```
clc;  % Clears the command window
clear;  % Clears all variables from the workspace
%close all;  % Closes all open figures

disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')
disp('Energy Efficient (EE) Motor parameters')
disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')

f_EE=50;               %Supply frequency [Hz]
p_EE=4;                %Number of poles
V1_EE=380/sqrt(3);     %Supply voltage [phase]
R1_EE=1.5;             %Stator winding resistance [ohms/phase]
X1_EE=3.642;           %Stator winding leakage reactance [ohms/phase]
Xm_EE=72.252;          %Stator winding magnetising reactance [ohms/phase]
X2p_EE=3.642;          %Rotor winding leakage reactance reffered to stator [ohms/phase]
R2p_EE=1.994;          %Rotor winding resistance reffered to stator [ohms/phase]

fprintf('EE Motor\n');
fprintf('\n');

fprintf('f=%f\n',f_EE);
fprintf('p=%f\n',p_EE);
fprintf('V1=%f\n',V1_EE);
fprintf('R1=%f\n',R1_EE);
fprintf('X1=%f\n',X1_EE);
fprintf('Xm=%f\n',Xm_EE);
fprintf('X2p=%f\n',X2p_EE);
fprintf('R2p=%f\n',R2p_EE);

f_SE=50;               %Supply frequency [Hz]
p_SE=4;                %Number of poles
V1_SE=380/sqrt(3);     %Supply voltage [phase]
R1_SE=2.087;             %Stator winding resistance [ohms/phase]
X1_SE=4.274;           %Stator winding leakage reactance [ohms/phase]
Xm_SE=66.56;          %Stator winding magnetising reactance [ohms/phase]
X2p_SE=4.2742;          %Rotor winding leakage reactance reffered to stator [ohms/phase]
R2p_SE=2.122;          %Rotor winding resistance reffered to stator [ohms/phase]

fprintf('\n');
fprintf('SE Motor\n');
fprintf('\n');

fprintf('f=%f\n',f_SE);
fprintf('p=%f\n',p_SE);
fprintf('V1=%f\n',V1_SE);
fprintf('R1=%f\n',R1_SE);
fprintf('X1=%f\n',X1_SE);
fprintf('Xm=%f\n',Xm_SE);
fprintf('X2p=%f\n',X2p_SE);
fprintf('R2p=%f\n',R2p_SE);
```

```
disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')
disp('Question 1:Thevenin Equiv Cct Parameters for EE and SE Motor:')
disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')

Vth_EE=Xm_EE/sqrt(R1_EE^2+(X1_EE+Xm_EE)^2)*V1_EE;         %Thevenin equiv voltage source↙
[V] (Equ 5.45 - Sen)
Zth_EE=1i*Xm_EE*(R1_EE+1i*X1_EE)/(R1_EE+1i*(X1_EE+Xm_EE));   %Thevenin equiv impedance
Rth_EE=real(Zth_EE);                             %Thevenin equiv resistance [ohms]
Xth_EE=imag(Zth_EE);                             %Thevenin equiv reactance [ohms]

fprintf('EE Motor\n');
fprintf('\n');

fprintf('Vth=%f\n',Vth_EE);
fprintf('Rth=%f\n',Rth_EE);
fprintf('Xth=%f\n',Xth_EE);

Vth_SE=Xm_SE/sqrt(R1_SE^2+(X1_SE+Xm_SE)^2)*V1_SE;         %Thevenin equiv voltage source↙
[V] (Equ 5.45 - Sen)
Zth_SE=1i*Xm_SE*(R1_SE+1i*X1_SE)/(R1_SE+1i*(X1_SE+Xm_SE));   %Thevenin equiv impedance
Rth_SE=real(Zth_SE);                             %Thevenin equiv resistance [ohms]
Xth_SE=imag(Zth_SE);                             %Thevenin equiv reactance [ohms]

fprintf('\n');
fprintf('SE Motor\n');
fprintf('\n');

fprintf('Vth=%f\n',Vth_SE);
fprintf('Rth=%f\n',Rth_SE);
fprintf('Xth=%f\n',Xth_SE);

disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')
disp('QUESTION 2:Torque versus speed characteristics for EE and SE Motor:')
disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')

ns=120*f_EE/p_EE;          %Synchronous speed [rpm]
ws=2*pi*ns/60;       %Synchronous speed [rad/sec]
s=0.0005:0.0005:1;   %Slip [pu]
n=(1-s)*ns;          %Rotor speed [rpm]
w=2*pi*n/60;         %Rotor speed [rad/sec]

Tmech_EE=3/ws*Vth_EE^2./((Rth_EE+R2p_EE./s).^2+(Xth_EE+X2p_EE)^2).*R2p_EE./s;    %Total↙
Tmech = {3*(Equ5.54 - Sen)}
Tmech_SE=3/ws*Vth_SE^2./((Rth_SE+R2p_SE./s).^2+(Xth_SE+X2p_SE)^2).*R2p_SE./s;

% Find starting and maximum torque
% Starting torque: s = 1
T_start_EE = 3/ws*Vth_EE^2./((Rth_EE+R2p_EE./1).^2+(Xth_EE+X2p_EE)^2).*R2p_EE./1;
T_start_SE = 3/ws*Vth_SE^2./((Rth_SE+R2p_SE./1).^2+(Xth_SE+X2p_SE)^2).*R2p_SE./1;

% Max torque
```

```
T_max_EE = (3/(2*ws)).*Vth_EE^2./((Rth_EE+(Rth_EE^2 +(Xth_EE+X2p_EE)^2)^0.5));
T_max_SE = (3/(2*ws)).*Vth_SE^2./((Rth_SE+(Rth_SE^2 +(Xth_SE+X2p_SE)^2)^0.5));

st_max_EE = R2p_EE/(Rth_EE^2+(Xth_EE+X2p_EE)^2)^0.5;
n_max_EE = (1 - st_max_EE) * ns;

st_max_SE = R2p_SE/(Rth_SE^2+(Xth_SE+X2p_SE)^2)^0.5;
n_max_SE = (1 - st_max_SE) * ns;

% Plot Torque vs Speed for EE and SE Motors
figure;
plot(n, Tmech_EE, 'r', 'LineWidth', 2), hold on;
plot(n, Tmech_SE, 'b', 'LineWidth', 2);
xlabel('Rotor Speed (RPM)'), ylabel('Torque (Nm)'),...
title('Torque vs Speed for EE and SE Motors'), grid on;
legend('EE Motor', 'SE Motor');

fprintf('\n2.a)\n Starting torque for EE Motor: %.4f Nm\n', T_start_EE);
fprintf(' Starting torque for SE Motor: %.4f Nm\n\n', T_start_SE);

disp(' The starting torque will vary with a change in the rotor resistance R2p.');
disp(' The starting torque is also proportional to the square of supply voltage Vth.');

fprintf('\n2.b)\n Maximum torque for EE Motor: %.4f Nm\n', T_max_EE);
fprintf(' Maximum torque for SE Motor: %.4f Nm\n\n', T_max_SE);

disp('The maximum torque will vary with a change in the supply voltage Vth, as it is↙
independent of R2p.');

fprintf('\n2.c) Speed at which maximum torque occurs for EE Motor: %.4f rpm\n',↙
n_max_EE);
fprintf('Speed at which maximum torque occurs for SE Motor: %.4f rpm\n\n', n_max_SE);

disp('The value of the rotor circuit resistance R2p determines the speed at which maximum↙
torque will occur.');


% Extend the code to calculate the stator current vs. speed
disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')
disp('QUESTION 3: Stator Current vs. Speed Characteristics for EE and SE Motor:')
disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')

% Stator current calculation
Z1_EE = R1_EE+(1i*X1_EE)+1i*Xm_EE*((R2p_EE./s)+1i*X2p_EE)./((R2p_EE./s)+1i*↙
(Xm_EE+X2p_EE)); %(Equ5.65a - Sen)
I1_EE = V1_EE./Z1_EE;  %(Equ5.65c - Sen)
I1_mag_EE = abs(I1_EE);
I1_phase_EE = angle(I1_EE);

Z1_SE = R1_SE+(1i*X1_SE)+1i*Xm_SE*((R2p_SE./s)+1i*X2p_SE)./((R2p_SE./s)+1i*↙
(Xm_SE+X2p_SE)); %(Equ5.65a - Sen)
```

```
I1_SE = V1_SE./Z1_SE;  %(Equ5.65c - Sen)
I1_mag_SE = abs(I1_SE);
I1_phase_SE = angle(I1_SE);

% Plot Stator Current vs Speed for EE and SE Motors
figure;

plot(n, I1_mag_EE, 'r', 'LineWidth', 2), hold on;
plot(n, I1_mag_SE, 'b', 'LineWidth', 2);
xlabel('Rotor Speed [RPM]'), ylabel('Stator Current [A]'),...
