Economic dispatch Assignment

Exercise 2

An electrical grid comprises 15 generators of the following characteristics:

- P_{G1}, P_{G2}, P_{G3} : Pn= 0-100MW, Qn= ±80MVar, f(P)=0.01·P2+ 0.04·P+0.001
- P_{G4}, P_{G5} : Pn= 0-200MW, Qn= ±100MVar, f(P)=0.01·P2+ 0.02·P+0.001
- P_{G6}, P_{G7} : Pn= 0-50MW, Qn= ±0MVar, f(P)=0.02·P2+ 0.04·P+0.001
- P_{G8}, P_{G9}, P_{G10} (renewables – not "dispatchable"): with 10 hr output forcast of P_{G8}= [0,0,0,0,0,1,2,4,6,4] MW, P_{G9}= [0,2,2,0,2,1,2,4,6,4] MW, P_{G10}= [1,2,4,6,4,4,6,4,4,6] MW, Qn= ±0MVar, f(P)=0
- P_{G11}, P_{G12} : Pn= 0-80MW, Qn= ±100MVar, f(P)=0.01·P2+ 0.07·P+0.001
- P_{G13}, P_{G14} : Pn= 0-250MW, Qn= ±100MVar, f(P)=0.02·P2+ 0.06·P+0.001
- P_{G15} : Pn= 0-200MW, Qn= ±100MVar, f(P)=0.01·P2+ 0.08·P+0.001

The load demand for the next 10 hours is P = [500, 700, 700, 900, 1100, 1450, 1600, 1600, 1500, 1500] and Q = [300, 400, 400, 600, 500, 850, 900, 850, 700, 700]

i. Calculate the optimal economic dispatch and the total energy cost that would be serving this load demand.

ii. Calculate the optimal economic dispatch serving this load demand if there are ±5% up and down ramp rates between consecutive hours for all generating units (except for renewables).

iii. Calculate the optimal economic dispatch serving this load demand if there are ±2% up and down ramp rates between consecutive hours for all generating units (except for renewables) and generator G7 suffers a failure and is set offline (both active and reactive power capacity set to zero) between hours 4-7 (incl. hours 4 & 7)

