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Evaluation of Percentage Wasted Power in Electrical Loads with Constructed Power Factor Correction Equipment

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***Abstract-* Fixed capacitive low power factor correction measurements was done to calculate percentage wasted power. The output of the nine operational amplifier voltage comparator controlled stabilizer was connected to a fixed CBB61; 450V 2uF AC run capacitor unto which each load was connected and computation of apparent power, power factor and percentage wasted power were made. It was found that very high percentage of required real power was wasted when power factor was uncorrected in electrical appliances studied. 52% of power was wasted in three laptops combination that reduced to 8.6% after CPF compare to 36.5% when 3 loads comprising of a laptop, printer and electric fan was used that was reduced to 3.3%. Minimum power was wasted in Philips Elance 3100, Electric iron with 32.3% when the power factor was uncorrected and 3.2% when power factor was corrected.**

***IndexTerms*—Electrical Power, loads, Power factor, Percentage Wasted Power, Required.**

I. Introduction

Electrical distribution is in the form of a low frequency high voltage and low current to save cost incurred in conducting and insulating materials; to reduced overheating of cables and for ease of transformation from high to low voltage required at the consumer points. Alternating current systems supply two forms of energy: Real energy measured in kilowatt hours (kWh) which is converted into mechanical work, heat, light, etc and Reactive energy needed to generate magnetic fields by inductive circuits (transformers, motors, cables, refrigerators, inverters discharge lamps (with magnetic ballasts) etc.), Schneider Electric, 2008, Sugawara et al., 2007. In industries, Low power factor results when inactive motors are operated at less than full load. This often occurs in cycle processes occurring in circular saws, mills, conveyors, compressors, Grinders and punch presses, www.eaton.com, 2014. Low power factor is easily corrected by adding, in parallel to load, a capacitive reactance that acts in opposite sign as the load's inductive reactance. Low power factor input in distribution systems causes power losses in transmission and distribution systems by heating the conductors, ON Semiconductor 2007. The combination of inductive reactance in transmission and distribution systems and that of consumer loads produces the worst possible conditions of low power factor. Power factor correction capacitors reduce the (inductive) reactive current in upstream conductors, thereby reducing or eliminating voltage drops (electroschematics, 2015; fairchildsemi, 2015).

By improving the power factor of a load supplied from a transformer,

(a) the current or power through the transformer will be reduced, thereby allowing more load to be added (it is cheaper to improve the power of transformer than to replace it with a bigger one),

(b) the excess bill or penalties for excessive consumption of reactive power is reduced because the apparent power kVA demand, on which standing charges are usually based is reduced,

(c) the size of the cables supplying the local distribution boards is reduced and the cables have additional capacity for possible load increases,

(c) heat losses in cables, transformers and loads will be reduced and they will have longer lifespan.

From the power triangle (Fig.1) the bigger the reactive power component, the higher is the power factor of the circuit

$$\text{kVAR} = \text{kVA}\sin\theta \quad \ldots\ldots 1$$

but

$$\text{kVA} = \frac{\text{kW}}{\cos\theta} \quad \ldots\ldots 2$$

$$\text{kVA} = \frac{\text{kW}\sin\theta}{\cos\theta} = \text{kW}\tan\theta \quad \ldots\ldots 3$$

The lower the power factor (cosθ) the more the apparent power(kVA) or electrical bill.

$$\text{kVA}^2 = \text{kW}^2 + \text{kVAR}^2 \quad \ldots\ldots 4$$

For an electrical appliance with the power factor corrected, the apparent power is reduced since real power (kW) is fixed then the reactive power is reduced hence apparent power is affected by the reactive power (see equation 4).

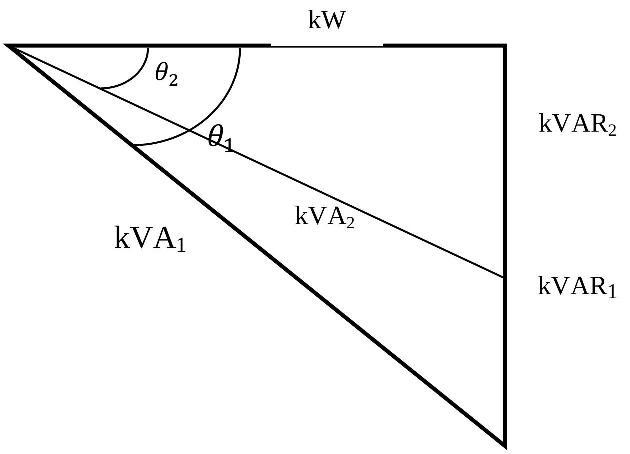

Fig. 1: Increase in kVA$_2$,kVAR$_2$ and θ_2 due to induction sources

II. Material and Method

A constructed stabilized power factor corrected and current voltage measuring equipment with ability to measure input voltage and output voltage and current (see Fig. 2) was used for the data collection in eleven electrical loads. The output of the stabilizer is connected to a CBB61; 450V 2uF AC run capacitor unto which each load was connected and computation of apparent power, power factor and percentage wasted power with and without the correction was done.