title('Stator Current vs Speed for EE and SE Motors'), grid on;
legend('EE Motor', 'SE Motor');

% a) Stator current at start-up (s=1)

Z1_start_EE = R1_EE+(1i*X1_EE)+1i*Xm_EE*((R2p_EE./1)+1i*X2p_EE)./((R2p_EE./1)+1i*↙
(Xm_EE+X2p_EE)); %(Equ5.65a - Sen)
I_start_EE = V1_EE./Z1_start_EE;

Z1_start_SE = R1_SE+(1i*X1_SE)+1i*Xm_SE*((R2p_SE./1)+1i*X2p_SE)./((R2p_SE./1)+1i*↙
(Xm_SE+X2p_SE)); %(Equ5.65a - Sen)
I_start_SE = V1_SE./Z1_start_SE;

fprintf('\n3.a) Stator current at start-up\n');
fprintf('Stator current for EE Motor at start-up: %.4f < %.2f° A\n', abs(I_start_EE),↙
rad2deg(angle(I_start_EE)));
fprintf('Stator current for SE Motor at start-up: %.4f < %.2f° A\n', abs(I_start_SE),↙
rad2deg(angle(I_start_SE)));

fprintf('\n');
disp('At start-up the stator current of the EE motor is 4.08 A greater than the SE motor.↙
The result is as expected and the slight difference aligns with the general↙
characteristics of EE vs SE motors. The values of R1, X1 and R2p, X2p are lower for EE↙
motors, and these lower resistances cause the higher start-up current.')

% b) Explain stator current change under no-load and full-load conditions
fprintf('\n');
disp('b) Under no-load: The motor experiences high inrush current at start-up, but as the↙
speed increses, the required torque is minimal, so the current drop to a small↙
magnetising current.\n Under full-load: The motor experiences high inrush current at↙
start-up, however, as the speed increases, the load torque requires higher current to↙
sustain it.');

% c) Stator current at maximum torque
Z1_tmax_EE = R1_EE+(1i*X1_EE)+1i*Xm_EE*((R2p_EE./st_max_EE)+1i*X2p_EE)./((R2p_EE.↙
/st_max_EE)+1i*(Xm_EE+X2p_EE));
I_tmax_EE = V1_EE./Z1_tmax_EE;

Z1_tmax_SE = R1_SE+(1i*X1_SE)+1i*Xm_SE*((R2p_SE./st_max_SE)+1i*X2p_SE)./((R2p_SE.↙
/st_max_SE)+1i*(Xm_SE+X2p_SE));
I_tmax_SE = V1_SE./Z1_tmax_SE;
```

```
fprintf('\n3.c) Stator current at maximum torque\n');
fprintf('Stator current for EE Motor at maximum torque: %.4f < %.2f° A\n', abs
(I_tmax_EE), rad2deg(angle(I_tmax_EE)));
fprintf('Stator current for SE Motor at maximum torque: %.4f < %.2f° A\n', abs
(I_tmax_SE), rad2deg(angle(I_tmax_SE)));
disp('At maximum torque, the stator current is higher as the motor draws more current to
maintain the required torque. The value depends on the supply voltage and the stator
impedance.');

% d) Stator current under no-load conditions (s=0)
Z1_nl_EE = R1_EE+1i*(X1_EE+Xm_EE);
I_nl_EE = V1_EE./Z1_nl_EE;

Z1_nl_SE = R1_SE+1i*(X1_SE+Xm_SE);
I_nl_SE = V1_SE./Z1_nl_SE;

fprintf('\n3.d) Stator current under no-load conditions\n');
fprintf('Stator current for EE Motor under no-load:: %.4f < %.2f° A\n', abs(I_nl_EE),
rad2deg(angle(I_nl_EE)));
fprintf('Stator current for SE Motor under no-load:: %.4f < %.2f° A\n', abs(I_nl_SE),
rad2deg(angle(I_nl_SE)));
disp('Under no-load conditions, the stator current is relatively low as only the
magnetizing current is required to maintain the magnetic field.');

disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')
disp('QUESTION 4: Power Factor vs. speed characteristics for EE and SE Motor:')
disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')

PF_EE = cos(I1_phase_EE);
PF_SE = cos(I1_phase_SE);

% Plot Power factor vs Speed for EE and SE Motors
figure;
plot(n, PF_EE, 'r', 'LineWidth', 2), hold on;
plot(n, PF_SE, 'b', 'LineWidth', 2);
xlabel('Rotor Speed (RPM)'), ylabel('Power Factor'),...
title('Power Factor vs Speed for EE and SE Motors'), grid on;
legend('EE Motor', 'SE Motor');


% a) Calculate the power factors at start-up.
