ELECTRONICS ENGINEERING

Circuit Theory II

Project

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Abstract

Power compensation plays a crucial role in circuit theory as it enables the efficient management of power flow and improves the overall performance of electrical systems. This project focuses on investigating different power compensation techniques and their application in various circuits. The objectives of the study are to analyse the impact of power compensation on voltage stability, power factor correction, and harmonic reduction. To achieve these objectives, a comprehensive review of relevant literature and theoretical concepts related to power compensation is conducted. The project also involves the design and simulation of power compensation circuits using software tools such as MATLAB and PSpice. The performance of these circuits is evaluated by measuring parameters such as power factor, voltage regulation, and total harmonic distortion. The results obtained from the simulations highlight the effectiveness of power compensation techniques in improving the overall power quality of electrical systems. The findings demonstrate that the implementation of power compensation methods leads to reduced losses, improved voltage stability, and enhanced power factor. Furthermore, the harmonic distortion is significantly reduced, resulting in cleaner and more efficient power distribution. The project also includes a comparative analysis of different power compensation techniques, such as shunt capacitor banks, synchronous condensers, and active power filters. The advantages and limitations of each technique are discussed, providing valuable insights for selecting the most suitable power compensation method for specific applications. Overall, this project contributes to a deeper understanding of power compensation in circuit theory and its significance in enhancing the performance and efficiency of electrical systems. The findings serve as a foundation for future research and application of power compensation techniques in real-world scenarios.

Theory

1.AC Power

In AC circuits, power represents the energy delivered by alternating current. It is determined by multiplying the voltage and current values. However, in AC circuits, where voltage and current have sinusoidal waveforms, power fluctuates over time. It can be expressed in terms of instantaneous power, average power, and effective power. Instantaneous power is calculated by multiplying the instantaneous values of voltage and current. It constantly changes as the waves vary, oscillating between positive and negative values. To obtain a more stable measure, the average power is calculated by averaging the instantaneous power values over a specific period. Average power represents the total energy expended over a period, typically one cycle of the sinusoidal waveform. It is obtained by summing up the instantaneous power values over time and dividing by the period. Effective power, also known as real power, refers to the actual energy transfer in an AC circuit. It is the average product of the voltage and current waveforms and is typically measured in watts (W). For resistive loads, effective power is equal to both the instantaneous power and average power. Calculating power in AC circuits often involves complex mathematical operations. Consideration of different components such as resistance, inductance, and capacitance, as well as their phase differences, is necessary for accurate power calculations.