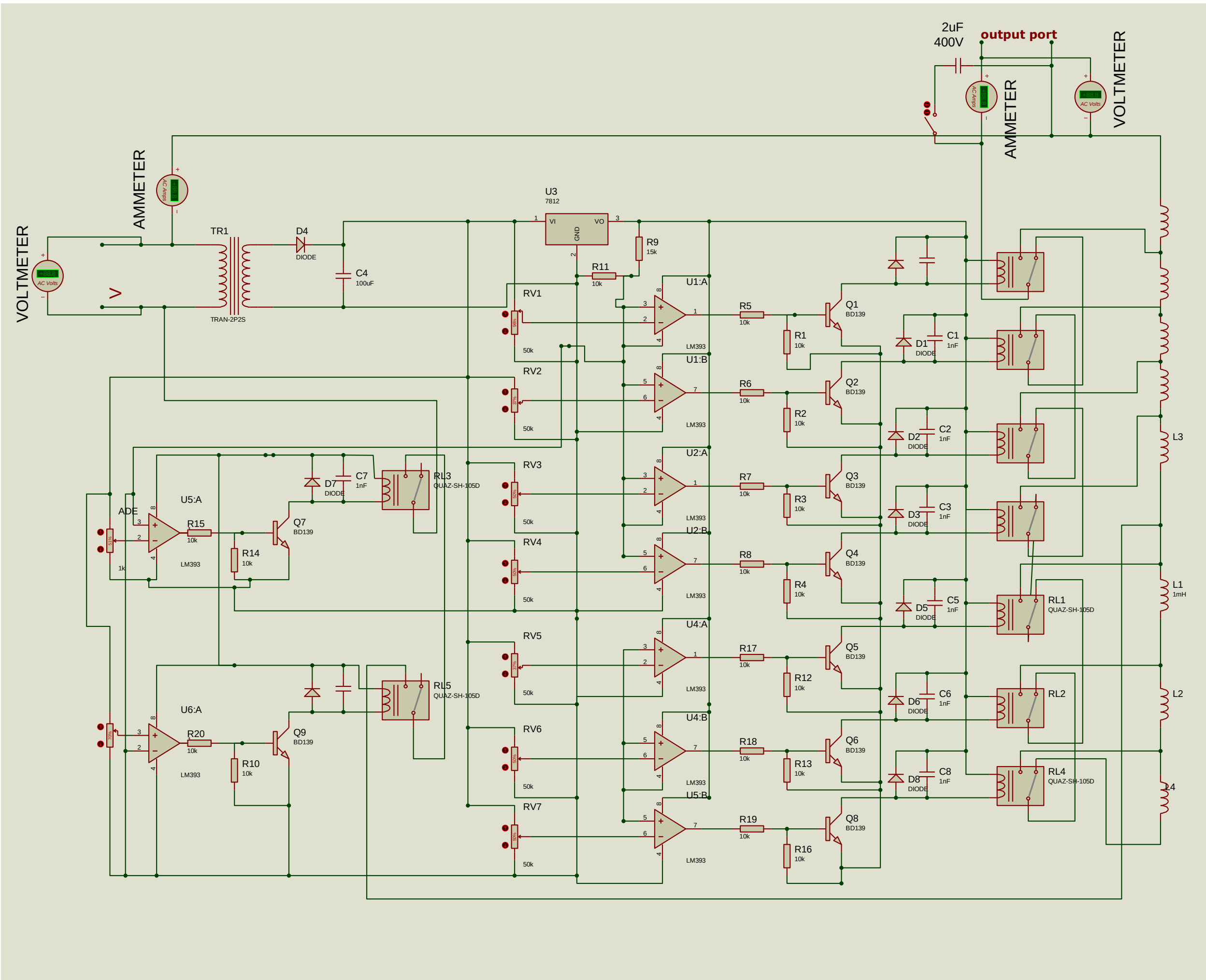

Fig. 2 Stabilized power factor measuring circuit

III. Result and Discussion

Tables 1 and 2 show the measurement of voltage and current for corrected power factor (CPF) and uncorrected power factor (UPF). The voltages and current in uncorrected power factor are higher than when they are corrected; this resulted in more apparent power (see Tables 3)

