Contents

Microgrid Simulation

Created: ECE 530 class of fall 2024

```
%clc
%close all   % close figure windows
%clear
%format compact
```

Simulation settings

```
simu.endTime = 60*60*20.5; %60*60*24;
simu.maxStepSize = 1e-1;
```

Data

```
load windspeedtimeseries
load loadtimeseries
load illuminationcurrenttimeseries
load illuminationcurrenttimeseries_clouded

meanWindSpeed = 8;
maxWindSpeed = 15;

meanLoadPower = 1.98e3; % Average Load
maxLoadPower = 2.36e3;  % Peak Load

maxIlluminationCurrent = 10; % 10 is fully sunny day

% Scaling
windspeedtimeseries.Data = fn_scaling(...
    meanWindSpeed*windspeedtimeseries.Data,meanWindSpeed,maxWindSpeed);
loadtimeseries.Data = fn_scaling(...
    loadtimeseries.Data,meanLoadPower,maxLoadPower);
% illuminationcurrenttimeseries.Data = ...
    % illuminationcurrenttimeseries.Data*maxIlluminationCurrent/max(illuminationcurrenttimeseries.Data);

% Contingency Condition: Cloudy Day
illuminationcurrenttimeseries.Data = ...
    illuminationcurrenttimeseries_clouded.Data*maxIlluminationCurrent/max(illuminationcurrenttimeseries_clouded.Data);
```

```
Equation solved.

fsolve completed because the vector of function values is near zero
as measured by the value of the function tolerance, and
the problem appears regular as measured by the gradient.


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```

Wind Turbine Parameters

```
wt.N_turbines = 1;

wt.rho = 1.2; % Density of air kg/m^3

% XANT 100 kW
```

```
wt.Pgen_rated = 100e3;
wt.Cfric = 0.01*100e3/6^2;    % Nm/(rad/s)    B*6^2 = 0.01*100e3
wt.bladeLength = 11;
wt.bladeWeight = 1000;    % From http://windpower.sandia.gov/other/041605C.pdf
wt.J = 3*1/3*wt.bladeWeight*wt.bladeLength^2;  % Missing generator, gearbox, shaft, etc...

wt.A = pi*wt.bladeLength^2;

wt.w_0 = 0;

% Cp curve modeling
% lambdaai = 1/( (1/(lambda+0.08*beta)) - 0.035/(beta^3+1) )
% cp = c1*(c2/lambdaai-c3*beta-c4)*exp(-c5/lambdaai) + c6*lambda
plot_cp = 0;
if plot_cp
    wt.c = [
        0.5176
        116
        0.4
        5
        21
        0.0068
        ];
    figure
    lambda = [0:0.1:13];
    for beta = [0:5:30];
        lambdaai = 1./(1./(lambda+0.08*beta) - 0.035./(beta.^3+1));
        cp = wt.c(1)*(wt.c(2)./lambdaai - wt.c(3)*beta - wt.c(4)) .* exp(-wt.c(5)./lambdaai) + wt.c(6)*lambda;
        hold on
        plot(lambda,cp)
        hold off
    end
    axis([0 13 0 0.5])
    xlabel('lambda (tip speed ratio)')
    ylabel('Cp')
end

% From Cp(lambda) plot
wt.lambda_opt = 8.1;
wt.Cp_opt = 0.48;

% Region 2 and 3 boundary -> rated rotational speed and wind speed
wt.u_rated = (wt.Pgen_rated/(wt.Cp_opt*0.5*1.2*wt.A))^(1/3);   % P_rated = Cp_max*0.5*A*bladeLength*u_rated^3
wt.w_rated = wt.lambda_opt*wt.u_rated/wt.bladeLength;
wt.Tgen_rated = wt.Pgen_rated/wt.w_rated;

wt.pitchctrl.kp = 1;
wt.pitchctrl.ki = 0.1;
wt.pitchctrl.upperLimit = 1;
wt.pitchctrl.lowerLimit = 0;
```

Solar

