning reserve to cover any shortfalls in generation. 3. The loading of each unit must be within its minimum and maximum allowable rating. 4.The minimum up and down times of each unit must be observed. The unit commitment is aimed at devising a proper generator commitment schedule for a power system over a period of one day to one week. The main objective of unit commitment is to minimize the total production cost over the study period & to satisfy the constraints imposed on the system such as power generation-load balance, spinning reserve, operating constraints, minimum up time & minimum down time, etc. Several conventional methods are available to solve the unit commitment problem. But all these methods need the exact mathematical model of the system & there may be a chance of getting stuck at the local optimum.

UNIT COMMITMENT PROBLEM

The electrical unit commitment problem is the problem of deciding which electricity generation units should be running in each period so as to satisfy a predictably varying demand for electricity. The problem is interesting because in a typical electrical system there are a variety of units available for generating electricity and each has its own characteristics. At one extreme, a nuclear power unit can provide electricity at a very low incremental cost for each additional megawatthour (MWH) of energy, but it has both a high cost of starting up again once it has been shut down and it takes awhile to bring it back up to full power. A typical nuclear unit may be shut down only in the Spring or Autumn, when there is very little heating or air-conditioning demand, so demand is lowest. At the other extreme, a gas turbine generator can be started up in a few minutes. However, its incremental cost per megawatthour (MWH) is much more expensive. The obvious policy is that as demand increases, we first turn on the efficient, but costly to start generators and lastly turn on the least efficient, but cheap to start. As demand decreases, we shut down units in the reverse order. Decisions are a little more interesting if there is a modest peak in demand of short duration. Then it may be economic to skip an intermediate unit and instead turn on an inefficient, but cheap-to-start unit for the duration of the short spike. Various other features of various types of units also complicate the decision [16].

UNIT COMMITMENT PROBLEM FORMULATION

The objective of the UC problem is the minimization of the total production costs over the scheduling horizon. Therefore, the objective function is expressed as the sum of fuel and start-up costs of the generating units. For N generators, the operation cost is defined mathematically as shown in eqn. (1)

$$TPC_N = \sum_{i=1}^{N} [F_i(P_{ih}) + ST_i(1-U_{i(h-1)})]U_{ih} \quad (1)$$

The operating cost accumulates over the total number of operating hours, H, where H=24 which represents 24 hours of operation for each unit of generator. Therefore, eqn. (1) is rewritten as:

$$TPC_{HN} = \sum_{h=1}^{H}\sum_{i=1}^{N} [F_i(P_{ih}) + ST_i(1-U_{i(h-1)})]U_{ih} \quad (2)$$

Where, N is the number of generators, H is the number of hours, U_{ih} is the ON/OFF status of the i^{th} unit at h^{th} hour, ST_i is the Start-Up cost of the i^{th} unit, $F_i(P_{ih})$ is the fuel cost function of the i^{th} unit with generator output P_{ih} at the h^{th} hour, P_{ih} is the generation output of the i^{th} unit at the h^{th} hour, TPC is the Total production Cost of the power generation, TPC_N is the total production cost for N units of generators and TPC_{HN} denotes the total production cost for N units of generators over H number of operating hours. Owing to the operational requirements, the minimization of the objective function is subjected to the Power balance constraint, Spinning reserve constraint, Generation limit constraint, Minimum-Up time constraint and Minimum-Down time constraint.