Table 1: Stabilized Output Voltage and Load Current without Power Factor Correction

S/N	LOAD	INPUT VOLTAGE (V)	STABILIZED OUTPUT VOLTAGE (V)	LOAD CURRENT (A)
1	Sharp air conditioner	230	250.0	4.80
2	Haier thermocool refrigerator HRF250DX	230.0	245.0	2.00
3	Hand hair dryer	230.0	245.0	5.00
4	Electric iron	225.0	245.0	10.80
5	Electric clipper	230.0	240.0	0.06
6	Electric stove	230.0	240.0	5.80
7	Electric fan 18” century product	230.0	240.0	0.60
8	Hp pavilion DV600 and Acer V5series laptops	230.0	240.0	0.80
9	Hp pavilion DV600, Hp 630 and Acer laptops	230.0	240.0	1.40
10	Acer laptop V5series, hp printer P1102 and Century fan 18”	230.0	245.0	4.40
11	Battery charger	230.0	240.0	6.00

Table 2: Stabilized Output Voltage and Load Current with Power Factor Correction.

S/N	LOAD	INPUT VOLTAGE (V)	STABILIZED OUTPUT VOLTAGE(V)	LOAD CURRENT (A)
1	Sharp air conditioner	230.0	240.0	4.20
2	Haier thermocool refrigerator HRF250DX	230.0	240.0	1.60
3	Hand hair dryer	230.0	240.0	4.00
4	Electric iron	230.0	240.0	8.60
5	Electric clipper	230.0	240.0	0.05

6	Electric stove	230.0	240.0	4.40
7	Electric Century fan 18”	230.0	240.0	0.50
8	Hp pavilion DV600 and Acer V5series laptops	230.0	240.0	0.60
9	Hp pavilion DV600, Hp 630 and Acer laptops	230.0	240.0	1.00
10	Acer laptop V5series, hp printer P1102 and Century fan 18”	230.0	240.0	3.40
11	Battery charger	230.0	240.0	4.40

Table 3: Loads’ Real Power and Computed Apparent Power for CPF and UPF

S/N	LOAD	REAL POWER (W)	STABILIZED AND CORRECTED POWER FACTOR APPARENT POWER (VA)	STABILIZED AND UNCORRECTED POWER FACTOR APPARENT POWER (VA)
1	Sharp air conditioner	900	1008.0	1200.0
2	Haier thermocool refrigerator HRF250DX	360	384.0	490.0
3	Hand hair dryer (Bestside RCE 2300)	900	960.0	1225.0
4	Electric iron (Philips Elance 3100)	2000	2064.0	2646.0
5	Electric clipper (Kinsclip NC-222)	10	12.0	14.40
6	Electric stove	1000	1056.0	1392.0
7	Electric fan 18” century product	100	120.0	144.0
8	Hp pavilion DV600 and Acer V5series laptops	131	144.0	192.0
9	Hp pavilion DV600, Hp 630 and Acer laptops	221	240.0	336.0
10	Acer laptop V5series, hp printer P1102 and Century fan 18”	790	816.0	1078.0
11	Battery charger	1000	1056.0	1440.0

Table 4: Percentage Wasted Power for Corrected and Uncorrected Power factor

S/N	LOAD	WASTED POWER WITH NO PFC (VA)	WASTED POWER WITH PFC (VA)	PERCENTAGE WASTED POWER WITH NO PFC (%)	PERCENTAGE WASTED POWER WITH PFC (%)
1	Sharp air conditioner	300	108	33.3	12
2	Haier thermocool refrigerator HRF250DX	130	24	36.1	6.7
3	Hand hair dryer (Bestside RCE 2300)	325	60	36.1	6.7
4	Electric iron (Philips Elance 3100)	646	64	32.3	3.2
5	Electric clipper (Kinsclip NC-222)	4.4	2	44	20
6	Electric stove	392	56	39.2	5.6
7	Electric fan 18” century product	44	20	44	20
8	Hp pavilion DV600 and Acer V5series laptops	61	13	46.6	9.9
9	Hp pavilion DV600, Hp 630 and Acer laptops	115	19	52.0	8.6