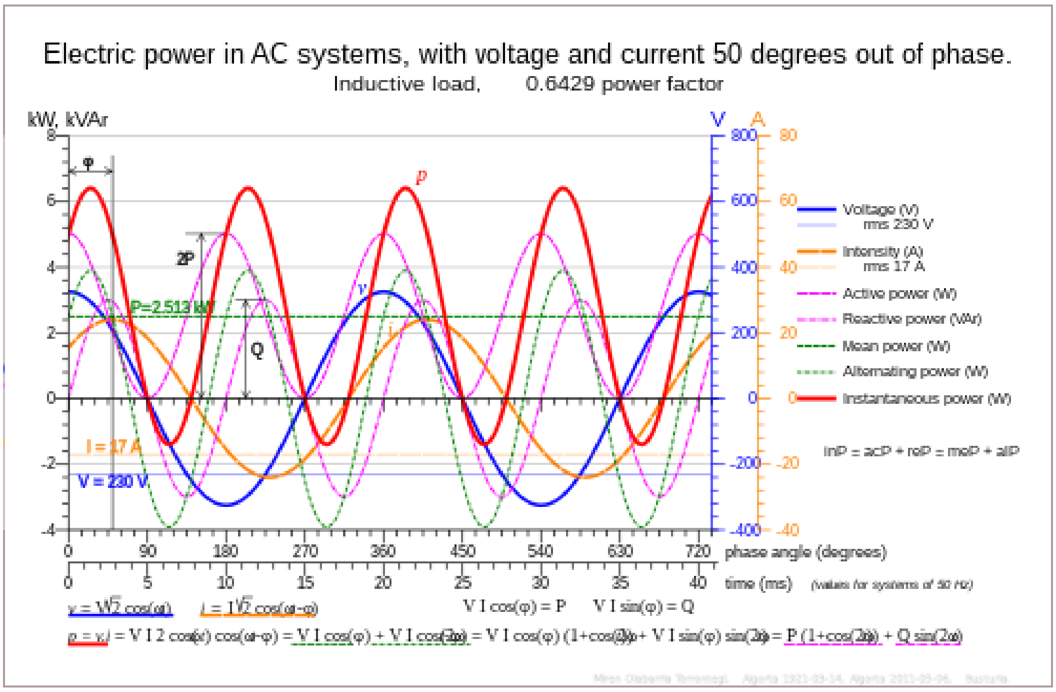


Figure 1: Graph of AC Electric Power

2.Apparent, Active and Reactive Power

Apparent power refers to the total power in an electrical circuit, considering both the active and reactive components. It is calculated by multiplying the voltage and current and is measured in volt-amperes (VA) or kilovolt-amperes (kVA).

Active power, also known as real power, represents the actual power consumed or converted by the load in the electrical circuit. It is determined by the cosine of the angle between the voltage and current waveforms. Active power is measured in watts (W) or kilowatts (kW) and contributes to the useful work or energy conversion in the circuit.

Reactive power, on the other hand, is the power associated with inductive or capacitive elements in the circuit. It is determined by the sine of the angle between the voltage and current waveforms. Reactive power is measured in volt-amperes reactive (VAR) or kilovolt-amperes reactive (kVAR). Reactive power is required by inductive loads (such as motors and transformers) to store and release energy, or by capacitive loads to compensate for energy storage.

Understanding the concepts of apparent, active, and reactive power is crucial for analysing the performance of electrical systems, monitoring energy consumption, and evaluating power factor. Power factor is the ratio of active power to apparent power and indicates the efficiency of power utilization in a system. By managing and optimizing these power components, electrical systems can operate more efficiently and economically.

