Economically Operation of Power Utilities Base on MILP Approach

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Abstract: In this paper a new approach will be presented for solving one the complicated problems in power systems, known as the unit commitment. Indeed, in this paper, the proposed unit commitment is converted and formulated as the mixed-integer linear programming (MILP) model and solved by utilizing the Yalmip toolbox. Results demonstrates the high efficiency of the proposed method.

Keywords: Yalmip, power system economic, unit commitment, mixed-integer linear programming.

I. INTRODUCTION

Unit commitment (UC) is a complicated power system problem that has been widly investigated so far. In this problem, we try to determine the status of the units for the next day. Indeed, we should determine the ON and OFF status of the units by having the load demand. ON and OFF status of the units means the binary variables within the problem. When a unit is ON, the corresponding binary variable is one, otherwise, it is zero [1-5]. Hence, this problem is very hard to solve So far many heuristic (evolutionary) algorithms have been used to solve this problem [6-8]. However, heuristic methods are very time consuming and may trapping in the local minimum. Moreover, many mathematical models are developed, where many of them are unable to solve the large scale problem or have a convergence problem [9-14]. To this end, this paper proposes a new approach for solving the unit commitment problem based on the matlab toolbox known as the Yalmip. This method is very fast and the problem convergence is guaranteed [15].

II. Unit Commitment Formulations

In the UC problem, we try to minimized the cost, as [16]

$$min \sum_{\forall i}[C_i P_{it} I_{it} + SU_{it} + SD_{it}] \quad (1)$$

I: binary variable that can be zero or one and determine the status of generation unit *i* at time *t.*

SU, *SD:* Startup and shutdown costs of the *i*th unit at time *t*

The UC problem has some constraints as [17]

$$P_{it,min} \leq P_{it} \leq P_{it,max} \quad (2)$$

P: Output power of generators

$$P_{it} - P_{i(t-1)} \leq RU_i \quad (3)$$

$$P_{i(t-1)} - P_{it} \leq RD_i \quad (4)$$

RU_i , RU_i : Ramp up and ramp down rates of the *i*th generation units

$$T_{(on)it} \geq UT_i(I_{it} - I_{i(t-1)} \quad (5)$$

$$T_{(off)it} \geq DT_i(I_{i(t-1)} - I_{it} \quad (6)$$

UT_i , DT_i: Minimum up and down rates of the *i*th generation unit.

$T_{(on)}$, $T_{(off)}$: Number of successive on and off hours of the generation units