10	Acer laptop V5series, hp printer P1102 and Century fan 18"	288	26	36.5	3.3
11	Battery charger	440	56	44	5.6

Table 4 and Figure 3 show that very high percentage of required real power is wasted when power factor is uncorrected. 52% of power is wasted in three laptops combination that reduced to 8.6% after CPF compare to 36.5% when 3 loads comprising of a laptop, printer and electric fan was used that was reduced to 3.3% and 46.6% that reduced to 9.9% after CPF when two laptops, Hp pavilion DV600 and Acer V5series laptops were used. Minimum power was wasted in Philips Elance 3100, Electric iron with 32.3% when the power factor was uncorrected and 3.2% when power factor was corrected. The highest wasted power after correction of power factor is in Century 18" Electric fan and Kinsclip NC-222 Electric clipper with similar 20% wasted power and corresponding 44% uncorrected wasted power.

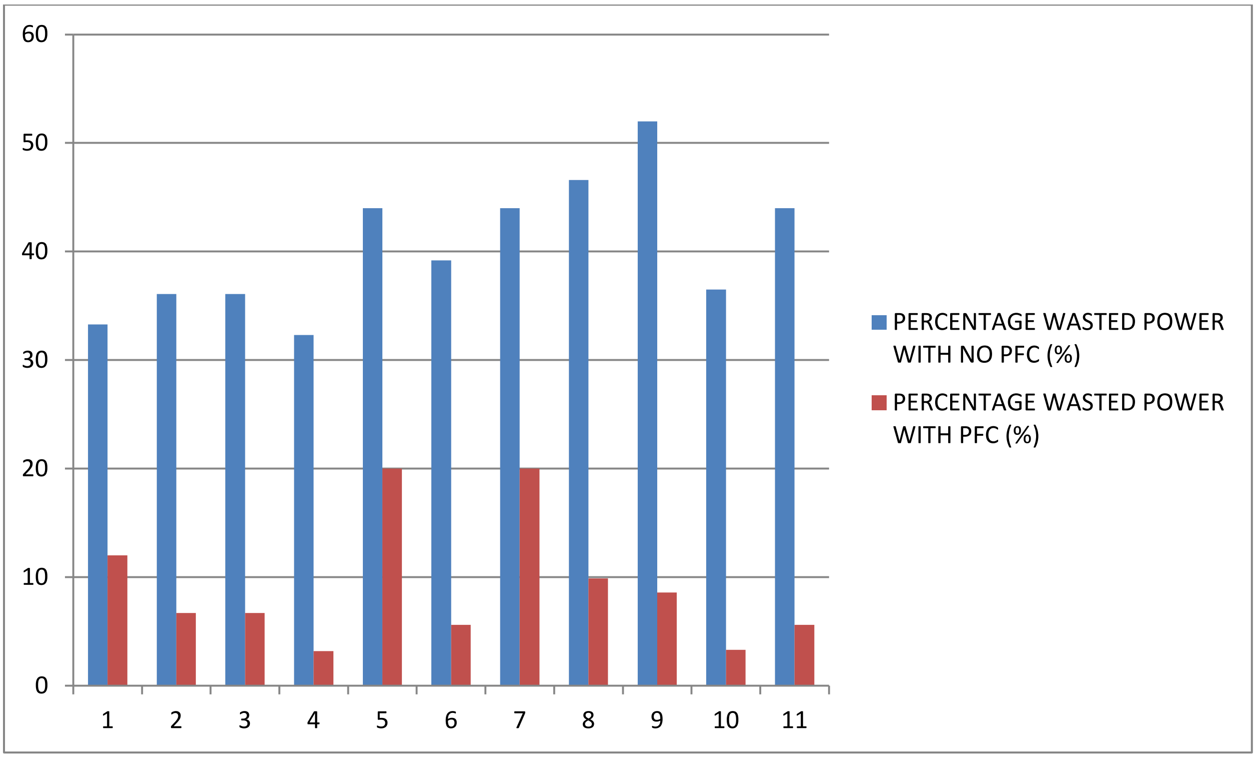

Fig. 3: Percentage wasted power in electrical loads

IV. Conclusion

A stabilized power factor corrected and current voltage measuring equipment useful to evaluate power factor was designed and constructed. It was found that more voltage and current were consumed when power factor was not corrected resulting in more percentage of real power being wasted. The corrected power factor reduced the apparent power needed for the loads to operate this will reduce electrical power wasted as heat with lower electrical bill, reactive power penalties and a longer lasting electrical distribution system and consumer appliances.

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