Simulation Project

Project

POWER FACTOR CORRECTION USING MATLAB

Creator

Himesh Agrawal

Created On:
11th April 2024

Content

Power Factor Correction Using Matlab

Problem Statement:

A company uses various loads of different power factor in parallel. For Example, they use three loads in parallel from 8am to 10 am, five loads from 10am to 6pm,two loadsfrom 6pm to 11pm etc. Thus the overall power factor varies from time to time. The overall power factor in a company should be no less than 0.9 lagging. Whatever may bethe load, the company decides to keep the power factor 0.9 or above.

Generally a capacitor bank is placed in parallel with the whole combination to improve the power factor when necessary.

Now we will discuss how to develop a program which can give instantly what value of capacitor is necessary for a general situation.

Solution:

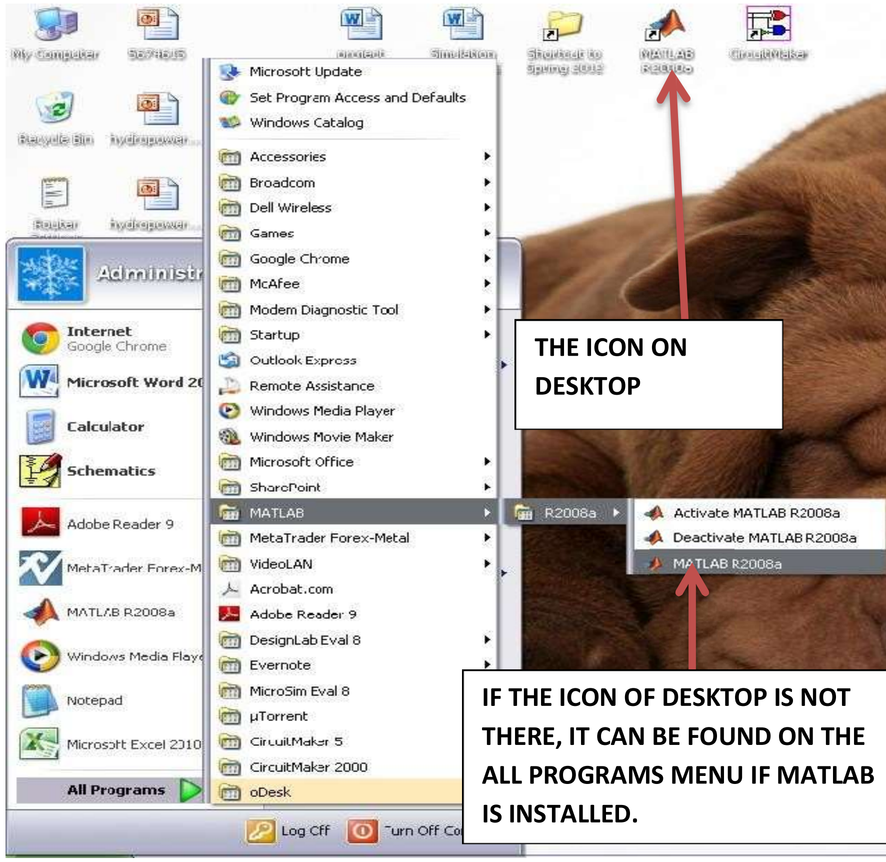
To solve the above problem we will have to write a program in matlab that can solve automatically to find the power factor of the circuit after giving only a few necessary inputs and. if it below 0.9, calculate the value of capacitor needed to correct the power factor into the desired value.

- **STARTING MATLAB**

We will first start matlab by double clicking it's icon from the all programs menu or on the desktop (Figure 1). Then from the matlab window we will go to file>new>M-File (Figure 2).