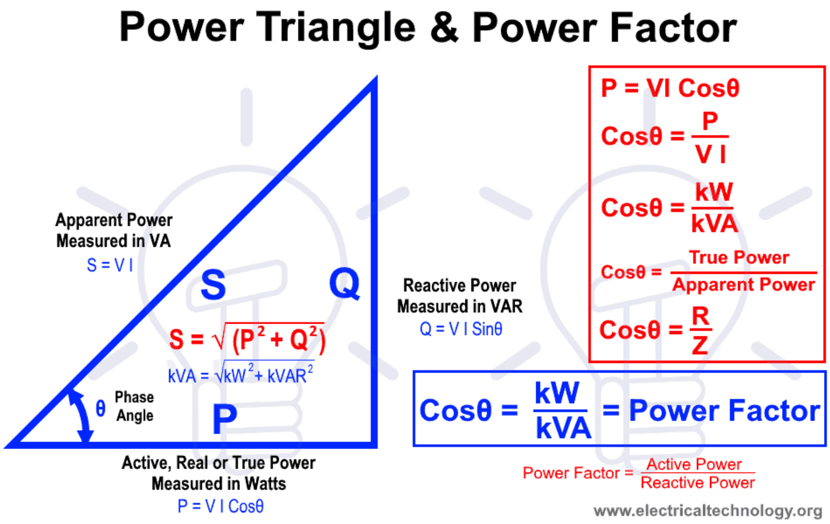


Figure 2: Scheme of Power Triangle

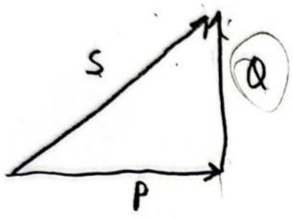
Theoretical Solutions

$y = 1$
$z = 3$
$x = 3$

Load 1: $S = 23k\,VA$, $Pf = 0{,}63$

Load 2: $P = 5kW$ $\quad Pf = 0{,}81$

Load 3: $P = 13kw$ $\quad Pf = 1$



$P = S.\,Pf$

for Load 1: $P = S \cdot Pf$

$P = 23k \cdot 0{,}63 = 14490$

$Q = \sqrt{S^2 - P^2} = 17861{,}688$

For Load 2: $P = 5k$

$5k = S \cdot (0{,}81) \Rightarrow S = 6172{,}839$ $\qquad$ 319039300

13103941,32

$Q = \sqrt{S^2 - P^2} \Rightarrow Q = 3619{,}9366$

for Load 3: $P = 13k$ $\quad Pf = 1$

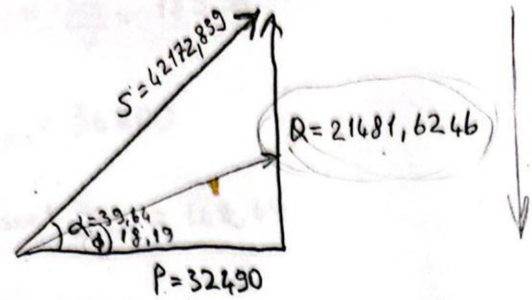
$P = S\,Pf \Rightarrow 13k = S \cdot 1$

$S = 13k$

$Q = 0$

$P_{total} = 32490$ $\qquad S_{total} = 42172{,}839$ $\qquad Q_{total} = 21481{,}6246$

a)



$\alpha = 39{,}64$

$Pf = 0{,}77 \longrightarrow 0{,}93$

$\phi = 18{,}19$

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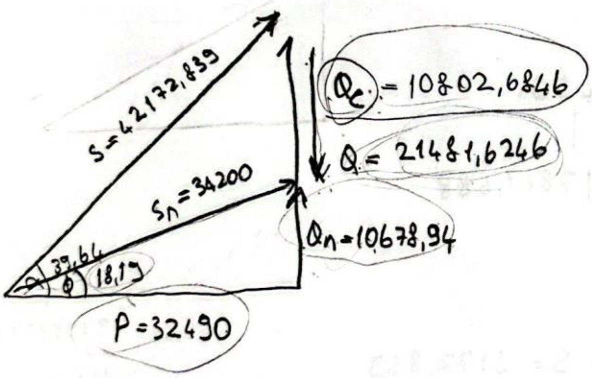
$P = S_n . Pf$

$32490 = S_n . 0{,}93 \qquad S_n = 34200$

$Q_n = 10678{,}94$



$X_c = \frac{V^2}{Q_c} = \frac{230^2}{10802{,}6846}$

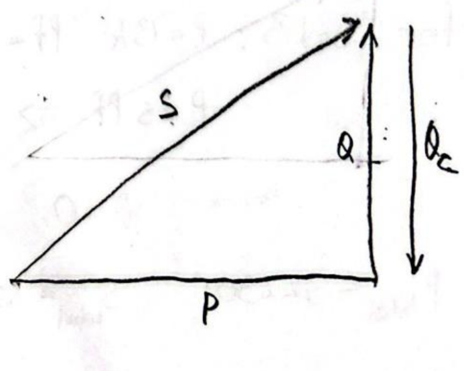
$X_c = 4{,}89$

$4{,}89 = \frac{1}{2\pi f . c} = \frac{1}{2\pi . 50 . c} = 4{,}89$

$c = 6{,}51 . 10^{-4}$

b) $X_c = \frac{V^2}{Q_c} = \frac{230^2}{21481{,}62} = 2{,}46$

$c = \frac{1}{2\pi . 50 . (2{,}46)} = 1{,}294 . 10^{-3}$



c) $S_{ilk} = 42172{,}839$

$I_{ilk} = \frac{S_{ilk}}{V} = 183{,}36$

$S_{son} = 34200$

$I_{son} = \frac{S_{son}}{V} = 148{,}69$

MATLAB Section

D)