```
% Parameters based on SolarWorld 300 module
% 300 W panel, 60 cells, 5 W per cell
% Open circuit voltage of 40 V (0.66 V per cell)
% Short circuit current of 9.83 A
% Maximum power point at 32.6 V (0.54 V per cell) and 9.31 A

pv.P_rated = 9.7e3; % Homer Output

pv.Is = 1e-10; % Produces about  0.66 V at 9.8 A of current
pv.Rs = 0.0001; % Adjusting down increased power by up to 8%.
pv.Rp = 2500;  % Based off of L. Ma et al. "The Measurement of Series and Shunt Resistances of the Silicon Solar Cell Based on LabVIEW"
pv.VT = 0.026;

pv.vd_0 = 0.7;

pv.MPPT_sampleTime = 1;  % LEFT at ONE SECOND
```

Energy Storage

```
es.eta_pe = 0.95;
es.eta_sm = sqrt(0.9);
es.SOC_0 = 0.5;

es.P_pe_rated = 25.3e3; % Homer Output
es.P_pe_rated = pv.P_rated; % To address insufficiency power of converter
es.P_pe_slew_upper = es.P_pe_rated / 1;
es.P_pe_slew_lower = -es.P_pe_rated / 1;

es.E_rated_kWh = 30.7; % SEE REPORT SUMMARY

es.E_rated = es.E_rated_kWh*1000*3600;
```

```
es.P_rated = es.P_pe_rated;
```

Microgrid

```
mg.H = 5;
mg.D = 1;
mg.P_base = maxLoadPower;
mg.wpu_0 = 1;
mg.X = 0.05;

es.Kgpri = 20;

ht.Kgpri = 20;
ht.Kgsec = 20/60;
```

Hydro

```
ht.P_rated = 5; % Homer Output

% Parameters for Hills Creek Reservoir unit
ht.tauw = 1.6;
ht.q_0 = 0.1;
ht.beta = 10;
ht.powercontroller.kp = 1.5/20; % Divide by 20 to account for droop
ht.powercontroller.ki = 0.3/20;
ht.powercontroller.kd = 0.55/20;

ht.powercontroller.int_0 = 0.1;
ht.powercontroller.kt = 1;
ht.powercontroller.Td = 0.05;

ht.powercontroller.lowerLimit = 0;
ht.powercontroller.upperLimit = 1;

ht.servo.tau = 0.35;
ht.servo.kg = 3;
ht.servo.speedUpperLimit = 0.077;
ht.servo.speedLowerLimit = -0.077;
ht.servo.posUpperLimit = 1;
ht.servo.posLowerLimit = 0.05;
ht.servo.initPos = 0.1;
```

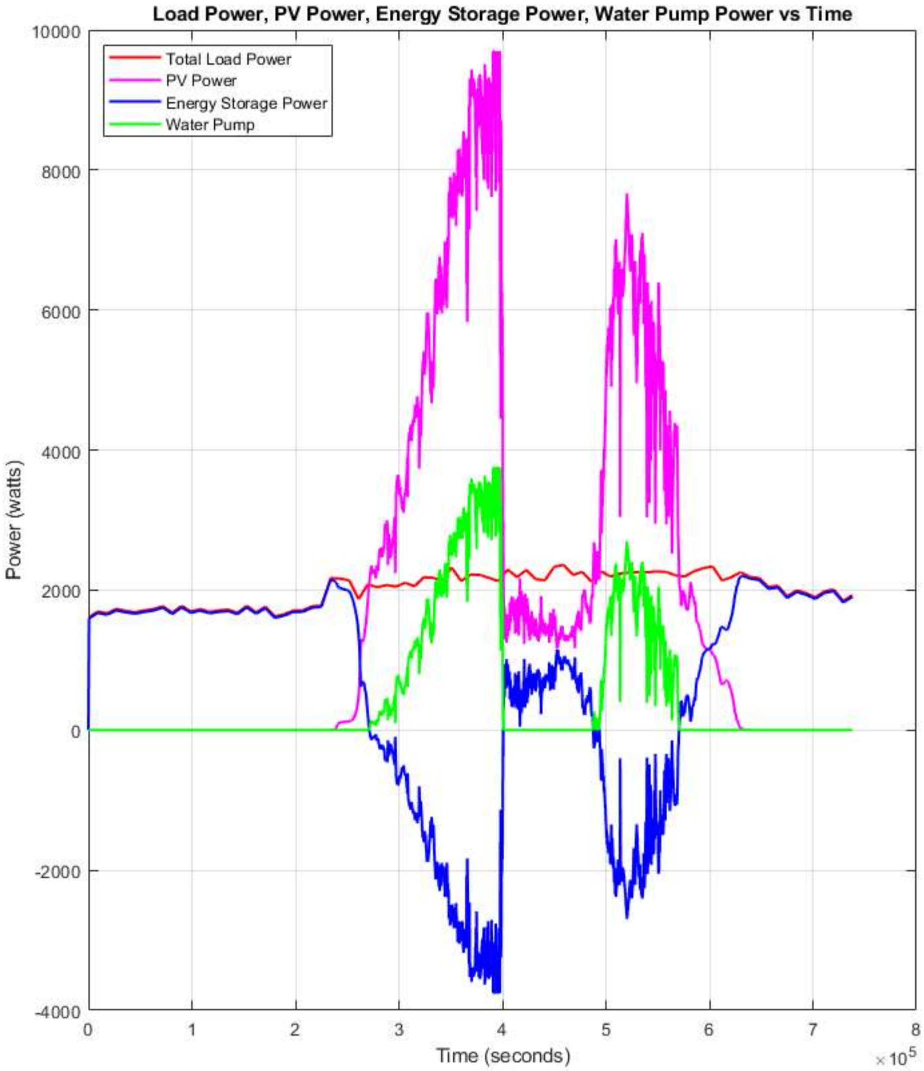
Water Pump (Deferrable Load)