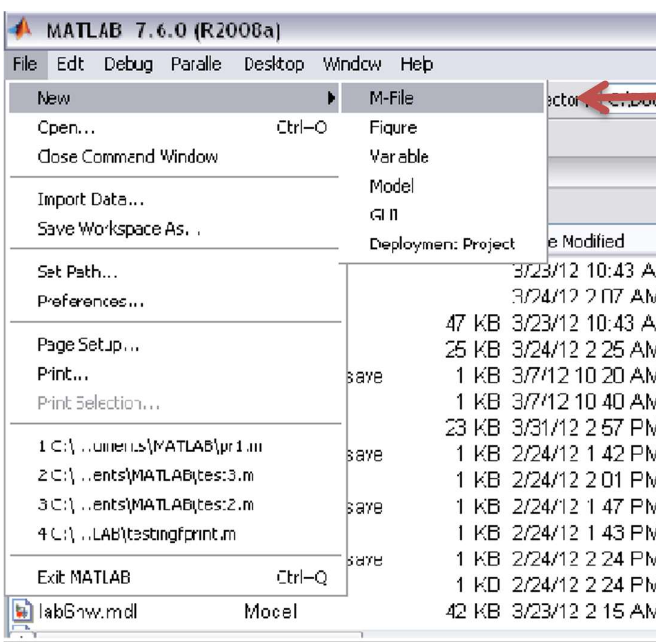
This will open a new blank editor window where we will write the program to correct the power factor.

FIGURE 1



THE ICON ON DESKTOP

IF THE ICON OF DESKTOP IS NOT THERE, IT CAN BE FOUND ON THE ALL PROGRAMS MENU IF MATLAB IS INSTALLED.



CLICK ON “FILE” THEN “NEW” FOLLOWED BY “M-FILE”.

FIGURE 2

- **WRITING THE CODE**

Inputs

Firstly we will have to give a name to the program by saving it in the matlab folder with a suitable name. We named our program PFC.m which can be done by clicking on the "file" button on the menu bar of the editor window and then clicking on "save as". Nowwe will have to tell the program to ask for inputs like voltage, frequency and value of the loads when it runs. We can do so as follows:

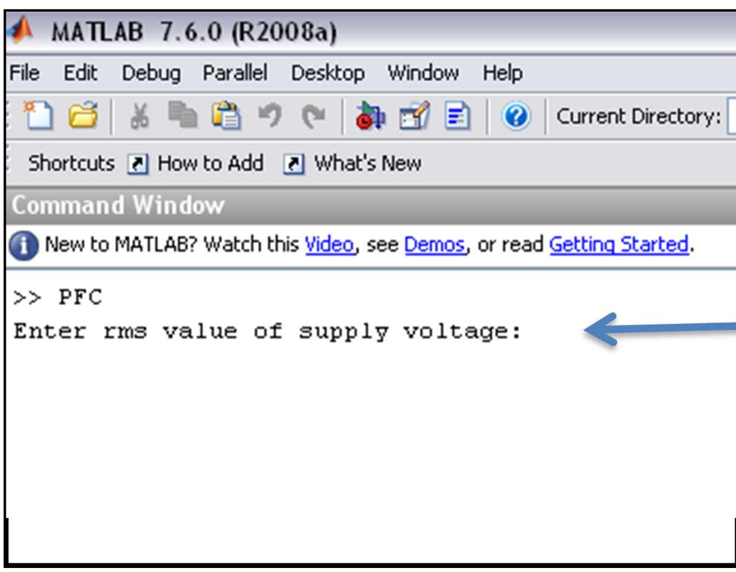
This is to tell the program to ask for this value of Vr when it is run.

Vr=input('Enter the rms value of voltage:');

This is the name of the variable on which the value entered will be assigned to

The statement inside the bracket and inverted comma will be used by the program to ask for the input.

The code will generate the following lines when the program named "PFC" is typed on the command window.



When a value is entered here, the program will assign it to Vr. For example, if 10 is entered ; Vr will be assigned to be 10.

In the same way we can write codes to ask for other necessary parameters of the circuit of our concern.

```
Vr=input('Enter rms value of supply voltage:');
Qv=input('Enter phase angle of supply voltage in degree:');
f=input('Enter the frequency of supply voltage:');
n=input('Enter the number of Load:');
Z=input('Enter the loads in a row vector[ each R+jX form ]:');
```

The above code will ask for the rms value of voltage, phase angle of voltage, frequency of supply voltage, number of loads and the values of load; and assign them to Vr, Qv, f, n and Z respectively.

Calculation of Power Factor

Now using the entered parameters we can calculate the power factor by the following codes (line 7 to 14). Each line has been explained later below the codes.