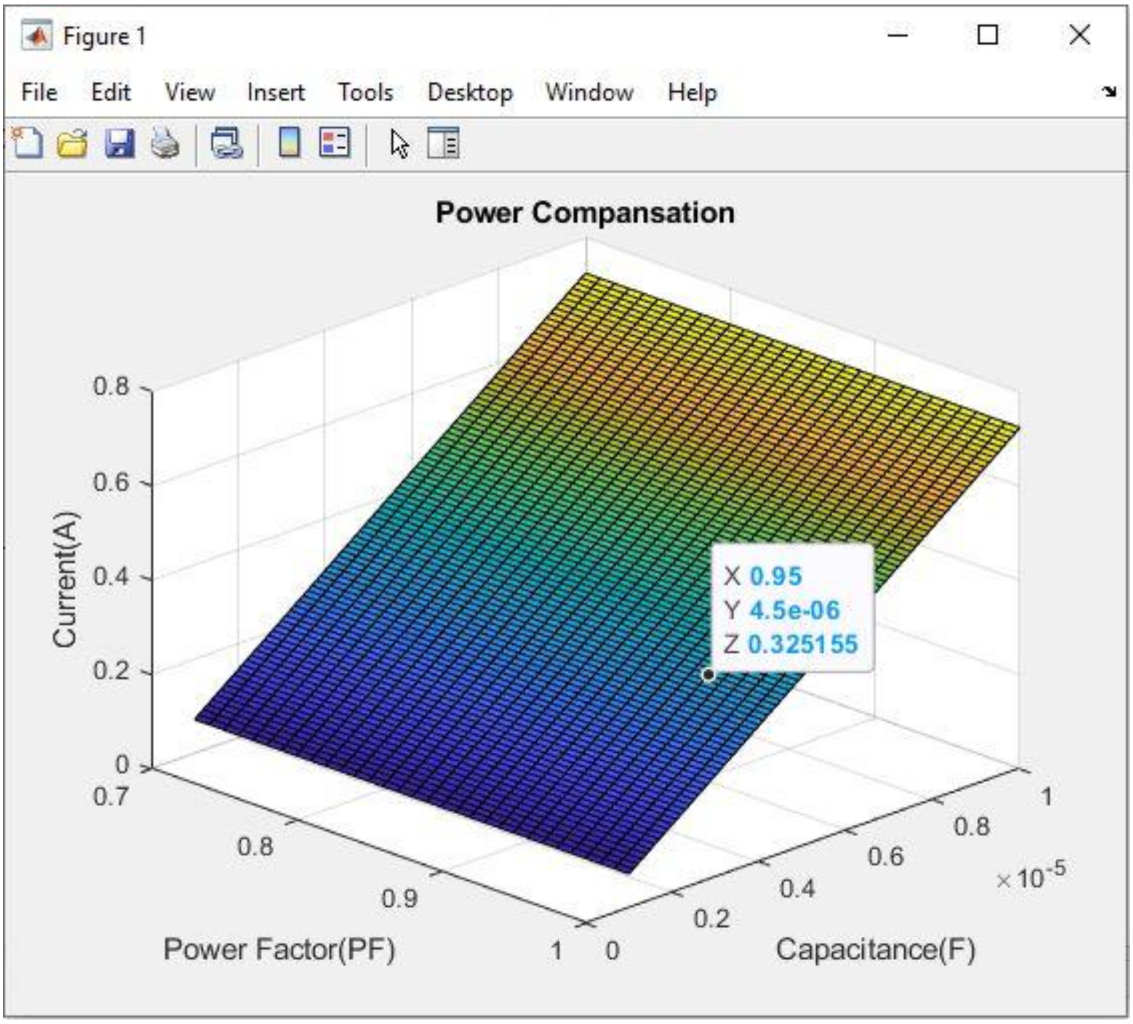


Figure 3: Output of Simulation

Code:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%% Ahmet Turan Ate?    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%% 1901022033          %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
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Vrms = 230; % RMS voltage
f = 50; % Frequency

% Power factor range
pf_range = 0.7:0.01:1;

% Capacitance range
C_range = 1e-6:1e-7:1e-5;

% Assign Variables
current_values = zeros(length(C_range), length(pf_range));
```