```
wp.P_rated = pv.P_rated;
wp.height = 40;

wp.P_upper = wp.P_rated;
wp.P_lower = 0;
wp.P_upperRate = wp.P_rated/10;
wp.P_lowerRate = -wp.P_upperRate;
wp.Kgpri = 20;
```

```
simresults = sim("microgrid_y24f_step10");   % ADDED to access data

loggedData = simresults.logsout;      % ADDED to access data
p_ld = loggedData.get('p_ld').Values.Data;  % load
p_pv = loggedData.get('p_pv').Values.Data;
p_es = loggedData.get('p_es').Values.Data;
%p_ht = loggedData.get('p_ht').Values.Data;
p_wp = loggedData.get('p_wp').Values.Data; % water pump - Deferrable load
soc = loggedData.get('SOC').Values.Data;
delta_wpu = loggedData.get('delta_wpu').Values.Data;


x_time = 1:length(soc);
figure(1);

plot(x_time, p_ld, 'r-', 'LineWidth', 1.5);
hold on;
plot(x_time, p_pv, 'm-', 'LineWidth', 1.5);
plot(x_time, p_es, 'b-', 'LineWidth', 1.5);
plot(x_time, p_wp, 'g-', 'LineWidth', 1.5);
%plot(x_time, p_ht, 'k-', 'LineWidth', 1.5);
ylabel('Power (watts)');

hold off;


set(gcf, 'Position', [1550, 50, 800, 900]);
xlabel('Time (seconds)');
```

```
title('Load Power, PV Power, Energy Storage Power, Water Pump Power vs Time');
legend('Total Load Power', 'PV Power','Energy Storage Power', 'Water Pump');  % Add legend
legend location northwest
grid on;
```

```
Warning: Model
'<a href="matlab:open_system ('microgrid_y24f_step10')">microgrid_y24f_step10</a>'
contains 1 algebraic
loops.
Suggested Actions:
    • Highlight and view
    information about the
    algebraic loops in
    the model using the
    Simulink.BlockDiagram.getAlgebraicLoops
    function. - <a href="matlab:Simulink.BlockDiagram.getAlgebraicLoops('microgrid_y24f_step10');">Open</a>
    • Suppress this
    diagnostic by setting
    the 'Algebraic Loop'
    diagnostic parameter
    to 'none'. - <a href="matlab:set_param('microgrid_y24f_step10','AlgebraicLoopMsg', 'none');">Fix</a>