PRIORITY LIST UNIT COMMITMENT

Priority list unit commitment method is the simplest unit commitment solution method to list all combinations of units on and off, as well as the corresponding total cost to create a rank list, and then make the decision according to the rank table [9, 10, 17]. The generation of initial solution is important, particularly, for the UC problem. The initial solution is usually generated at random. However this technique is difficult to get a feasible solution for the UC problem with many constraints, resulting in the quality of solution obtained being unsatisfactory [17]. The priority list method is an efficient method to overcome this problem. This method is simple and requires short computing time and small computer memory [13]. A simple unit priority list can be created by sorting generating units by average full-load cost (AFLC) in ascending order. The AFLC is simply the generating unit average heat rate at full load, in MBtu/MWh, multiplied by the fuel cost, in $/MBtu. The UC will commit units on the top of the list one unit at a time, if their unit minimum down-time constraints are not violated, until the demand and spinning-reserve are met. When there is excessive generation capacity in any hour, the last committed units, which have higher AFLC than the other on-line units, will be decommitted, if their unit minimum up-time constraints are not violated, until there is no excessive capacity or no further unit decommitment can be performed. This method is simple and requires short computing time and small computer memory. However, the UC solution obtained from the priority list method may not be the optimal schedule because start-up cost and ramp rate constraints are not included in determining the priority commitment order and AFLC does not adequately reflect the operating cost of generating units when they do not operate at the full load [3,4,5,8]. Some other techniques are therefore incorporated into the priority list method to improve the UC solution.

Burns et al. in [1] proposed a dynamic priority list that varies with the system demand. Shoults et al. in [2] included the average start-up cost, in addition to the AFLC, in the determination of a unit priority list for multi-area unit commitment with area import/export constraints. Lee, et al. in [4-5] presented the priority list based on Commitment Utilization Factor (CUF) in association with the AFLC and claimed that the CUF can reflect the impact of multi-area transmission interconnection constraints and the priority list based on CUF and AFLC yields better results. Y. Tingfang and T. O. Ting proposed a methodological priority list method which is simple and more efficient than conventional priority list method and incorporates more intelligent strategy with priority list as the backbone[13]. The solutions obtained by Methodology Priority List method are deterministic [3-5]. The simplicity of the MPL and fast calculation of ED leads to a methodological and competent method in comparison with conventional method [17].

PROPOSED UNIT COMMITMENT PROBLEM

In this research problem, the benchmark system comprising of 10 generating units is adopted as the test bed. The cost function parameters of 10-units system are specified in Table-1 and Load demand for single area system over 24-hour period is available in Figure-1. Also, 10% reserve is considered to compute the result.

Table1: Cost Function Parameters of 10-Unit System

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	Unit 10
P_{Max} (MW)	455	455	130	130	162	80	85	55	55	55
P_{Min} (MW)	150	150	20	20	25	20	25	10	10	10
a	1000	970	680	680	450	370	480	660	665	670
b	16.19	17.26	16.6	16.5	19.7	22.26	27.74	25.92	27.27	27.79
c	0.00048	0.00031	0.002	0.00211	0.00398	0.00712	0.0079	0.00413	0.00222	0.00173
Min Up (h)	8	8	5	5	6	3	3	1	1	1
Min Down (h)	8	8	5	5	6	3	3	1	1	1
Hot Start Cost($)	4500	5000	550	560	900	170	260	30	30	30
Cold Start Cost($)	9000	10000	1100	1120	1800	340	520	60	60	60
Cold Start Hrs	5	5	4	4	4	2	2	0	0	0
Initial Status	8	8	-5	-5	-6	-3	-3	-1	-1	-1

