Impact Study on Power Factor of Electrical Load in Power Distribution System

Syirrazie CS[1], H.Hasim[1] Ahmad Asraf AS[2]

[1]*Bahagian Sokongan Teknikal, Agensi Nuklear Malaysia*
[2]*University of Western Australia*

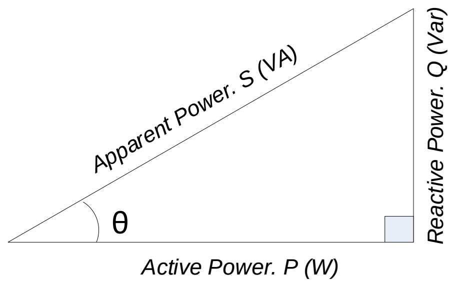
Abstract

Low Power Factor of electrical loads cause high current is drawn from power supply. The impact of this circumstance is influenced by impedance of electrical load. Therefore, the key consideration of this study is how impedance of electrical loads influence power factor of electrical loads, and then power distribution as the whole. This study is important to evaluate the right action to mitigate low power factor effectively for electrical energy efficiency purpose.

Keyword : Power Factor, Electrical Load, Impedance, Current

Introduction

Power factor is the ratio of the real power flowing through the load to the apparent power. Real power is the capacity of the circuit for performing work in a particular time while apparent power is the product of voltage and current drawn into the circuit. The ideal power factor is 1 where the real power is equal to the apparent power. In this condition, there is no effective power known as reactive power drawn into the circuit because current is in phase with the voltage.



This power triangle is showing the relationship among Power Factor and its Related Parameters. Based on this triangle, Power Factor itself is defined as $\cos\theta$.

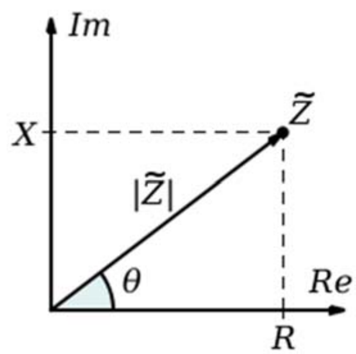
The lower the power factor, the higher the current drawn into the circuit whereby not all of the current drawn contribute to the real power. This study is done to understand the power factor comprehensively, starting from how the AC circuit works and the effect of capacitive and inductive reactance onto power factor of power distribution circuit.

In AC circuits, there are two additional impeding mechanisms besides the normal resistance as in DC circuits, namely inductance and capacitance. Inductance and capacitance are called inductive reactance (X_L) and capacitive reactance (X_C) respectively and forms the imaginary part of the complex impedance whereas resistance (R) forms the real part.

Inductive and capacitive reactances are functions of system frequency of inductance, L and capacitance, C respectively.

$$Inductive\ Reactance, X_L = \omega L = 2\pi f L$$

$$Capacitive\ Reactance, X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$



Impedance, Z is written in complex Cartesian form as:

$Z = R + jX$ [unit: Ω]

The polar form of the impedance is:

$$Z = |Z|\angle\theta$$

Research Objective

Determine Power Factor Correction Potential in Power Distribution System based on impedance of electrical load.

Problem Statement

Low power factor of electrical causes high power consumption in power distribution system.

Methodology

The research approaches to implement this study is through laboratory work. Simulation and calculation in laboratory regarding to power factor is preferred in this study. The following figure, Figure 1 shows the research flow to implement this study.

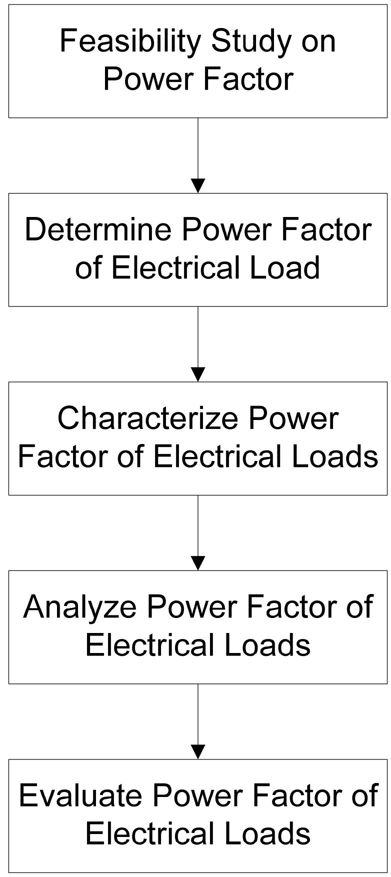


Figure 1: Research Flow

Implementation of all the stages of research flow based on the following matters:

1. Feasibility Study on Power Factor: Literature review on theoretical background about the truth of power factor, others related study on mitigation plan and activities of low power factor of electrical load.
2. Determine Power Factor of Electrical Load: Data collection through measurement the power factor of electrical load based on impedance belongs to an electrical load.
3. Characterize Power Factor of Electrical Load: Data of measured power factor is gathered and organized.
4. Analyze Power Factor of Electrical Load: Observe the result of characterization of power factor, then extract the related finding matters and identify the relationship between related Power Factor components of electrical load.
5. Evaluate Power Factor of Electrical Load: Justify the analysis on Power Factor Characteristics related component of electrical load.