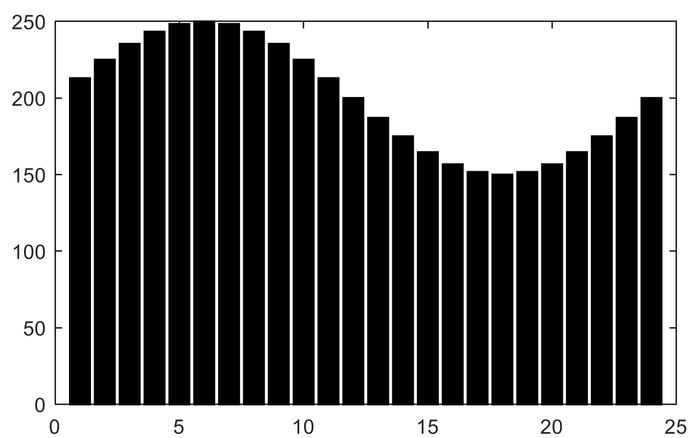
III. Proposed Method and Results

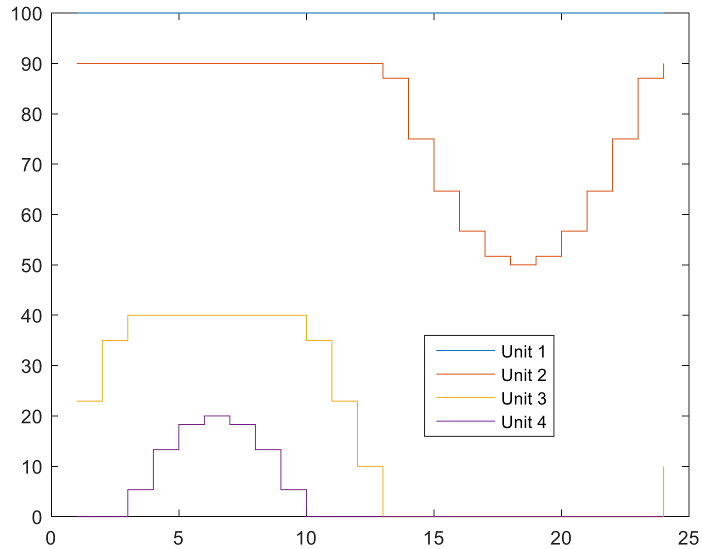
Here is the code of the Yalmip for the UC problem:

```
Nunits = 4;
```

```
    Horizon = 24;

    Pmax = [100;90;40;25];
    Pmin = [20;40;1;1];

    C = [10 10 11 12];

    Pforecast = 200 + 50*sin((1:Horizon)*2*pi/24);
    onoff = binvar(Nunits,Horizon,'full');
    P     = sdpvar(Nunits,Horizon,'full');
    Constraints = [];
    for k = 1:Horizon
      Constraints = [Constraints, onoff(:,k).*Pmin <= P(:,k) <= onoff(:,k).*Pmax];
    end
    for k = 1:Horizon
      Constraints = [Constraints, sum(P(:,k)) >= Pforecast(k)];
    end
    Objective = 0;
    for k = 1:Horizon
      Objective = Objective + C*P(:,k);
    end
    ops = sdpsettings('verbose',1,'debug',1);
    optimize(Constraints,Objective,ops)
    stairs(value(P)');
legend('Unit 1','Unit 2','Unit 3','Unit 4');
```

In this problem, we have 3 units and we forecasted the load for 24 hours. Here is the assumption of the load and result of the units.



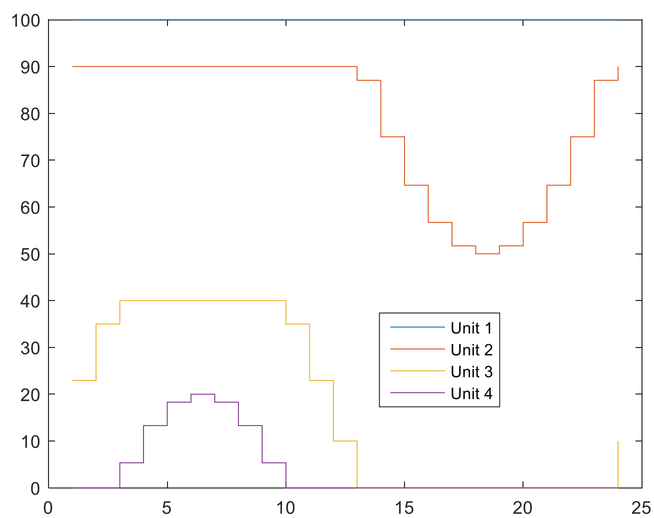


Also, we can consider the minimum up and down rates, the code would be:

```
Nunits = 4;
Horizon = 24;

Pmax = [100;90;40;25];
Pmin = [20;40;1;1];
minup   = [6;30;1;1];
mindown = [3;6;3;3];

C = [10 10 11 12];

Pforecast = 200 + 50*sin((1:Horizon)*2*pi/24);
onoff = binvar(Nunits,Horizon,'full');
P     = sdpvar(Nunits,Horizon,'full');
Constraints = [];
for k = 1:Horizon
  Constraints = [Constraints, onoff(:,k).*Pmin <= P(:,k) <= onoff(:,k).*Pmax];
end
for k = 1:Horizon
  Constraints = [Constraints, sum(P(:,k)) >= Pforecast(k)];
end
Objective = 0;
for k = 1:Horizon
  Objective = Objective + C*P(:,k);
end
for k = 2:Horizon
 for unit = 1:Nunits
  % indicator will be 1 only when switched on
```

```
    indicator = onoff(unit,k)-onoff(unit,k-1);
    range = k:min(Horizon,k+minup(unit)-1);
    % Constraints will be redundant unless indicator = 1
    Constraints = [Constraints, onoff(unit,range) >= indicator];
   end
  end
  for k = 2:Horizon
   for unit = 1:Nunits
    % indicator will be 1 only when switched off
    indicator = onoff(unit,k-1)-onoff(unit,k);
    range = k:min(Horizon,k+mindown(unit)-1);
    % Constraints will be redundant unless indicator = 1
    Constraints = [Constraints, onoff(unit,range) <= 1-indicator];
   end
  end
  ops = sdpsettings('verbose',1,'debug',1);
  optimize(Constraints,Objective,ops)
  stairs(value(P)');
legend('Unit 1','Unit 2','Unit 3','Unit 4');
```

Also, the units output is



IV. Conclusion

In this paper, we defined a new approach not only for the unit commitment problem, even for all of the MILP problems. This method is open access software and it is a toolbox of the matlab. The model is very fast, where the convergence is guaranteed as well. The method can be used for industrial projects to solve the economic problems.

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