PF_start_EE = cos(angle(I_start_EE));
PF_start_SE = cos(angle(I_start_SE));

fprintf('\n4.a) Power factor at start-up\n');
fprintf('Power factor at start-up for EE motor: %.4f\n', PF_start_EE);
fprintf('Power factor at start-up for SE motor: %.4f\n', PF_start_SE);

% b)  Determine the power factors when the machines develop maximum torque.
```

```
PF_max_torque_EE = cos(angle(I_tmax_EE));
PF_max_torque_SE = cos(angle(I_tmax_SE));

fprintf('\n4.b) Power factor at max torque\n');
fprintf('Power factor at max torque for EE motor: %.4f\n', PF_max_torque_EE);
fprintf('Power factor at max torque for SE motor: %.4f\n', PF_max_torque_SE);

% c) PF at no-load

PF_nl_EE = cos(angle(I_nl_EE));
PF_nl_SE = cos(angle(I_nl_SE));

fprintf('\n4.c) Power factor at no-load\n');
fprintf('Power factor at no-load for EE motor: %.4f\n', PF_nl_EE);
fprintf('Power factor at no-load for SE motor: %.4f\n', PF_nl_SE);
disp('This is as expected, the PF under no-load is very low, because the current is
mostly reactive (magnetizing current), and the real power is minimal since there is no
load.');

% d) Best PF
disp('The best PF for the EE motor (from the graph) is: 0.847859')
disp('The best PF for the SE motor (from the graph) is: 0.820597')

% e) Best speed
disp('The speed at best PF for the EE motor (from the graph) is: 1363.5 rpm')
disp('The speed at best PF for the SE motor (from the graph) is: 1356.75 rpm')


 disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')
 disp('QUESTION 5: Power vs. speed characteristics for EE and SE Motor:')
 disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')

% a) Calculate the stator and rotor copper losses at start-up.

P1_cu_start_EE = 3 * R1_EE * abs(I_start_EE)^2;
I2_start_EE = Vth_EE./sqrt((Rth_EE+R2p_EE./1).^2 + (Xth_EE+X2p_EE)^2); % s = 1 at start-
up
P2_cu_start_EE = (I2_start_EE^2)*R2p_EE;

P1_cu_start_SE = 3 * R1_SE * abs(I_start_SE)^2;
I2_start_SE = Vth_SE./sqrt((Rth_SE+R2p_SE./1).^2 + (Xth_SE+X2p_SE)^2); % s = 1 at start-
up
P2_cu_start_SE = (I2_start_SE^2)*R2p_SE;

fprintf('\n5.a) Stator and Rotor Copper losses at start-up\n');
fprintf('Stator copper loss at start-up for EE motor: %.4f W\n', P1_cu_start_EE);
fprintf('Rotor copper loss at start-up for EE motor: %.4f W\n\n', P2_cu_start_EE);

fprintf('Stator copper loss at start-up for SE motor: %.4f W\n', P1_cu_start_SE);
fprintf('Rotor copper loss at start-up for SE motor: %.4f W\n', P2_cu_start_SE);
```

```
% b) Calculate the stator and rotor copper losses at no-load

P1_cu_nl_EE = 3 * R1_EE * abs(I_nl_EE)^2;
P1_cu_nl_SE = 3 * R1_SE * abs(I_nl_SE)^2;

P2_cu_nl_EE = 0;
P2_cu_nl_SE = 0;

fprintf('\n5.b) Stator and Rotor Copper losses at no-load\n');
fprintf('Stator copper loss at no-load for EE motor: %.4f W\n', P1_cu_nl_EE);
fprintf('Rotor copper loss at no-load for EE motor: %.4f W\n\n', P2_cu_nl_EE);

fprintf('Stator copper loss at no-load for SE motor: %.4f W\n', P1_cu_nl_SE);
fprintf('Rotor copper loss at no-load for SE motor: %.4f W\n', P2_cu_nl_SE);

% c) Finding the input power, shaft power and air gap power.

