Optimization of Solar Energy by Power Factor Correction at Saint Thomas University

Saint Thomas University's Solar Energy Project
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Abstract

The power factor of the water pumps from the Organic Research Garden (ORG) and Chickee Hut (CH), which are powered by the solar station, were measured, calculated, and corrected. By using a Fluke 43B Single Phase Power Quality Analyzer, the values of real and apparent power were obtained, and with these values, the reactive power and power factors were deduced. The computer software that was used to provide the numerical results was Excel and MatCad, which gathered these results from the manually implemented formulas. Based on these results, it was concluded that the water pump for ORG required the installation of a 177 μF capacitor in its circuit, whereas the water pump from CH required the installation of a 120 μF capacitor. The effect of adding the corresponding capacitors to each of respective water pumps' circuits resulted in a rise in power factor from 0.76 to 0.98 for ORG and 0.82 to 0.98 for CH. Upon analyzing the amount of energy saved by this correction every year, total energy savings would be 163.80 kWh/year for the water pump from ORG and 6.09kWh/year for CH's water pump.

Theoretical Description

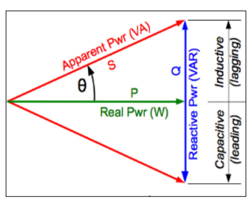


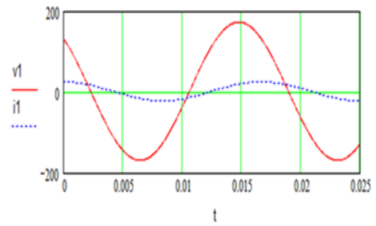
Figure 1. PF: Power Factor, kVA: Apparent Power, kVAR: Reactive Power, kW: Real Power

The Organic Research Garden's system had an overall power factor (pf1) of 0.76, which was working with a voltage of 120.9 V, a current of 16.63 A, and a frequency (f) of 60 Hz. The Chickee Hut's system had an overall power factor (pf1) of 0.82, which was working with a voltage of 119.0 V, a current of 13.45 A, and a frequency (f) of 60 Hz.

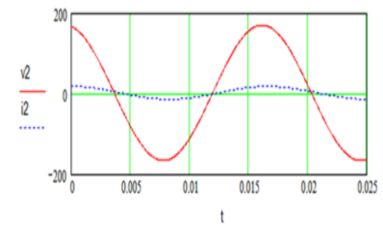
To correct both systems' power factor, the following formulas were input into Mathcad:

1) $Irms = (S \cdot 1000) / Vrms$
2) $\omega = 2\pi f$
3) $\theta = acos(pf)$
4) $Im = \sqrt{2} \cdot Irms$
5) $Vm = \sqrt{2} \cdot Vrms$
6) $i = Im \cos(\omega t)$
7) $v = Vm \cos(wt + \theta)$
8) $a = i \cdot v = p + r$
9) $p = Irms\ Vrms \cos(\theta)(1+\cos(2\omega t))$
10) $r = -\ Irms\ Vrms \sin(2\omega t) \sin(\theta)$
11) $A = \sqrt{<p>^2 + (\mathbf{max}(r))^2}$
12) $C = ((Q1-Q2)\ \mathbf{10^6}) / (2\pi f\ Vrms^2)\ \mu F$

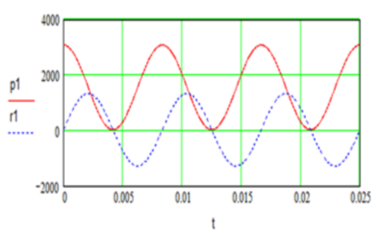
Organic Research Garden Results



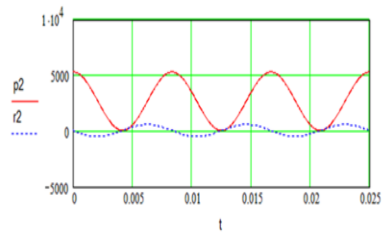
Graph 1. Shows offset of the Current from the Voltage. Current and Voltage are 40.5⁰ out of phase.



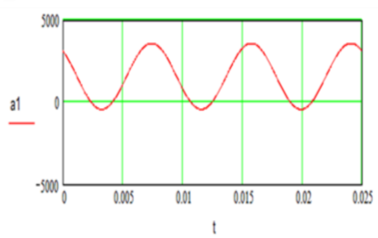
Graph 4. Shows offset of the Current from the Voltage. Current and Voltage are 11.5⁰ out of phase.



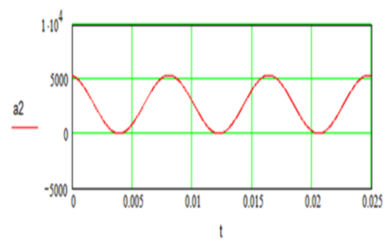
Graph 2. Real Power (p) vs. Reactive Power (r). Reactive power produces additional energy wasted in the circuit.



Graph 5. Correction of Reactive Power. Reactive power was greatly reduced after correcting the power factor.



Graph 3. Apparent Power slightly shifts negatively due to problems with the system's power factor before the correction.