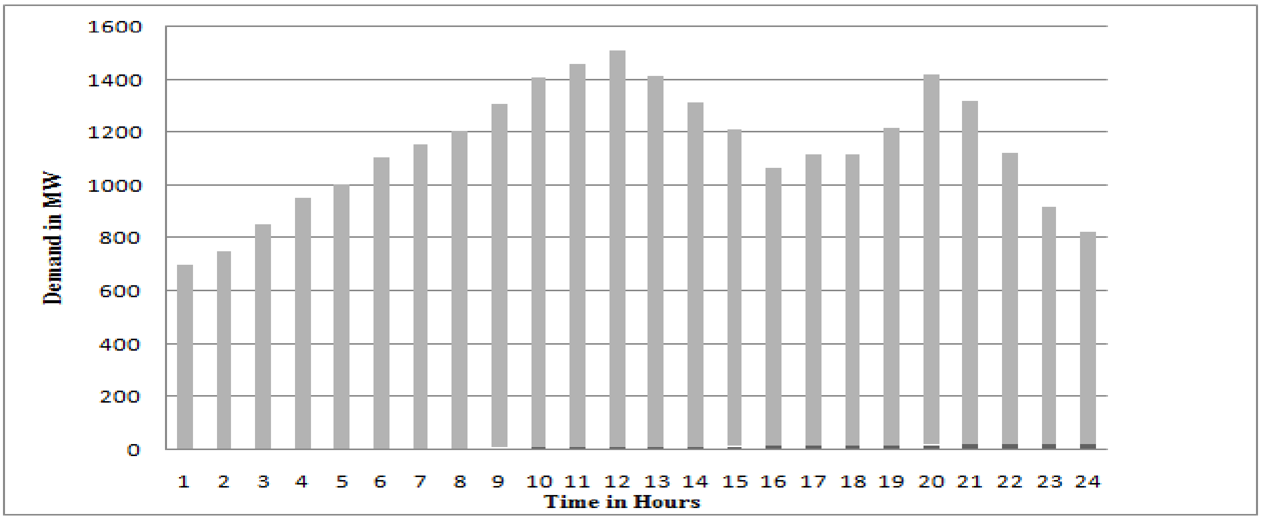

Figure1. Load Demand for Single Area System for 24-Hours

SOLUTION OF PRIORITY LIST UNIT COMMITMENT IN MIPOWER

1. To solve Unit Commitment program by using MiPower Package, invoke "MiPower Tools" in the MiPower main screen and select “Unit Commitment ". one window will popup as shown in Figure2, In this window enter the file name and press open.
2. Enter the no. of generators, for each generator enter the system operator data and every time click on the save button.
3. Enter the no. of load hours, and select the reserve type, for each load hour enter load and click on save button.
4. After entering all the values the window will appear as shown in Figure2.
5. Click on Execute button to run UC program.
6. Click on Report to see the output.

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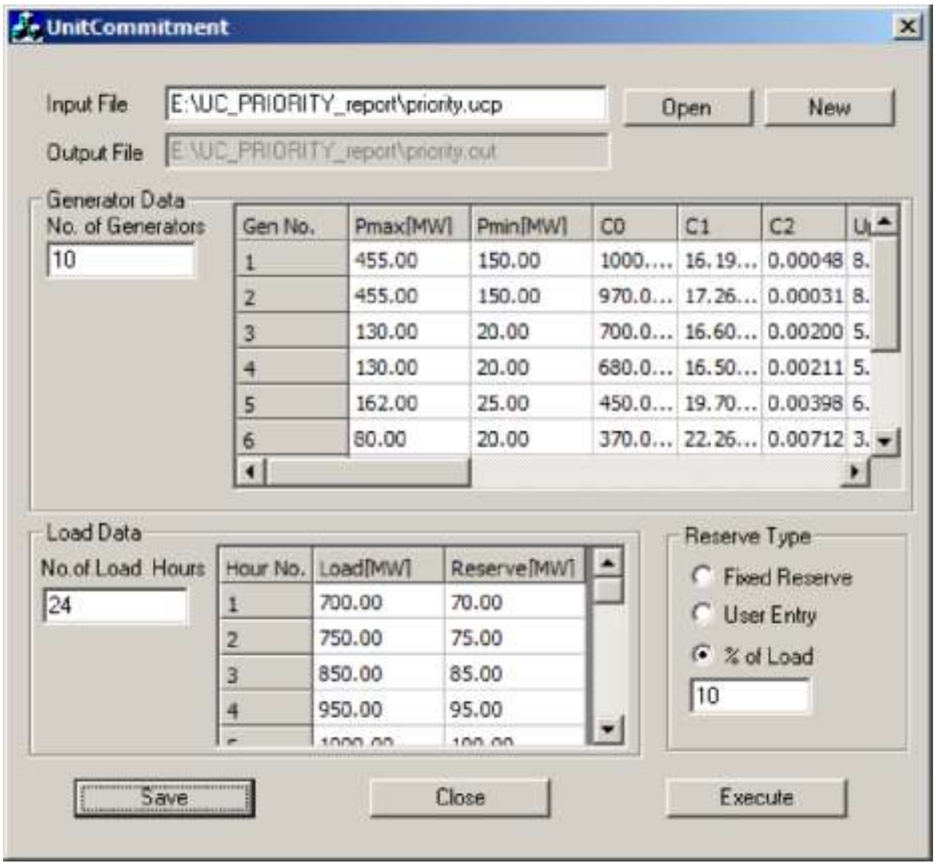

