

Comparative study and analyzes the power factor variation due to loading effect

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Abstract: Power factor is most important for all industrial as well as domestic sectors. In this research paper present the comparative study and analyzes the power factor variation due to loading effect. For this comparison we take different values of inductance, three different range of capacitor and two range of resistance and their total impedance is calculated. The calculated theoretical and practical values of power factor on the basis of different combination loads. Pure sinusoidal sine waves are displayed in computer through sound card and calculate the load phase angle between the fundamental components of the load voltage and current.

Keywords: Microcontroller, power system, signal processing technique, power factor, resistance, inductance, capacitance.

I. INTRODUCTION

The power factor of an AC power system is expressed as the ratio of the actual power to the apparent power, where as the apparent is greater than the actual power. The apparent is the product of load voltage and current. PF is also defined as the cosine of the angle of lag or lead and also defined as the ratio of resistance to the impedance. In an electric power system, a low power factor can be the result of either a significant phase difference between the load voltage and load current. There are three parameters play the important role on power factor such as resistance (R), capacitance (C), inductance (L). In pure resistive load, there is no phase difference between voltage and current. In pure inductive load, the current is lagging behind the voltage but practically it is not possible. In pure capacitive load, the current is leading behind the voltage but practically pure capacitive load is also not possible [1-11]. In RC series circuit is connected to the supply voltage. The impedance (Z) and phase angle of RC series circuit is calculated as shown in equation (1) and (2).

$$Z = \sqrt{R^2 + X_C^2} \quad (1)$$

To calculate the reactance for the capacitor

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

$$\phi = \tan^{-1} \left(\frac{X_C}{R} \right) \quad (2)$$

In RLC series circuit are connected to the supply voltage. The impedance (Z) and phase angle of RLC series circuit is calculated as shown in equation (3) and (4).

$$Z = \sqrt{R^2 + (X_L - X_C)^2} \quad (3)$$

To calculate the reactance's for the inductor and the capacitor [12]

$$X_L = 2\pi fL$$

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

$$\phi = \tan^{-1} \left(\frac{X_L - X_C}{R} \right) \quad (4)$$

II. METHODOLOGY

In this research work we are analyzed the power factor variation due to loading effect. Now, we are taking the different blocks; First block is AC power stabilization with sensing circuit (i.e voltage and current), second block is different combination of load section, third block is step down voltage transformer (PT) and current transformer (CT) and the fourth block is sound card with signal processing unit. In the first block, the AC input voltage is applied to power stabilization with sensing circuit. In this block, the AC input voltage drop due to the fluctuations are stabilized by the PIC based microcontroller with other driver circuits. The output from the AC power stabilization with sensing circuit block is applied to the load which consists of series combinations of RC (resistor-capacitor) and RLC (resistor-inductor-capacitor). We have taken three different values of capacitance, two different values of resistance and varying inductance. The output from the load section is applied to the step down voltage transformer. PT and CT are used for measurement of the load voltage and current. Sinusoidal sine waves are displayed in computer through sound card and calculate the load phase angle between load voltage and current. The estimation of the power factor was taken by recording the voltage and current waveforms at 16,000sa/s at 16-bit quantization and processing using digital signal processing algorithms.

In Table I, three observations are taken by changing the values of capacitor (2.5μF, 15μF and 50μF) and the value of resistance constant (124Ω). In Table II, three observations are taken by changing the values of inductor (269.1mH, 590.6mH and 1232.0mH), changing the values of capacitor (2.5μF, 15μF and 50μF) and keeping the value of resistor (124Ω) are constant. In Table III, three observations are taken by changing the values of inductor (363.0mH, 590.6mH and 1232.0mH), keeping the value of

resistor (36Ω) and capacitor (2.5μF) are constant. In Table IV, three observations are taken by changing the values of inductor (873.0mH, 1073.0mH and 1232.0mH), keeping the value of resistor (36Ω) and capacitor (15μF) are constant.