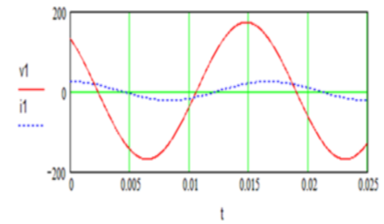


Graph 6. Apparent Power after the power factor correction. Graph shows the shift after the power factor nears 0.98.

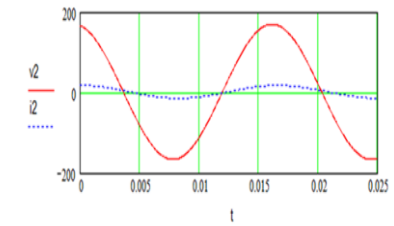
Power Factor	Real Power (kW)	Reactive Power (kVAR)	Apparent Power (kVA)
0.76	1.53	1.29	2.01
0.98	1.53	0.31	1.56
Difference			22%

Table 1. List of values showing the change in power factor, real power (kW), reactive power (kVAR), and apparent power (kVA) when the capacitor was implemented and the power factor corrected.

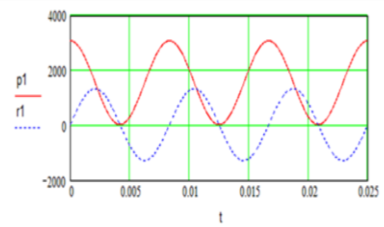
Chickee Hut Results



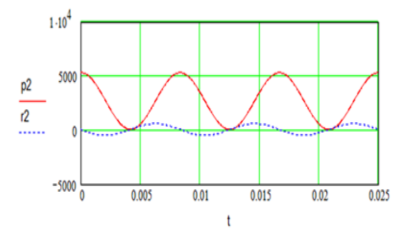
Graph 1. Shows offset of the Current from the Voltage. Current and Voltage are 35⁰ out of phase.



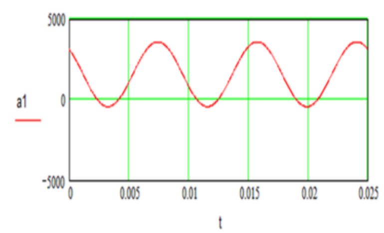
Graph 4. Shows offset of the Current from the Voltage. Current and Voltage are 11.5⁰ out of phase.



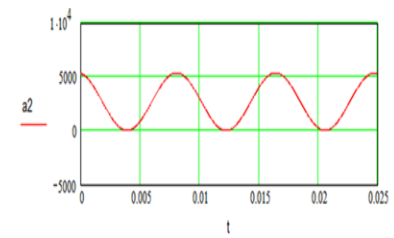
Graph 2. Real Power (p) vs. Reactive Power (r). Reactive power produces additional energy wasted in the circuit.



Graph 5. Correction of Reactive Power. Reactive power was greatly reduced after correcting the power factor.



Graph 3. Apparent Power slightly shifts negatively due to problems with the system's power factor before the correction.



Graph 6. Apparent Power after the power factor correction. Graph shows the shift after the power factor nears 0.98.

Power Factor	Real Power (kW)	Reactive Power (kVAR)	Apparent Power (kVA)
0.82	1.31	0.91	1.60
0.98	1.31	0.27	1.34
Difference			16%

Table 1. List of values showing the change in power factor, real power (kW), reactive power (kVAR), and apparent power (kVA) when the capacitor was implemented and the power factor corrected.

Calculations

Organic Research Garden

Input Voltage: Vrms = 120.90 V
Power Factor (pf1): 0.76
θ1 = acos(pf1) = 40.53
Corrected Power Factor (pf2): 0.98
θ2 = acos(pf2) = 1.48
Input current before PF corrected: Irms = 16.63 A
Input current after PF corrected: Irms = 12.91 A

PF Capacitor corrector: 177 μF

Chickee Hut

Input Voltage: Vrms = 119.0 V
Power Factor (pf1): 0.82
θ1 = acos(pf1) = 34.92
Corrected Power Factor (pf2): 0.98
θ2 = acos(pf2) = 1.48
Input current before PF corrected: Irms = 13.45 A
Input current after PF corrected: Irms = 11.23 A

PF Capacitor corrector: 120 μF

Conclusion

Improving the power factor can maximize current-carrying capacity, reduce power losses, and lower electric bills. Initially, the power consumption for the Organic Research Garden's motor was 2.01 kW. After correcting the power factor, it was reduced to 1.56 kW without diminishing their functionality. The Chickee Hut's motor was consuming 1.60 kW. After correcting the power factor, it was reduced to 1.34 kW. As a result, w/o the installed capacitor, 1467 kWh/year was consumed in the Organic Research Garden and 1168 kWh/year in the Chickee Hut. However, with the installed capacitor it was reduced to 1139 kWh/year and 978 kWh/year respectively, saving 518 kWh/year (20%). The application of this technique in other areas of STU can save tens of thousands of dollars a year in electricity.

References

- **Alternating-current circuits [by] Russell M. Kerchner [and] George F. Corcoran. 4th ed. Published by Wiley in New York**
- **Fluke 43B Single Phase Power Quality Analyzer Applications Guide**
- **Power factor correction: A guide for the plant engineer. Technical Data SA026070001E. Nov. 2010**
- **"Practical Power Factor Correction." All About Circuits Forum RSS. Web. 24 July 2015.**
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