Figure2. Unit Commitment Solution using MiPower

RESULTS & DISCUSSION

The following results are obtained after simulating the unit commitment problem of 10-generating units for 24-hour load demand for in MiPower:

```
Priority List based on Max generation and Average cost per unit load(ACPL)

 slno   Pmax      AFLC  (Average Full load cost)
   1    455.00     18.61
   2    455.00     19.53
   5    162.00     23.12
   4    130.00     22.01
   3    130.00     22.24
   7     85.00     34.06
   6     80.00     27.45
   8     55.00     38.15
   9     55.00     39.48
  10     55.00     40.07
```

Under opr hrs in output -1 indicates generator is just shutdown and 1 indicates generator is just started in that particular hour

```
HOUR  =  1
Load  is  700.00

 slno  state   ophrs     pgen     cost
```

-----		--------	-------	-------
1	1	9.00	455.00	8465.82
2	1	9.00	245.00	5217.31
5	0	-7.00	0.00	0.00
4	0	-6.00	0.00	0.00
3	0	-6.00	0.00	0.00
7	0	-4.00	0.00	0.00
6	0	-4.00	0.00	0.00
8	0	-2.00	0.00	0.00
9	0	-2.00	0.00	0.00
10	0	-2.00	0.00	0.00

The total cost of generation is 13683.13

HOUR = 2
Load is 750.00

slno	state	ophrs	pgen	cost
1	1	10.00	455.00	8465.82
2	1	10.00	295.00	6088.68
5	0	-8.00	0.00	0.00
4	0	-7.00	0.00	0.00
3	0	-7.00	0.00	0.00
7	0	-5.00	0.00	0.00
6	0	-5.00	0.00	0.00
8	0	-3.00	0.00	0.00
9	0	-3.00	0.00	0.00
10	0	-3.00	0.00	0.00

The total cost of generation is 14554.50

HOUR = 3
5 to be started
5 - hot start cost considered
Load is 850.00

slno	state	ophrs	pgen	cost
1	1	11.00	455.00	8465.82
2	1	11.00	370.00	7398.64
5	1	1.00	25.00	944.99
4	0	-8.00	0.00	0.00
3	0	-8.00	0.00	0.00
7	0	-6.00	0.00	0.00
6	0	-6.00	0.00	0.00
8	0	-4.00	0.00	0.00
9	0	-4.00	0.00	0.00
10	0	-4.00	0.00	0.00

The total cost of generation is 17709.45

HOUR = 4
Load is 950.00

slno	state	ophrs	pgen	cost
1	1	12.00	455.00	8465.82
2	1	12.00	455.00	8887.48
5	1	2.00	40.00	1244.37
4	0	-9.00	0.00	0.00
3	0	-9.00	0.00	0.00
7	0	-7.00	0.00	0.00
6	0	-7.00	0.00	0.00
8	0	-5.00	0.00	0.00
9	0	-5.00	0.00	0.00
10	0	-5.00	0.00	0.00