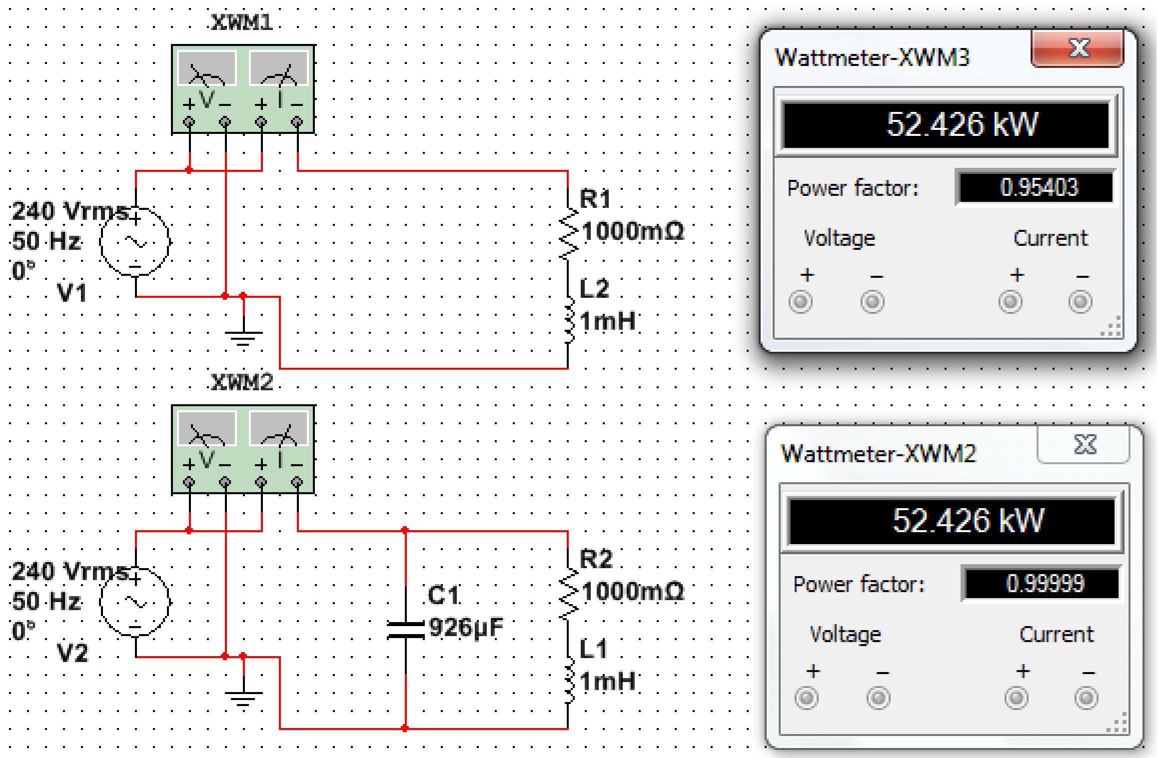


Figure 2: Circuitry of Power Factor Study

Figure 2 shows the circuit that is simulated to gain the result that related to the power factor impact. This circuit operated through 240Vrms at 50Hz. The case for this experiment is based on Load Impedance with resistance, R of 1000 mΩ and Inductance, L of 1 mH with original power factor, pf of 0.95403.

Result & Discussion

Based on cases as referred to Figure 2, the related impact of power factor of electrical load is shown on the following result in Table 1.

Table 1: Power Factor Techno-economic Impact

P (kW)	C (uF)	power factor, pf	Apparent Power, S (kVA)	Delta SP (kW)	Losses at cost incurred, RM 0.21 per kW with full pf charge (RM)	Actual Cost Incurred (RM)	Saving Percentage (%)
52.426	0	0.95403	54.95215	2.52615	RM1,018.54	RM22,156.71	0.00%
52.426	100	0.96305	54.43746	2.01146	RM811.02	RM21,949.19	0.94%
52.426	200	0.97125	53.97786	1.55186	RM625.71	RM21,763.87	1.77%
52.426	300	0.97853	53.57628	1.15028	RM463.79	RM21,601.96	2.50%
52.426	400	0.98485	53.23247	0.80647	RM325.17	RM21,463.33	3.13%
52.426	500	0.99013	52.94860	0.52260	RM210.71	RM21,348.88	3.65%
52.426	600	0.99432	52.72548	0.29948	RM120.75	RM21,258.91	4.05%
52.426	700	0.99738	52.56372	0.13772	RM55.53	RM21,193.69	4.35%
52.426	800	0.99928	52.46377	0.03777	RM15.23	RM21,153.39	4.53%
52.426	900	0.99999	52.42652	0.00052	RM0.21	RM21,138.37	4.60%
52.426	920	0.99999	52.42652	0.00052	RM0.21	RM21,138.37	4.60%
52.426	926	0.99999	52.42652	0.00052	RM0.21	RM21,138.37	4.60%
52.426	1000	0.99952	52.45118	0.02518	RM10.15	RM21,148.31	4.55%
52.426	1100	0.99786	52.53843	0.11243	RM45.33	RM21,183.50	4.39%
52.426	1200	0.99503	52.68786	0.26186	RM105.58	RM21,243.74	4.12%
52.426	1300	0.99107	52.89838	0.47238	RM190.46	RM21,328.63	3.74%
52.426	1400	0.98601	53.16985	0.74385	RM299.92	RM21,438.08	3.24%
52.426	1450	0.98308	53.32832	0.90232	RM363.81	RM21,501.98	2.95%
52.426	1500	0.9799	53.50138	1.07538	RM433.59	RM21,571.76	2.64%