Pin_SE = 3 .* V1_SE .* I1_mag_SE .* PF_SE;
Pin_EE = 3 .* V1_EE .* I1_mag_SE .* PF_EE;

P1_cu_SE = 3 .* (I1_mag_SE.^2).*R1_SE;
P1_cu_EE = 3 .* (I1_mag_EE.^2).*R1_EE;

P_ag_SE = Pin_SE - P1_cu_SE;
P_ag_EE = Pin_EE - P1_cu_EE;

P2_cu_SE = s.*P_ag_SE;
P2_cu_EE = s.*P_ag_EE;

P_shaft_SE = (1.-s).*P_ag_SE;% rotational losses neglected hence P_shaft = P_mech = (1-s)
P_airgap
P_shaft_EE = (1.-s).*P_ag_EE;

figure;
plot(n, Pin_EE,'LineWidth', 1), hold on;
plot(n, P_shaft_EE,'LineWidth', 1); hold on;
plot(n, P_ag_EE,'LineWidth', 1); hold on;
plot(n, P1_cu_EE,'LineWidth', 1); hold on;
plot(n, P2_cu_EE,'LineWidth', 1); hold on;
xlabel('Speed [RPM]'), ylabel('Power [W]'),...
title('Power vs Speed for EE Motor'), grid on;
legend('Pin', 'Pshaft', 'Pag', 'P1cu', 'P2cu');

figure;
plot(n, Pin_SE,'LineWidth', 1), hold on;
plot(n, P_shaft_SE,'LineWidth', 1); hold on;
plot(n, P_ag_SE,'LineWidth', 1); hold on;
plot(n, P1_cu_SE,'LineWidth', 1); hold on;
plot(n, P2_cu_SE,'LineWidth', 1); hold on;
xlabel('Speed [RPM]'), ylabel('Power [W]'),...
```

```
title('Power vs Speed for SE Motor'), grid on;
legend('Pin', 'Pshaft', 'Pag', 'P1cu', 'P2cu');




disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')
disp('QUESTION 6: Efficiency vs. speed characteristics for EE and SE Motor:')
disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')

% a) Machine efficiency at maximum torque


Pin_Tmax_EE = 3 * V1_EE * abs(I_tmax_EE) * PF_max_torque_EE;
Pin_Tmax_SE = 3 * V1_SE * abs(I_tmax_SE) * PF_max_torque_SE;

P_ag_Tmax_EE = Pin_Tmax_EE - (3*(abs(I_tmax_EE))^2*R1_EE);
P_ag_Tmax_SE = Pin_Tmax_SE - (3*(abs(I_tmax_SE))^2*R1_SE);

Pout_Tmax_EE = P_ag_Tmax_EE*(1-st_max_EE);
Pout_Tmax_SE = P_ag_Tmax_SE*(1-st_max_SE);% P_shaft = P_mech = Pout

Eff_Tmax_EE = (Pout_Tmax_EE/Pin_Tmax_EE)*100;
Eff_Tmax_SE = (Pout_Tmax_SE/Pin_Tmax_SE)*100;

fprintf('\n6.a) Efficiency at max torque\n');
fprintf('Efficiency at maximum torque for EE motor: %.4f W\n', Eff_Tmax_EE);
fprintf('Efficiency at maximum torque for SE motor: %.4f W\n', Eff_Tmax_SE);

% b) Maximum Machine efficiency

Eff_SE = (P_shaft_SE./Pin_SE).*100;
Eff_EE = (P_shaft_EE./Pin_EE).*100;

figure;
plot(n, Eff_EE, 'r', 'LineWidth', 2); hold on;
plot(n, Eff_SE, 'b', 'LineWidth', 2);
xlabel('Rotor Speed (RPM)');
ylabel('Machine Efficiency');
title('Efficiency vs Speed for SE and EE Motor');
legend({'EE Efficiency','SE Efficiency'}, 'Location', 'Best');
grid on;
hold off;

[max_Eff_SE,Max_Eff_SE_index] = max(Eff_SE);
[max_Eff_EE,Max_Eff_EE_index] = max(Eff_EE);

fprintf('\n6.b) Maximum efficiency\n');
fprintf('Maximum Efficiency for EE motor: %.4f %%\n', max_Eff_EE);
fprintf('Maximum Efficiency for SE motor: %.4f %%\n', max_Eff_SE);
```

```
% c) Finding the speed at maximum efficiency

% Finding speed using array indices.