Editor - C:\Documents and Settings\Administrator\My Documents\MATLAB\PFC.m

```
1   Vr=input('Enter rms value of supply voltage:');
2   Qv=input('Enter phase angle of supply voltage in degree:');
3   f=input('Enter the frequency of supply voltage:');
4   n=input('Enter the number of Load:');
5   Z=input('Enter the loads in a row vector  [ each R+jX form ]:');
6
7   Qvr=Qv*(pi/180);       %PHASE ANGLE of VOLTAGE IN RADIAN
8   V=Vr*exp(i*Qvr);       %VOLTAGE IN RECTANGULAR FORM
9
10  Y=Z.^(-1);
11  Yt=sum(Y);             %TOTAL ADMITANCE
12  I=V*Yt;                %TOTAL CURRENT
13  Qi=phase(I);           %phase angle of current
14  pf=cos(Qvr-Qi);        %POWER FACTOR
15
```

Line-7:

The phase angle of voltage (Qv) will be changed into radian assigned to Qvr.

By default matlab calculates everything in radian, so to make other calculations easier the phase angle is changed into radian.

Line-8:

The voltage will be changed into rectangular form using its rms value (Vr) and phase angle in radian (Qvr).

$$a + bi = Re^{i\theta}$$

Here,

R=rms value of volage(Vr) θ = phase angle(Vr)

Line-10:

It will inverse each component of the matrix Z thus creating a new matrix Y where each component will be the admittance of each branch.

Line-11:

Each admittance will be added to find the total admittance of the parallel circuit.

Line-12:

The total current will be calculated in rectangular form assigned to I.

In Parallel circuit:

$$\frac{1}{Z_T} = \frac{1}{Z_1} + \frac{1}{Z_2} + \cdots + \frac{1}{Z_n}$$

Or, $\frac{1}{Z_T} = Y_1 + Y_2 + \cdots + Y_n = Y_t$

So, $I = \frac{V}{Z_T} = V \times \frac{1}{Z_t} = V \times Y_t$

Line-13:

The phase angle of the current in radian will be calculated assigned to Qi.

Line-14:

The power factor will be calculated assigned to pf using the formulae,

$$power\ factor = \cos(\theta_V - \theta_i)$$

$$\theta_V = phase\ angle\ of\ voltage(Qvr)$$

$$\theta_i = phase\ angle\ of\ current(Qi)$$

Correction of Power Factor

Now we will tell the program to display a message, if power factor is more or equal to 0.9, mentioning that there is no need of correction. Otherwise, if power factor is less than 0.9, to display message mentioning the need of correction and further calculate the value of capacitor needed. We can do so by the following codes:

```
16   if pf>=0.9
17   fprintf('\nThe overall power factor before correction is %6.6f which is already greater or equal to 0.9. No correction is needed.',pf)
18
19   elseif pf<0.9
20   fprintf('\n The overall power factor before correction is %6.6f which is less than 0.9.\n\n POWER FACTOR SHOULD BE CORRECTED.',pf)
21
22   S=Vr*abs(I);                %APARENT POWER
23   P=S*pf;                     %REAL POWER
24   QQ=sqrt(S^2-P^2);           %REACTIVE POWER
25   Snew=P/0.9;                 %DESIRED APARENT POWER TO CORRECT THE POWER FACTOR TO 0.9
26   QQnew=sqrt(Snew^2-P^2);     %DESIRED REACTIVE POWER  TO CORRECT THE POWER FACTOR TO 0.9
27   QQc=QQ-QQnew;               %DESIRED REACTIVE POWER ACROSS THE CAPACITOR
28
29   Xc=Vr^2/QQc;                %REACTANCE OF THE CAPACITOR
30   C=1/(2*pi*f*Xc);            %VALUE OF CAPACITANCE IN FARAD TO CORRECT THE POWER FACTOR TO 0.9
31
32   %CALCULATING THE POWER FACTOR AGAIN TO VERIFY THE CORRECTION
33   newYt=Yt+(2*pi*f*C)*i;          %ADMITANCE AFTER CONNECTING THE CAPACITOR IN PARALLEL
34   newI=V*newYt;                   %TOTAL CURRENT AFTER CONNECTING THE CAPACITOR
35   newQi=phase(newI);              %PHASE ANGLE OF THE NEW CURRENT
36   newpf=cos(Qvr-newQi);           %POWER FACTOR AFTER CORRECTION
37   fprintf('\n\n A capacitor bank of %6.8f Farad is needed to be parallely connected that will improve powerfactor to%6.2f.\n',C,newpf)
38   end
```

Line-16

The program will run the code of line 17 only when the calculated power factor will be more or equal to 0.9.