TABLE I. DIFFERENT COMBINATIONS OF LOAD (R, C)

S. No.	R(Ω)	C(μF)
1	124	2.5
2	124	15
3	124	50

TABLE II. DIFFERENT COMBINATIONS OF LOAD (L, C WITH R 124Ω)

S. No.	R(Ω)	L(mH)	C(μF)
1	124	269.1	50
2	124	590.6	15
3	124	1232.0	2.5

TABLE III. DIFFERENT COMBINATIONS OF LOAD (L, C WITH R 36Ω)

S. No.	R(Ω)	L(mH)	C(μF)
1	36	363.0	2.5
2	36	590.6	2.5
3	36	1232.0	2.5

TABLE IV. DIFFERENT COMBINATIONS OF LOAD (VARYING INDUCTOR WITH CONSTANT RESISTANCE 36Ω AND CAPACITOR 15μF)

S. No.	R(Ω)	L(mH)	C(μF)
1	36	873.0	15
2	36	1073.0	15
3	36	1232.0	15

III. RESULT AND DISCUSSION

Experimental results are obtained from the comparison of different combination of loads (RC and RLC) on the microcontroller based power system. Investigations of the change in the power factor due to loading effect has been evaluated and analyzed. Calculations of the power factor are carried out using signal system and processing unit. Fig. 1(a-c) represents the segmented output voltage and current waveforms for three different combinations of the load (constant resistor 124Ω and varying capacitor) with duration of 0.3s. Fig. 2(a-c) represents the segmented output voltage and current waveforms for three different combinations of the load (constant resistor 124Ω, varying inductor and capacitor) with duration of 0.3s. Fig. 3(a-c) represents the segmented output voltage and current waveforms for three different combinations of the load (varying inductor, keeping resistor 36Ω and capacitor 2.5μF are constant) with duration of 0.3s. Fig. 4(a-c) represents the segmented output voltage and current waveforms for three different combinations of the load (varying inductor, keeping resistor 36Ω and capacitor 15μF are constant) with duration of 0.3s and their total impedance is calculated with all the values of the capacitor, inductor and resistor. Theoretical values of the power factor were calculated. From the output waveforms of current and voltage the practical value of the power factor were obtained. Both theoretical and practical calculated values of power factor are shown in Table V,

Table VI, Table VII, and Table VIII. In Table V, the minimum value of theoretical power factor is 0.097 and corresponding practical power factor is 0.104. The maximum value of theoretical power factor is 0.89 and corresponding practical power factor is 0.89. In Table VI, the minimum value of theoretical power factor is 0.1384 and corresponding practical power factor is 0.1478. The maximum value of theoretical power factor is 0.986 and corresponding practical power factor is 0.987.

TABLE V. CALCULATION OF IMPEDANCE, THEORETICAL AND PRACTICAL VALUE OF PF FOR LOAD (CONSTANT RESISTANCE AND VARYING CAPACITOR)

S. No.	Impedance Z(Ω)	P.F. Theoretical	P.F. Practical	Error
1	1279.3	0.097	0.104	0.932
2	245.8	0.504	0.515	0.978
3	139.4	0.89	0.89	1.000

TABLE VI. CALCULATION OF IMPEDANCE, THEORETICAL AND PRACTICAL VALUE OF PF WITH ERROR FOR LOAD (VARYING INDUCTOR AND CAPACITOR WITH CONSTANT RESISTANCE 124Ω)

S. No.	Impedance Z(Ω)	P.F. Theoretical	P.F. Practical	Error
1	125.7	0.986	0.987	0.998
2	126.8	0.977	0.997	0.979
3	894.8	0.1384	0.1478	0.9364

TABLE VII. CALCULATION OF IMPEDANCE, THEORETICAL AND PRACTICAL VALUE OF PF WITH ERROR FOR LOAD (VARYING INDUCTOR WITH CONSTANT CAPACITOR 2.5μF AND RESISTANCE 36Ω)

S. No.	Impedance Z(Ω)	P.F. Theoretical	P.F. Practical	Error
1	1159.76	0.0310	0.0317	0.977
2	1088.29	0.0330	0.0334	0.988
3	886.93	0.0405	0.0410	0.987

TABLE VIII. CALCULATION OF IMPEDANCE, THEORETICAL AND PRACTICAL VALUE OF PF WITH ERROR FOR LOAD (VARYING INDUCTOR WITH CONSTANT RESISTANCE 36Ω AND CAPACITOR 15μF)