```
% Capacitance and Power Factor Equations
for i = 1:length(C_range)
    for j = 1:length(pf_range)
        % Impedence
        Xc = 1 / (2 * pi * f * C_range(i));
        Z = Xc;


        I = Vrms / Z;

        current_values(i, j) = I;
    end
end


[pf_mesh, C_mesh] = meshgrid(pf_range, C_range);

% Plotting
figure;
surf(pf_mesh, C_mesh, current_values);
xlabel('Power Factor(PF)');
ylabel('Capacitance(F)');
zlabel('Current(A)');
title('Power Compansation');

view(45, 30);
```

E)

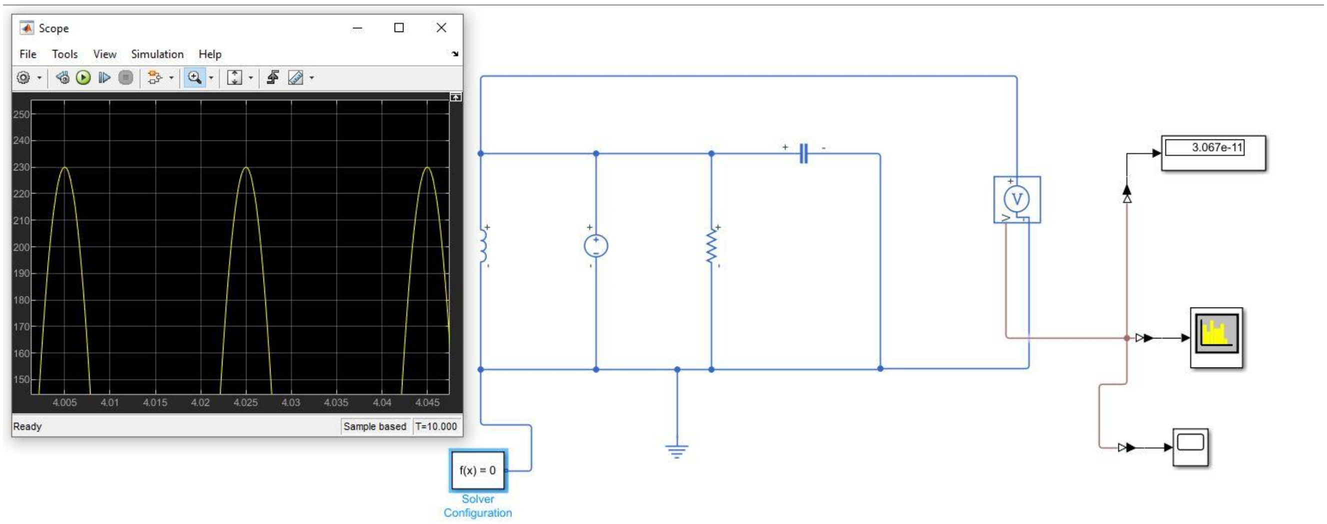

Figure 4: Circuit without Parallel Capacitor for Compensation

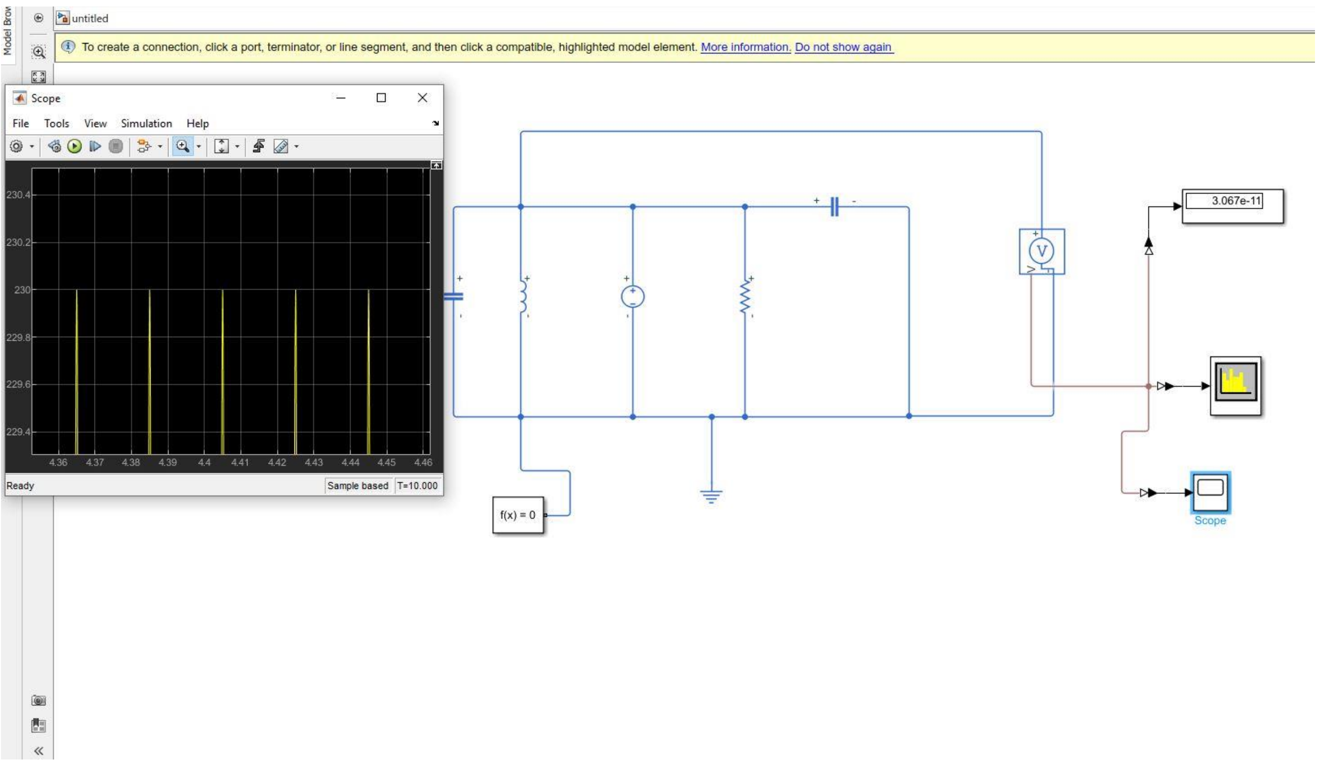

Figure 5: Circuit with Parallel Capacitor for Compensation

Conclusion

In this project, we investigated the power factor correction and compensation for a set of three loads. Through the analysis, we explored the impact of reactive power on the system and its consequences on the overall efficiency.

Firstly, we determined the capacitor value required to set the power factor at 0.95 for Load 1, considering a frequency of 50 Hz. This value ensures a near unity power factor, leading to improved power utilization and reduced reactive power losses.

Next, we focused on compensating for the reactive power completely. By calculating the absolute value of reactive power for Load 1 and Load 2, we identified the capacitor values necessary for compensation. These values effectively neutralize the reactive power and minimize the burden on the power source, leading to a more balanced and efficient power distribution.

Furthermore, we assessed the current drawn by the source before and after compensation. The current values reflect the effect of power factor correction, with lower currents observed after the introduction of capacitors. This reduction in current indicates reduced losses, lower voltage drops, and improved overall system performance.

Additionally, we generated a surface plot that depicted the relationship between power factor, capacitor values, and current drawn by the source. This visualization allowed us to observe the effects of different power factor levels on the system and provided valuable insights for power factor correction strategies. The surface plot showed that as the power factor approaches unity, the capacitor values decrease, resulting in reduced current drawn by the source.

Finally, we implemented a MATLAB Simulink model to simulate the system and validate our calculations. The Simulink model provided a practical representation of the system and allowed us to visualize the effects of power factor correction on load characteristics and overall system performance.

In conclusion, this project emphasized the significance of power factor correction and compensation in electrical systems. By implementing appropriate capacitor values, we can mitigate reactive power, enhance power factor, and improve the efficiency of power transmission. The findings of this project highlight the importance of considering power factor correction techniques to optimize energy consumption, reduce losses, and enhance the overall stability and reliability of electrical systems.