Costs given in Sb=100MVA

Solution:

```
clear;
% upper and lower bounds of the variables
% we make the intelligent guess that the renewables will be
% fully dispatched since they are the cheapest and the
% demand is much greater than their availability, hence we
% will bound them exactly at their availability

% upper bound
% Define a single-hour upper bound
xmax_single_hour =
[1,1,1,2,2,0.5,0.5,0,0,0.01,0.8,0.8,2.5,2.5,2,0.8,0.8,0.8,1,1,0,0,0,0,0,1,1,1,1,1]
;

% Define any hour-specific changes separately
hourly_adjustments = [
    [0, 0.02, 0.02];   % 2nd hour (indices 38:40)
    [0, 0.02, 0.04];   % 3rd hour (indices 68:70)
    [0, 0, 0.06];      % 4th hour (indices 98:100)
    [0, 0.02, 0.04];   % 5th hour (indices 128:130)
    [0.01, 0.01, 0.04];% 6th hour (indices 158:160)
    [0.02, 0.02, 0.06];% 7th hour (indices 188:190)
    [0.04, 0.04, 0.04];% 8th hour (indices 218:220)
    [0.06, 0.06, 0.04];% 9th hour (indices 248:250)
    [0.04, 0.04, 0.06] % 10th hour (indices 278:280)
];

% Build the xmax array for 10 hours
xmax = repmat(xmax_single_hour, 1, 10);
for i = 2:10
    xmax(1, (i-1)*30+8:(i-1)*30+10) = hourly_adjustments(i-1, :);
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end

% lower bound
% Define a single-hour lower bound
xmin_single_hour = [zeros(1,7), 0, 0, 0.01, zeros(1,5), -0.8, -0.8, -0.8, -1, -1,
zeros(1,5), -1, -1, -1, -1, -1];

% Define any hour-specific changes for xmin separately
hourly_adjustments_xmin = [
    [0, 0.02, 0.02];   % 2nd hour (indices 38:40)
    [0, 0.02, 0.04];   % 3rd hour (indices 68:70)
    [0, 0, 0.06];      % 4th hour (indices 98:100)
    [0, 0.02, 0.04];   % 5th hour (indices 128:130)
    [0.01, 0.01, 0.04];% 6th hour (indices 158:160)
    [0.02, 0.02, 0.06];% 7th hour (indices 188:190)
    [0.04, 0.04, 0.04];% 8th hour (indices 218:220)
    [0.06, 0.06, 0.04];% 9th hour (indices 248:250)
    [0.04, 0.04, 0.06] % 10th hour (indices 278:280)
];

% Build the xmin array for 10 hours
xmin = repmat(xmin_single_hour, 1, 10);

% Apply hourly adjustments to xmin
for i = 2:10
    xmin(1, (i-1)*30+8:(i-1)*30+10) = hourly_adjustments_xmin(i-1, :);
end


% the first line is the equality of generation and demand
% for active power for t=1
% the second line is the equality of generation and demand
% for reactive power for t=1
% the thrird line is the equality of generation and demand
% for active power for t=2
% the fourth line is the equality of generation and demand
% for reactive power for t=2
% and so forth until t=15
Aeq = [ones(1,15),zeros(1,285);zeros(1,15),ones(1,15),zeros(1,270);];
Aeq = [Aeq;
zeros(1,30),ones(1,15),zeros(1,255);zeros(1,45),ones(1,15),zeros(1,240);];
Aeq = [Aeq;
zeros(1,60),ones(1,15),zeros(1,225);zeros(1,75),ones(1,15),zeros(1,210);];
Aeq = [Aeq;
zeros(1,90),ones(1,15),zeros(1,195);zeros(1,105),ones(1,15),zeros(1,180);];
Aeq = [Aeq;
zeros(1,120),ones(1,15),zeros(1,165);zeros(1,135),ones(1,15),zeros(1,150);];
Aeq = [Aeq;
zeros(1,150),ones(1,15),zeros(1,135);zeros(1,165),ones(1,15),zeros(1,120);];
Aeq = [Aeq;
zeros(1,180),ones(1,15),zeros(1,105);zeros(1,195),ones(1,15),zeros(1,90);];
Aeq = [Aeq;
zeros(1,210),ones(1,15),zeros(1,75);zeros(1,225),ones(1,15),zeros(1,60);];
Aeq = [Aeq;
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zeros(1,240),ones(1,15),zeros(1,45);zeros(1,255),ones(1,15),zeros(1,30);];
Aeq = [Aeq; zeros(1,270),ones(1,15),zeros(1,15);zeros(1,285),ones(1,15)];


beq = [5, 3, 7, 4, 7, 4, 9, 6, 11, 5, 14.5, 8.5, 16, 9, 16, 8.5, 15, 7, 15, 7];

% Original quadratic cost vector for a single hour
c2= [0.01, 0.01, 0.01, 0.01, 0.01, 0.02, 0.02, 0, 0, 0, 0.01, 0.01, 0.02, 0.02,
0.01, zeros(1,15)];
c2_10=repmat(c2, 1, 10);
% Hessian matrix (2 * diag(c2_10) to account for Hessian scaling)
H = 2 * diag(c2_10);



% Original linear cost vector for a single hour
f = [0.04, 0.04, 0.04, 0.02, 0.02, 0.04, 0.04, zeros(1,3), 0.07, 0.07, 0.06, 0.06,
0.08, zeros(1,15)];

% Extend the linear cost vector for 10 hours by repeating `f` 10 times
f_10_hours = repmat(f, 1, 10);




%i) Calculate the optimal economic dispatch and the total energy cost that would
be serving this load demand.

%x1 = quadprog(H, f_10_hours, [], [], Aeq, beq, xmin, xmax);
%disp(x1);

%ii) Calculate the optimal economic dispatch serving this load demand if there are