The total cost of generation is 18597.67

HOUR = 5
4 tobe started

```
4   -  hot  start  cost  considered
Load is  1000.00
 slno    state    ophrs       pgen        cost
-----  --------    -------     -------     ------
1            1    13.00      455.00      8465.82
2            1    13.00      390.00      7748.55
5            1     3.00       25.00       944.99
```

```
   4        1      1.00      130.00      2860.66
   3        0    -10.00        0.00         0.00
   7        0     -8.00        0.00         0.00
   6        0     -8.00        0.00         0.00
   8        0     -6.00        0.00         0.00
   9        0     -6.00        0.00         0.00
  10       0     -6.00        0.00         0.00
 The  total  cost  of  generation  is  20580.02
------------------------------------------------------------------------------
HOUR  =  6
3 to  be  started
3 -  cold  start  cost  considered
 Load  is  1100.00

 slno   state     ophrs       pgen        cost
 -----  --------   -------     -------     ------
1            1    14.00      455.00      8465.82
2            1    14.00      360.00      7223.78
5            1     4.00       25.00       944.99
4            1     2.00      130.00      2860.66
3            1     1.00      130.00      2891.80
7            0    -9.00        0.00         0.00
6            0    -9.00        0.00         0.00
8            0    -7.00        0.00         0.00
9            0    -7.00        0.00         0.00
  10       0     -7.00        0.00         0.00
  The  total  cost  of  generation  is  23487.04
------------------------------------------------------------------------------

HOUR  =  7
Load  is  1150.00
 slno   state     ophrs       pgen        cost
-----  --------    -------     -------     ------
  1         1     15.00      455.00      8465.82
  2         1     15.00      410.00      8098.71
  5         1      5.00       25.00       944.99
  4         1      3.00      130.00      2860.66
  3         1      2.00      130.00      2891.80
  7         0    -10.00        0.00         0.00
  6         0    -10.00        0.00         0.00
  8         0     -8.00        0.00         0.00
  9         0     -8.00        0.00         0.00
 10        0     -8.00        0.00         0.00
 The  total  cost  of  generation  is  23261.98
------------------------------------------------------------------------------

HOUR  =  8
Load  is  1200.00
 slno   state     ophrs       pgen        cost
-----  --------    -------     -------     ------
  1         1     16.00      455.00      8465.82
  2         1     16.00      455.00      8887.48
  5         1      6.00       30.00      1044.58
  4         1      4.00      130.00      2860.66
  3         1      3.00      130.00      2891.80
  7         0    -11.00        0.00         0.00
```

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```
  6       0    -11.00      0.00       0.00
  8       0     -9.00      0.00       0.00
  9       0     -9.00      0.00       0.00
 10       0     -9.00      0.00       0.00
 The  total  cost  of  generation  is  24150.34
-------------------------------------------------------------------------------

HOUR  =  9
7  to  be  started
7  -  cold  start  cost  considered
6  to  be  started
6  -  cold  start  cost  considered

Load is 1300.00
```

```
 slno  state    ophrs     pgen      cost
-----  --------  -------  -------   ------
  1       1     17.00    455.00    8465.82
  2       1     17.00    455.00    8887.48
  5       1      7.00     85.00    2153.26
  4       1      5.00    130.00    2860.66
  3       1      4.00    130.00    2891.80
  7       1      1.00     25.00    1178.44
  6       1      1.00     20.00     818.05
  8       0    -10.00      0.00       0.00
  9       0    -10.00      0.00       0.00
 10       0    -10.00      0.00       0.00
 The  total  cost  of  generation  is  28115.50
-------------------------------------------------------------------------------

HOUR  =  10
8 to  be  started
8 -  cold  start  cost  considered
Load  is  1400.00
 slno  state    ophrs     pgen      cost
-----  --------  -------  -------   ------
1         1     18.00    455.00    8465.82
2         1     18.00    455.00    8887.48
5         1      8.00    162.00    3745.85
4         1      6.00    130.00    2860.66
3         1      5.00    130.00    2891.80
7         1      2.00     25.00    1178.44
6         1      2.00     33.00    1112.33
8         1      1.00     10.00     919.61
9         0    -11.00      0.00       0.00
10        0    -11.00      0.00       0.00
 The  total  cost  of  generation  is  30121.99
-------------------------------------------------------------------------------

  HOUR  =  11
9 to  be  started
9 -  cold  start  cost  considered
Load  is  1450.00
 slno  state    ophrs     pgen      cost
-----  --------  -------  -------   ------
1         1     19.00    455.00    8465.82
2         1     19.00    455.00    8887.48
5         1      9.00    162.00    3745.85
4         1      7.00    130.00    2860.66
3         1      6.00    130.00    2891.80
7         1      3.00     25.00    1178.44
6         1      3.00     73.00    2032.92
8         1      2.00     10.00     919.61
9         1      1.00     10.00     937.92
```

```
10          0     -12.00         0.00         0.00
  The  total  cost  of  generation  is  31980.50
-----------------------------------------------------------------------------