The Table 1 shows that, the greatest potential to make power factor correction for this case by installing the shunt capacitor as show in Figure 2 with capacitance value between 900uF to 926uF.

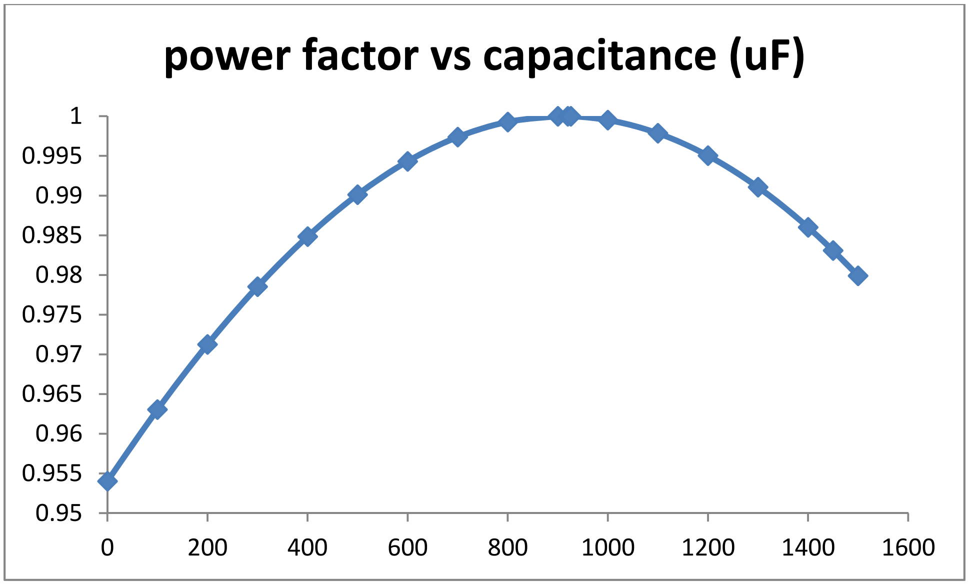


Figure 3: Relationship of Power Factor and Capacitance

The Figure 3 shows that, low power factor can be corrected optimally using the right capacitance value of installed shunt capacitor as shown in Figure 2. More or less of the capacitance value, between 900uF to 926uF causes non techno-economic wise on installation of shunt capacitor on Figure 2.

Limitation

Based on current effort, there is finding that the capacitance value is standard in market. The challenging for circuit designer is to modify the capacitance value of capacitor using the standard unit to gain the required capacitance value then fit them onto the electrical circuit.

Future Work

Analysis the Power Factor in Power System Losses. This analysis considered the losses in incurred by power system component, transformer. The rationale of this research is to justify of how worth many transformers are installed in power system

Conclusion

As the conclusion, power factor of electrical can be determined based on impedance value of electrical. The low power factor of electrical load in power distribution system can be corrected by using shunt capacitor which installed at electrical circuit with the right capacitance value.

Reference

1. Osama A. Al-Naseem and Ahmad Kh. Adi, Impact of Power Factor Correction on the Electrical Distribution Networkof Kuwait –A Case Study, OJPEE - Volume (2), Number (1), Reference Number: W10-0030, Page 173-176, January 2011
2. [2] Gagari Deb, Partha Sarathi Saha and Prasenjit Das, A Method of Finding Capacitor Value for Power Factor Improvement, International Journal of Electrical Engineering, ISSN 0974-2158 Volume 4, Number 8 (2011), pp. 913-922, © International Research Publication House, 2011
3. B. Sharifipour, J. S. Huang, P. Liao, L. Huber, and M. M. Jovanovic, Manufacturing and Cost Analysis of Power-Factor-Correction Circuit, IEEE Applied Power Electronics Conf. (APEC) Proc., Anaheim, CA, Feb. 15-19, 1998, pp. 490-494, 1998