Line-17

fprintf('\nThe overall power factor before correction is %6.6f which is already greater or equal to 0.9. No correction is needed.',pf)

Goes to next line

This tells the program to display the statement inside the bracket and the inverted comma.

They display the calculated value of powerfactor that was assigned previously to pf.

Line-19

The program will run the codes of line 20 to 37 only when the value of power factor assigned as pf is less than 0.9.

Line-20

As previously explained the statement inside the bracket and inverted comma will be displayed.

Line-22

It will calculate the apparent power of the circuit assigning it to S.

Apparent power, S= Voltage x Current (only the magnitude of each)

Here, Vr= Voltage and abs(I)=Current

S=Vr × abs(I)

Line-23

It calculates the real power of the system assigning it to P.

Real Power, P= V × I × cos($\theta_v - \theta_i$)

V × I=S and cos($\theta_v - \theta_i$)=powerfactor(pf)

So P=S × pf

Line-24

It calculates the reactive power of the system assigning it to QQ.

(Apparent Power)^2= (Real Power)^2 + (Reactive Power)^2

Or, $S^2=P^2+Q^2$

Or, $Q^2=S^2-P^2$

Or, $Q = \sqrt{S^2 - P^2}$

Or, $Q = \sqrt{S^2 - P^2}$

Line-25

It calculates that apparent power for which power factor will be 0.9 and assigns it to Snew.

We know that change in reactance only affects the apparent power and the reactive power but the real power stays the same. So if a capacitor is added to the system thereal power will still be same as previously calculated. Thus,

Real power = Apparent power × Power Factor

Or, New Apparent power= $\frac{\text{Real power}}{\text{Power factor}}$

<u>For a power factor of 0.9</u>

New Apparent power= $\frac{\text{Real power}}{0.9}$

Line-26

Calculates the new reactive power in the same way as in line-24 and assigns it to QQnew.

Line-27

It calculates the reactive power across the capacitor assigning it to QQc.

Capacitor's reactive power= Previous reactive power- New reactive power

Line-29

Calculates the reactance of the capacitor assigning it to Xc.

Reactive power of the capacitor (QQc)= $\frac{\{Voltage(Vr)\}^2}{Reactance\ of\ capacitor(Xc)}$

Or, QQc= $\frac{Vr^2}{Xc}$

Or, Xc= $\frac{Vr^2}{\text{QQc}}$

Line-30

It calculates the capacitance of the capacitor assigning it to C.

Xc=$\frac{1}{2\pi fC}$

Xc=$\frac{1}{2\pi fC}$

C=$\frac{1}{2\pi fXc}$

Line -33

It calculates the new total admittance of the system if the capacitor is connected in parallel.

Line-34 to 36

The power factor of the system, with the capacitor connected, is again calculated in the same way as the previous power factor calculation and the value is assigned to newpf.

Line-37

It displays the statement in the bracket and inverted comma mentioning the value of the capacitor needed to do the correction and the value of power factor after correction.

Line-38

It ends the if loops.

N.B. **Line 6, 9, 15, 18, 21, 28 and 31 are kept blank just for the purpose of presentation. The program can run without the blank lines. All the statements in green color followed by the sign % are comments to describe the codes; they are not necessary part of the code. The fprintf statement of line 20 and 37 can also be written together using only one fprintf command but for the purpose of presentation and to show sequence of work they are written in this manner.**

After saving the file we can now run the program to do power factor correction of any system.