HOUR  =  12
10  to  be  started
 10  -  cold  start  cost  considered
Load  is  1500.00
 slno   state     ophrs       pgen                          cost
-----  --------   -------    -------                       ------
   1        1     20.00     455.00                        8465.82
   2        1     20.00     455.00                        8887.48
   5        1     10.00     162.00                        3745.85
   4        1      8.00     130.00                        2860.66
   3        1      7.00     130.00                        2891.80
   7        1      4.00      25.00                        1178.44
   6        1      4.00      80.00                        2196.37

   8        1      3.00      43.00                        1782.20
   9        1      2.00      10.00                         937.92
  10        1      1.00      10.00                         948.07

 The  total  cost  of  generation  is  33954.61
-----------------------------------------------------------------------------

HOUR  =  13
Load  is  1400.00
 slno   state     ophrs       pgen       cost
-----  --------   -------    -------    ------
   1        1     21.00     455.00     8465.82
   2        1     21.00     455.00     8887.48
   5        1     11.00     162.00     3745.85
   4        1      9.00     130.00     2860.66
   3        1      8.00     130.00     2891.80
   7        1      5.00      25.00     1178.44
   6        1      5.00      33.00     1112.33
   8        1      4.00      10.00      919.61
   9        0     -1.00       0.00        0.00
  10        0     -1.00       0.00        0.00
 The  total  cost  of  generation  is  30061.99
-----------------------------------------------------------------------------
HOUR  =  14
Load  is  1300.00
 slno   state     ophrs       pgen       cost
-----  --------   -------    -------    ------
   1        1     22.00     455.00     8465.82
   2        1     22.00     455.00     8887.48
   5        1     12.00      85.00     2153.26
   4        1     10.00     130.00     2860.66
   3        1      9.00     130.00     2891.80
   7        1      6.00      25.00     1178.44
   6        1      6.00      20.00      818.05
   8        0     -1.00       0.00        0.00
   9        0     -2.00       0.00        0.00
  10        0     -2.00       0.00        0.00
 The  total  cost  of  generation  is  27255.50
-----------------------------------------------------------------------------