Found algebraic loop that contains:
<a href="matlab:open_and_hilite_hyperlink ('microgrid_y24f_step10/pv/Sum4','error')">microgrid_y24f_step10/pv/Sum4</a>
<a href="matlab:open_and_hilite_hyperlink ('microgrid_y24f_step10/pv/Gain3','error')">microgrid_y24f_step10/pv/Gain3</a>
<a href="matlab:open_and_hilite_hyperlink ('microgrid_y24f_step10/pv/Sum2','error')">microgrid_y24f_step10/pv/Sum2</a>
<a href="matlab:open_and_hilite_hyperlink ('microgrid_y24f_step10/pv/Gain1','error')">microgrid_y24f_step10/pv/Gain1</a>
<a href="matlab:open_and_hilite_hyperlink ('microgrid_y24f_step10/pv/Math Function','error')">microgrid_y24f_step10/pv/Math Function</a>
<a href="matlab:open_and_hilite_hyperlink ('microgrid_y24f_step10/pv/Sum3','error')">microgrid_y24f_step10/pv/Sum3</a>
<a href="matlab:open_and_hilite_hyperlink ('microgrid_y24f_step10/pv/Gain2','error')">microgrid_y24f_step10/pv/Gain2</a>
<a href="matlab:open_and_hilite_hyperlink ('microgrid_y24f_step10/pv/Sum1','error')">microgrid_y24f_step10/pv/Sum1</a>
<a href="matlab:open_and_hilite_hyperlink ('microgrid_y24f_step10/pv/Gain','error')">microgrid_y24f_step10/pv/Gain</a>
<a href="matlab:open_and_hilite_hyperlink ('microgrid_y24f_step10/pv/Sum','error')">microgrid_y24f_step10/pv/Sum</a>
<a href="matlab:open_and_hilite_hyperlink ('microgrid_y24f_step10/pv/Algebraic Constraint','error')">microgrid_y24f_step10/pv/Algebraic Constraint</a> (algebraic va
<a href="matlab:open_and_hilite_hyperlink ('microgrid_y24f_step10/pv/Product','error')">microgrid_y24f_step10/pv/Product</a> (algebraic variable)
```

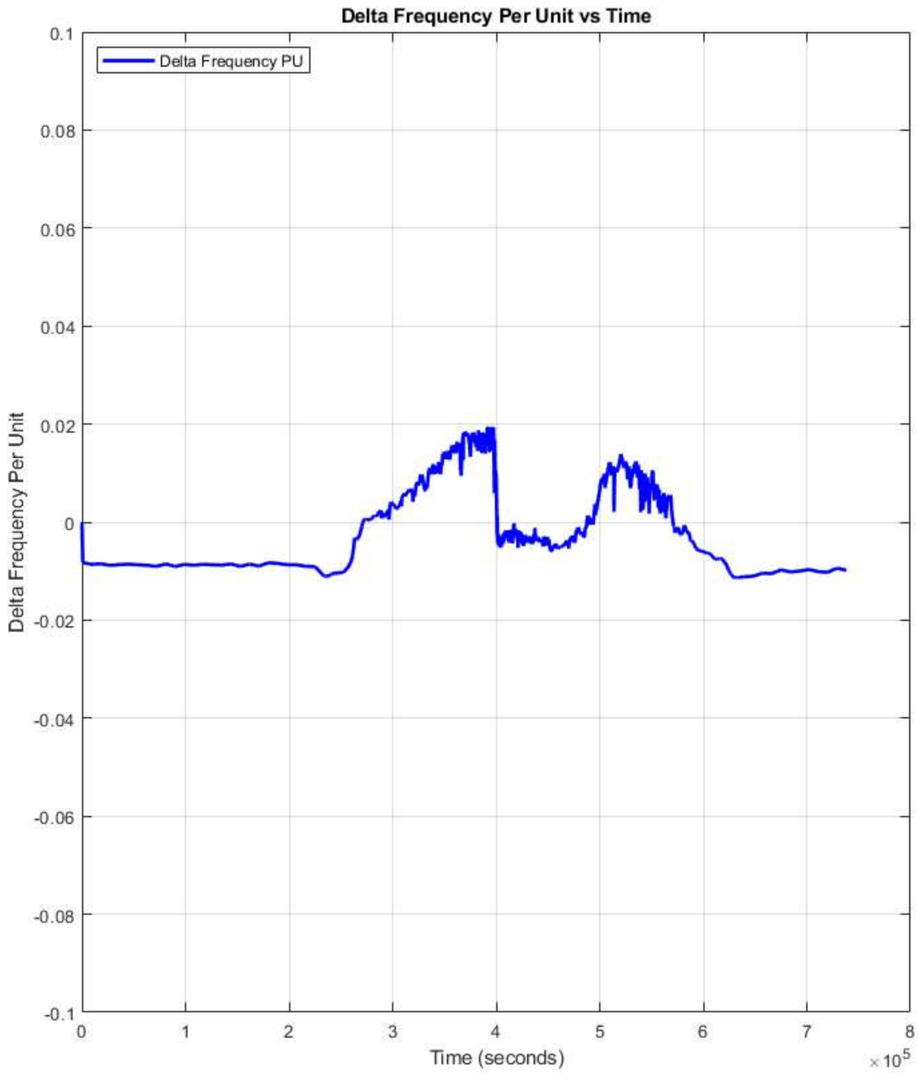


Plot #2 Delta Frequency Per Unit vs Time

The delta frequency per unit shows the frequency maintaining within +/- 0.10 per the problem statment.