n_max_Eff_SE = n(Max_Eff_SE_index);
n_max_Eff_EE = n(Max_Eff_EE_index);

fprintf('\n6.c) Speed at maximum efficiency\n');
fprintf('Speed at maximum efficiency for EE motor: %.2f rpm\n',n_max_Eff_EE);
fprintf('Speed at maximum efficiency for SE motor: %.2f rpm\n', n_max_Eff_SE);

disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')
disp('QUESTION 7: Adding a Centrifugal pump as a load to the EE and SE Motor:')
disp('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')

% a) Finding machine speed when operating the load

k_Load = 946.88 * 10^-6;
T_Load = k_Load .* (w.^2);

figure;
plot(n, Tmech_EE, 'r', 'LineWidth', 2); hold on;
plot(n, Tmech_SE, 'b', 'LineWidth', 2);
plot(n,T_Load, 'c', 'LineWidth', 2);
xlabel('Rotor Speed (RPM)');
ylabel('Torque (W)');
title('Torque vs Speed for EE and SE Motor');
legend({'Torque EE' ,'Torque SE', 'Load torque'}, 'Location', 'Best');
grid on;
hold off;

% The operating point is when T_mech and T_load are equal.

SE_TMEch_Tload_ratio = abs(Tmech_SE./T_Load - 1);
EE_TMEch_Tload_ratio = abs(Tmech_EE./T_Load - 1);

% Finding when the ratio is 1

[~,Operating_point_index_SE] = min(SE_TMEch_Tload_ratio); % done like this since the↙
values do not perfectly match.
[~,Operating_point_index_EE] = min(EE_TMEch_Tload_ratio);

Operating_speed_SE = n(Operating_point_index_SE);
Operating_speed_EE = n(Operating_point_index_EE);

fprintf('\n7.a) Operating speed\n');
fprintf('Speed when operating pump for EE motor: %.2f rpm\n',Operating_speed_EE);
fprintf('Speed when operating pump for SE motor: %.2f rpm\n', Operating_speed_SE);

% b) Current drawn during operation
```

```
I1_Operating_SE = I1_mag_SE(Operating_point_index_SE);
I1_Operating_EE = I1_mag_EE(Operating_point_index_EE);

fprintf('\n7.b) Current drawn \n');
fprintf('Current drawn when operating pump for EE motor: %.4f A\n',I1_Operating_EE);
fprintf('Current drawn when operating pump for SE motor: %.4f A\n', I1_Operating_SE);

% c) Machine efficiency during operation

Eff_Operating_SE = Eff_SE(Operating_point_index_SE);
Eff_Operating_EE = Eff_EE(Operating_point_index_EE);

fprintf('\n7.c) Efficiency\n');
fprintf('Efficiency when operating pump for EE motor: %.4f %%\n',Eff_Operating_EE);
fprintf('Efficiency when operating pump for SE motor: %.4f %%\n', Eff_Operating_SE);

% d) Power output/supply during operation

Pout_Operating_SE = P_shaft_SE(Operating_point_index_SE);
Pout_Operating_EE = P_shaft_EE(Operating_point_index_EE);

fprintf('\n7.d) Output power\n');
fprintf('Output power when operating pump for EE motor: %.4f W\n',Pout_Operating_EE);
fprintf('Output power when operating pump for SE motor: %.4f W\n', Pout_Operating_SE);


% e) Input Power during operation

Pin_Operating_SE = Pin_SE(Operating_point_index_SE);
Pin_Operating_EE = Pin_EE(Operating_point_index_EE);

fprintf('\n7.e) Input power\n');
fprintf('Input Power drawn when operating pump for EE motor: %.4f W\n',Pin_Operating_EE);
fprintf('Input Power drawn when operating pump for SE motor: %.4f W\n',↙
Pin_Operating_SE);

% f) Comparing input power for EE and SE

Diff_Pin_Comp = (Pin_Operating_SE - Pin_Operating_EE);

fprintf('The difference in input power is: %.4f W\n',Diff_Pin_Comp);
```