HOUR  =  15

Load  is  1200.00
```

slno	state	ophrs	pgen	cost
1	1	23.00	455.00	8465.82
2	1	23.00	455.00	8887.48
5	1	13.00	30.00	1044.58
4	1	11.00	130.00	2860.66
3	1	10.00	130.00	2891.80
7	0	-1.00	0.00	0.00
6	0	-1.00	0.00	0.00
8	0	-2.00	0.00	0.00
9	0	-3.00	0.00	0.00
10	0	-3.00	0.00	0.00

The total cost of generation is 24150.34

HOUR = 16
Load is 1050.00

slno	state	ophrs	pgen	cost
1	1	24.00	455.00	8465.82
2	1	24.00	310.00	6350.39
5	1	14.00	25.00	944.99
4	1	12.00	130.00	2860.66
3	1	11.00	130.00	2891.80
7	0	-2.00	0.00	0.00
6	0	-2.00	0.00	0.00
8	0	-3.00	0.00	0.00
9	0	-4.00	0.00	0.00
10	0	-4.00	0.00	0.00

The total cost of generation is 21513.66

HOUR = 17
Load is 1000.00

slno	state	ophrs	pgen	cost
1	1	25.00	455.00	8465.82
2	1	25.00	260.00	5478.56
5	1	15.00	25.00	944.99
4	1	13.00	130.00	2860.66
3	1	12.00	130.00	2891.80
7	0	-3.00	0.00	0.00
6	0	-3.00	0.00	0.00
8	0	-4.00	0.00	0.00
9	0	-5.00	0.00	0.00
10	0	-5.00	0.00	0.00

The total cost of generation is 20641.82

HOUR = 18
Load is 1100.00

slno	state	ophrs	pgen	cost
1	1	26.00	455.00	8465.82
2	1	26.00	360.00	7223.78
5	1	16.00	25.00	944.99
4	1	14.00	130.00	2860.66
3	1	13.00	130.00	2891.80
7	0	-4.00	0.00	0.00
6	0	-4.00	0.00	0.00
8	0	-5.00	0.00	0.00
9	0	-6.00	0.00	0.00
10	0	-6.00	0.00	0.00

The total cost of generation is 22387.04

HOUR = 19

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Load is 1200.00

slno	state	ophrs	pgen	cost
1	1	27.00	455.00	8465.82
2	1	27.00	455.00	8887.48
5	1	17.00	30.00	1044.58
4	1	15.00	130.00	2860.66
3	1	14.00	130.00	2891.80
7	0	-5.00	0.00	0.00
6	0	-5.00	0.00	0.00
8	0	-6.00	0.00	0.00
9	0	-7.00	0.00	0.00
10	0	-7.00	0.00	0.00

The total cost of generation is 24150.34

HOUR = 20
7 to be started
7 - hot start cost considered
6 to be started
6 - hot start cost considered
8 to be started
7- cold start cost considered
Load is 1400.00

Slno	state	ophrs	pgen	cost
1	1	28.00	455.00	8465.82
2	1	28.00	455.00	8887.48
5	1	18.00	162.00	3745.85
4	1	16.00	130.00	2860.66
3	1	15.00	130.00	2891.80
7	1	1.00	25.00	1178.44
6	1	1.00	33.00	1112.33
8	1	1.00	10.00	919.61
9	0	-8.00	0.00	0.00
10	0	-8.00	0.00	0.00

The total cost of generation is 30551.99

HOUR = 21
Load is 1300.00

slno	state	ophrs	pgen	cost
1	1	29.00	455.00	8465.82
2	1	29.00	455.00	8887.48
5	1	19.00	85.00	2153.26
4	1	17.00	130.00	2860.66
3	1	16.00	130.00	2891.80
7	1	2.00	25.00	1178.44
6	1	2.00	20.00	818.05
8	0	-1.00	0.00	0.00
9	0	-9.00	0.00	0.00
10	0	-9.00	0.00	0.00

The total cost of generation is 27255.50

HOUR = 22
Load is 1100.00

slno	state	ophrs	pgen	cost
1	1	30.00	455.00	8465.82
2	1	30.00	455.00	8887.48
5	1	20.00	145.00	3390.18
4	0	-1.00	0.00	0.00
3	0	-1.00	0.00	0.00
7	1	3.00	25.00	1178.44

```
  6         1      3.00       20.00       818.05
  8         0     -2.00        0.00         0.00
  9         0    -10.00        0.00         0.00
 10        0     -10.00        0.00         0.00
 The  total  cost  of  generation  is  22739.96
--------------------------------------------------------------------------------


HOUR  =  23
Load  is  900.00
 slno   state     ophrs       pgen        cost
 -----  --------   -------    -------    ------
  1         1     31.00      455.00      8465.82
  2         1     31.00      420.00      8273.88
  5         1     21.00       25.00       944.99
  4         0     -2.00        0.00         0.00
  3         0     -2.00        0.00         0.00
  7         0     -1.00        0.00         0.00
  6         0     -1.00        0.00         0.00
  8         0     -3.00        0.00         0.00
  9         0    -11.00        0.00         0.00
 10        0     -11.00        0.00         0.00
 The  total  cost  of  generation  is  17684.69
--------------------------------------------------------------------------------

HOUR  =  24
Load  is  800.00
 slno   state     ophrs       pgen        cost
 -----  --------   -------    -------    ------

  1         1     32.00      455.00      8465.82
  2         1     32.00      345.00      6961.60
  5         0     -1.00        0.00         0.00
  4         0     -3.00        0.00         0.00
  3         0     -3.00        0.00         0.00
  7         0     -2.00        0.00         0.00
  6         0     -2.00        0.00         0.00
  8         0     -4.00        0.00         0.00
  9         0    -12.00        0.00         0.00
 10        0     -12.00        0.00         0.00
The  total  cost  of  generation  is  15427.42
-----------------------------------------------------------------------------
```

The total Generation cost for 24 hours is 564017.01

CONCLUSION

In this paper, researchers have presented the introductory approach to solve the Single Area Unit Commitment Problem of electric power system for 10-unit system for 24-hour load demand using priority list method. The use of MiPower software tools for unit commitment problem is also described.

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