ScreenShot of the Code

```
Vr=input('Enter rms value of supply voltage:');
Qv=input('Enter phase angle of supply voltage in degree:');
f=input('Enter the frequency of supply voltage:');
n=input('Enter the number of Load:');
Z=input('Enter the loads in a row vector  [ each R+jX form ]:');

Qvr=Qv*(pi/180);      %PHASE ANGLE of VOLTAGE IN RADIAN
V=Vr*exp(i*Qvr);      %VOLTAGE IN RECTANGULAR FORM

Y=Z.^(-1);
Yt=sum(Y);            %TOTAL ADMITTANCE
I=V*Yt;               %TOTAL CURRENT
Qi=phase(I);          %PHASE ANGLE OF CURRENT
pf=cos(Qvr-Qi);       %POWER FACTOR

if pf>=0.9
fprintf('\nThe overall power factor before correction is %6.6f which is already greater or equal to 0.9. No correction is needed.',pf)

elseif pf<0.9
fprintf('\n The overall power factor before correction is %6.6f which is less than 0.9.\n\n POWER FACTOR SHOULD BE CORRECTED.',pf)

S=Vr*abs(I);               %APPARENT POWER
P=S*pf;                    %REAL POWER
QQ=sqrt(S^2-P^2);          %REACTIVE POWER
Snew=P/0.9;                %DESIRED APPARENT POWER TO CORRECT THE POWER FACTOR TO 0.9
QQnew=sqrt(Snew^2-P^2);    %DESIRED REACTIVE POWER  TO CORRECT THE POWER FACTOR TO 0.9
QQc=QQ-QQnew;              %DESIRED REACTIVE POWER ACROSS THE CAPACITOR

Xc=Vr^2/QQc;               %REACTANCE OF THE CAPACITOR
C=1/(2*pi*f*Xc);           %VALUE OF CAPACITANCE IN FARAD TO CORRECT THE POWER FACTOR TO 0.9

%CALCULATING THE POWER FACTOR AGAIN TO VERIFY THE CORRECTION
newYt=Yt+(2*pi*f*C)*i;           %ADMITTANCE AFTER CONNECTING THE CAPACITOR IN PARALLEL
newI=V*newYt;                    %TOTAL CURRENT AFTER CONNECTING THE CAPACITOR
newQi=phase(newI);               %PHASE ANGLE OF THE NEW CURRENT
newpf=cos(Qvr-newQi);            %POWER FACTOR AFTER CORRECTION
fprintf('\n\n A capacitor bank of %6.8f Farad is needed to be parallely connected that will improve powerfactor to%6.2f.\n',C,newpf)
end
```

The code in text:

```
Vr=input('Enter rms value of supply voltage:');
Qv=input('Enter phase angle of supply voltage in degree:');
f=input('Enter the frequency of supply voltage:');
n=input('Enter the number of Load:');
Z=input('Enter the loads in a row vector [ each R+jX form ]:');

Qvr=Qv*(pi/180);      %PHASE ANGLE of VOLTAGE IN RADIAN
V=Vr*exp(i*Qvr);      %VOLTAGE IN RECTANGULAR FORM

Y=Z.^(-1);
Yt=sum(Y);            %TOTAL ADMITTANCE
I=V*Yt;               %TOTAL CURRENT
Qi=phase(I);          %PHASE ANGLE OF CURRENT
pf=cos(Qvr-Qi);       %POWER FACTOR

if pf>=0.9
fprintf('\nThe overall power factor before correction is %6.6f which is already greater or equal to 0.9. No correction is needed.',pf)

elseif pf<0.9
fprintf('\n The overall power factor before correction is %6.6f which is less than 0.9.\n\n POWER FACTOR SHOULD BE CORRECTED.',pf)

S=Vr*abs(I);               %APPARENT POWER
P=S*pf;                    %REAL POWER
QQ=sqrt(S^2-P^2);          %REACTIVE POWER
Snew=P/0.9;                %DESIRED APPARENT POWER TO CORRECT THE POWER FACTOR TO 0.9
QQnew=sqrt(Snew^2-P^2); %DESIRED REACTIVE POWER TO CORRECT THE POWER FACTOR TO 0.9
QQc=QQ-QQnew;              %DESIRED REACTIVE POWER ACROSS THE CAPACITOR
```

```
Xc=Vr^2/QQc;            %REACTANCE OF THE CAPACITOR
C=1/(2*pi*f*Xc);        %VALUE OF CAPACITANCE IN FARAD TO CORRECT THE POWER FACTOR TO 0.9

%CALCULATING THE POWER FACTOR AGAIN TO VERIFY THE CORRECTION
newYt=Yt+(2*pi*f*C)*i;        %ADMITTANCE AFTER CONNECTING THE CAPACITOR IN PARALLEL
newI=V*newYt;                 %TOTAL CURRENT AFTER CONNECTING THE CAPACITOR
newQi=phase(newI);            %PHASE ANGLE OF THE NEW CURRENT
newpf=cos(Qvr-newQi);         %POWER  FACTOR  AFTER  CORRECTION
fprintf('\n\n A capacitor bank of %6.8f Farad is needed to be parallely connected that will improve
powerfactor to%6.2f.\n',C,newpf)
end
```