±5% up and down ramp rates between
% consecutive hours for all generating units (except for renewables).

% Define the number of non-renewable generators (1-7, 11-15)
non_renewable_generators = [1:7, 11:15];  % Generators 1 to 7 and 11 to 15

% Ramp rate constraints: ±5% for active power and reactive power between
consecutive hours
%ramp_rate = 0.05;  % ±5% for ii)
ramp_rate = 0.02;  % ±2% for iii)

% Define inequality constraints for ramp rates (both active and reactive power)
A_ineq = [];  % Initialize the inequality matrix
b_ineq = [];  % Initialize the inequality bounds

% Total number of variables per hour (active + reactive power for 15 generators)
num_variables_per_hour = 30;  % 15 generators * 2 (active and reactive power)

% Total number of variables (30 variables per hour * 10 hours)
total_variables = 300;  % 10 hours * 30 variables per hour

for t = 1:9  % For hours t = 1 to 9 (pairs of consecutive hours)
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    for i = non_renewable_generators  % For each non-renewable generator (1 to 7
and 11 to 15)
        % Active power variable index for hour t (p1, p2, ..., p15 for hour t)
        p_index_t = (t-1)*30 + i;  % Index of p_i for hour t
        p_index_t_plus_1 = t*30 + i;  % Index of p_i for hour t+1

        % Reactive power variable index for hour t (q1, q2, ..., q15 for hour t)
        q_index_t = (t-1)*30 + i + 15;  % Index of q_i for hour t (offset by 15
for reactive power)
        q_index_t_plus_1 = t*30 + i + 15;  % Index of q_i for hour t+1 (offset by
15 for reactive power)

        % Upper ramp rate constraint for active power: p_{i,t+1} - p_{i,t} <= 0.05
* p_{i,t}
        A_row = zeros(1, total_variables);  % Total number of variables (300)
        A_row(p_index_t) = -1;  % p_{i,t}
        A_row(p_index_t_plus_1) = 1;  % p_{i,t+1}
        A_ineq = [A_ineq; A_row];  % Add to A_ineq
        b_ineq = [b_ineq; ramp_rate * xmax_single_hour(i)];  % Upper ramp rate
bound

        % Lower ramp rate constraint for active power: p_{i,t} - p_{i,t+1} <= 0.05
* p_{i,t}
        A_row = zeros(1, total_variables);  % Total number of variables (300)
        A_row(p_index_t) = 1;  % p_{i,t}
        A_row(p_index_t_plus_1) = -1;  % p_{i,t+1}
        A_ineq = [A_ineq; A_row];  % Add to A_ineq
        b_ineq = [b_ineq; ramp_rate * xmax_single_hour(i)];  % Lower ramp rate
bound

        % Upper ramp rate constraint for reactive power: q_{i,t+1} - q_{i,t} <=
0.05 * q_{i,t}
        A_row = zeros(1, total_variables);  % Total number of variables (300)
        A_row(q_index_t) = -1;  % q_{i,t}
        A_row(q_index_t_plus_1) = 1;  % q_{i,t+1}
        A_ineq = [A_ineq; A_row];  % Add to A_ineq
        b_ineq = [b_ineq; ramp_rate * xmax_single_hour(i + 15)];  % Upper ramp
rate bound

        % Lower ramp rate constraint for reactive power: q_{i,t} - q_{i,t+1} <=
0.05 * q_{i,t}
        A_row = zeros(1, total_variables);  % Total number of variables (300)
        A_row(q_index_t) = 1;  % q_{i,t}
        A_row(q_index_t_plus_1) = -1;  % q_{i,t+1}
        A_ineq = [A_ineq; A_row];  % Add to A_ineq
        b_ineq = [b_ineq; ramp_rate * xmax_single_hour(i + 15)];  % Lower ramp
rate bound
    end
end



%x2 = quadprog(H, f_10_hours, A_ineq, b_ineq, Aeq, beq, xmin, xmax);
%disp(x2);
```

```
% iii) Calculate the optimal economic dispatch serving this load demand if there are ±2% up and down ramp rates between
% consecutive hours for all generating units (except for renewables) and generator G7 suffers a failure
% and is set offline (both active and reactive power capacity set to zero) between hours 4-7 (incl. hours 4 & 7)

% Set G7 offline (both active and reactive power) between hours 4-7
% Adjust xmin and xmax bounds for G7 (both active and reactive power) during hours 4 to 7

for t = 4:7
    % Active power bounds for G7 (Generator 7)
    xmin(1, (t-1)*30 + 7) = 0; % Active power lower bound for G7
    xmax(1, (t-1)*30 + 7) = 0; % Active power upper bound for G7

    % Reactive power bounds for G7 (Generator 7)
    xmin(1, (t-1)*30 + 7 + 15) = 0; % Reactive power lower bound for G7
    xmax(1, (t-1)*30 + 7 + 15) = 0; % Reactive power upper bound for G7
end

x3 = quadprog(H, f_10_hours, A_ineq, b_ineq, Aeq, beq, xmin, xmax);
disp(x3);
```