```
figure(2);
plot(x_time, delta_wpu, 'b-', 'LineWidth', 2);
ylabel('Delta Frequency Per Unit');
ylim([-0.1 .1]);
set(gcf, 'Position', [1550, 50, 800, 900]);
xlabel('Time (seconds)');
title('Delta Frequency Per Unit vs Time');
legend('Delta Frequency PU');  % Add legend
legend location northwest
grid on;
disp("finished.")
```

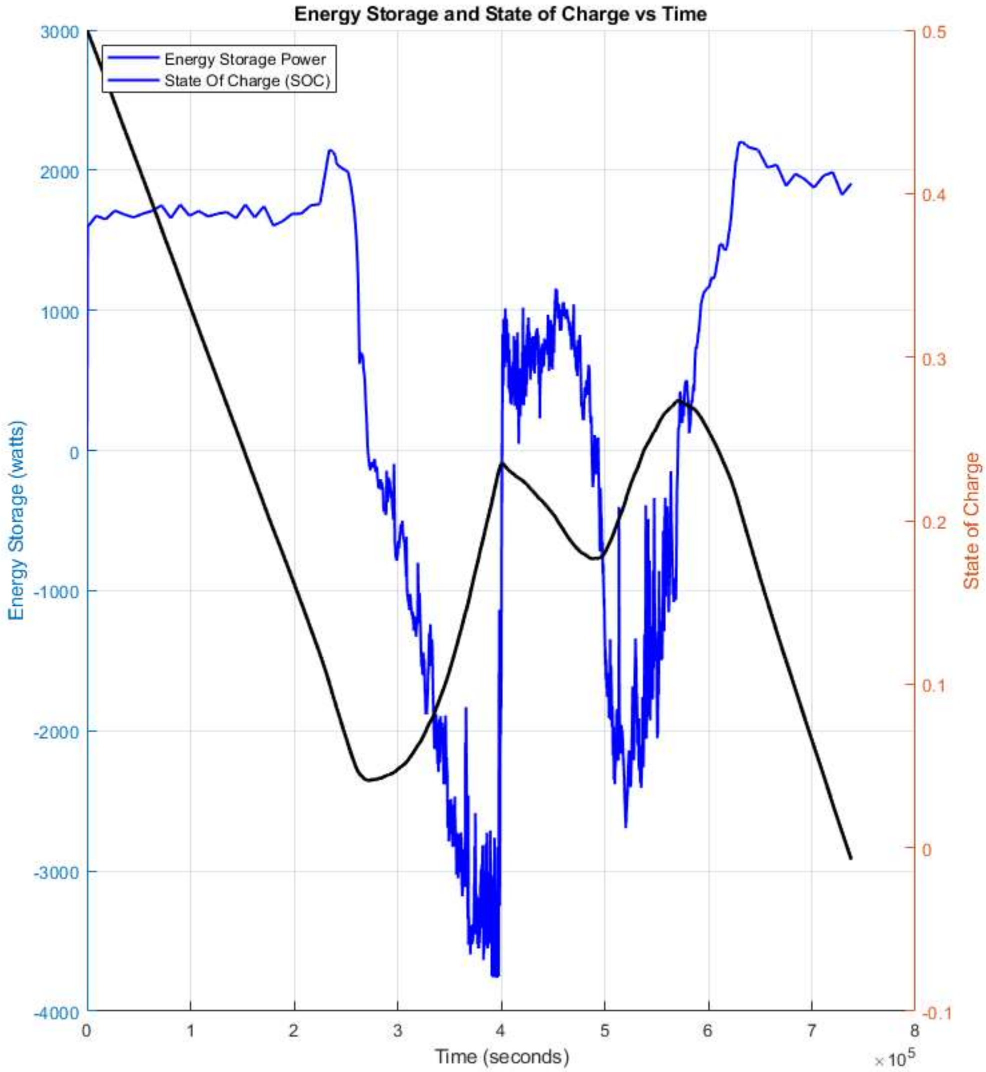
```
finished.
```



Plot #3 Delta Frequency Per Unit vs Time

The delta frequency per unit shows the frequency maintaining within +/-
0.10 per the problem statment.

```
figure(3);
yyaxis left

hold on;
plot(x_time, p_es, 'b-', 'LineWidth', 1.5);
ylabel('Energy Storage (watts)');
%set(gca, 'YColor', 'b');
%ylim([0 11e4]);
yyaxis right
plot(x_time, soc, 'k-', 'LineWidth', 2);
hold off;
ylabel('State of Charge');
%ylim([-0.1 1.015]);
set(gcf, 'Position', [1550, 50, 800, 900]);
xlabel('Time (seconds)');
title('Energy Storage and State of Charge vs Time');
legend('Energy Storage Power', 'State Of Charge (SOC)');  % Add legend
legend location northwest
grid on;
```



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