Original source file of the code

(The file can be accessed by double clicking on it to open the file then adding to the path of matlab by saving it with any suitable name and finally running it by typing that name in the command window)

Pfc.m

- **<u>Further Development:</u>**

We can also make the program to ask for any desired power factor and then improve the system's power factor to that value. It can be done only by making two changes to the previous program.

```
24 -    QQ=sqrt(S^2-P^2);           %REACTIVE POWER
25 -    pf1=input('\n\n Enter the desired value of power factor that is more than or equal to 0.9: ');
26 -    Snew=P/pf1;                 %DESIRED APPARENT POWER TO CORRECT THE POWER FACTOR TO 0.9
```

A new line is added at line 25 that will ask for the desired power factor assigning it to pf1 and line 26 is changed to calculate apparent power according to the desired power factor. The rest of the program will be same as before. Now we will have to save it with a new name and run it by typing that name in the command window.

<u>The code in text</u>

```
Vr=input('Enter rms value of supply voltage:');
Qv=input('Enter phase angle of supply voltage in degree:');
f=input('Enter the frequency of supply voltage:');
n=input('Enter the number of Load:');
Z=input('Enter the loads in a row vector [ each R+jX form ]:');

Qvr=Qv*(pi/180);      %PHASE ANGLE of VOLTAGE IN RADIAN
V=Vr*exp(i*Qvr);      %VOLTAGE IN RECTANGULAR FORM

Y=Z.^(-1);
Yt=sum(Y);            %TOTAL ADMITTANCE
```

```
I=V*Yt;                %TOTAL CURRENT
Qi=phase(I);           %PHASE ANGLE OF CURRENT
pf=cos(Qvr-Qi);        %POWER FACTOR

if pf>=0.9
fprintf('\nThe overall power factor before correction is %6.6f which is already greater or equal to 0.9. No correction is needed.',pf)

elseif pf<0.9
fprintf('\n The overall power factor before correction is %6.6f which is less than 0.9.\n\n POWER FACTOR SHOULD BE CORRECTED.',pf)

S=Vr*abs(I);             %APPARENT POWER
P=S*pf;                  %REAL POWER
QQ=sqrt(S^2-P^2);        %REACTIVE POWER
pf1=input('\n\n Enter the desired value of power factor that is more than or equal to 0.9: ');
Snew=P/pf1;              %DESIRED APPARENT POWER TO CORRECT THE POWER FACTOR TO 0.9
QQnew=sqrt(Snew^2-P^2); %DESIRED REACTIVE POWER TO CORRECT THE POWER FACTOR TO 0.9
QQc=QQ-QQnew;            %DESIRED REACTIVE POWER ACROSS THE CAPACITOR

Xc=Vr^2/QQc;             %REACTANCE OF THE CAPACITOR
C=1/(2*pi*f*Xc);     %VALUE OF CAPACITANCE IN FARAD TO CORRECT THE POWER FACTOR TO 0.9

%CALCULATING THE POWER FACTOR AGAIN TO VERIFY THE CORRECTION
newYt=Yt+(2*pi*f*C)*i;        %ADMITTANCE AFTER CONNECTING THE CAPACITOR IN PARALLEL
newI=V*newYt;                 %TOTAL CURRENT AFTER CONNECTING THE CAPACITOR
newQi=phase(newI);            %PHASE ANGLE OF THE NEW CURRENT
newpf=cos(Qvr-newQi);         %POWER  FACTOR  AFTER  CORRECTION
fprintf('\n\n A capacitor bank of %6.8f Farad is needed to be parallely connected that will improve powerfactor to%6.2f.\n',C,newpf)
end
```

Original Source File

Pfc2.m