S. No.	Impedance Z(Ω)	P.F. Theoretical	P.F. Practical	Error
1	71.74	0.5033	0.5012	1.004
2	129.97	0.2775	0.2769	1.002
3	178.51	0.2020	0.2008	1.005

In Table VII, the minimum value of theoretical power factor is 0.0310 and corresponding practical power factor is 0.0317. The maximum value of theoretical power factor is 0.0405 and corresponding practical power factor is 0.0410. In Table VIII, the minimum value of theoretical power factor is 0.2020 and corresponding practical power factor is 0.2008. The maximum value of theoretical power factor is 0.5033 and corresponding practical power factor is 0.5012. Also the error calculated by dividing theoretical and practical calculated values is shown. The calculated theoretical and practical values of power factor are plotted in Fig. 5 to Fig. 8 with different impedance values. There is also some difference in theoretical and practical calculated values are seen in the plot for different

combinations which may arise due to leakage of the inductive or capacitive components.

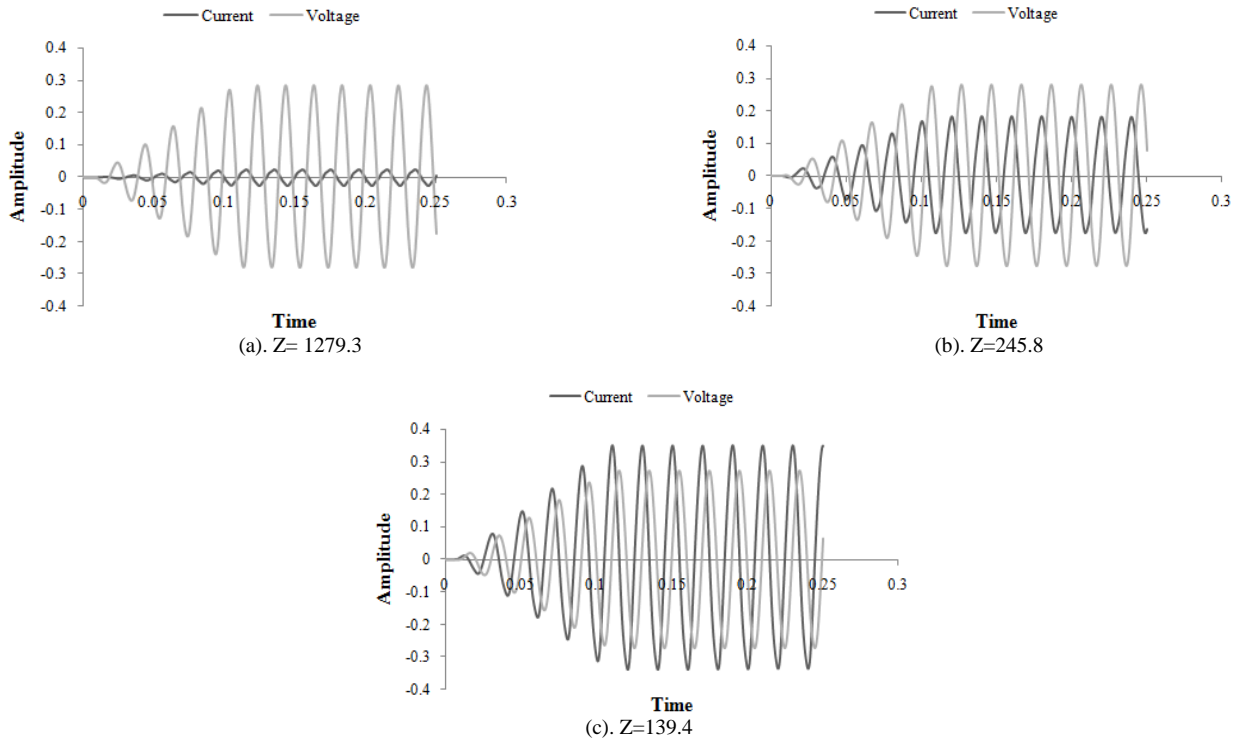


Fig. 1(a-c) Waveform of output current and voltage are recorded at 16,000 sampling rate for three different values of capacitance and resistance constant

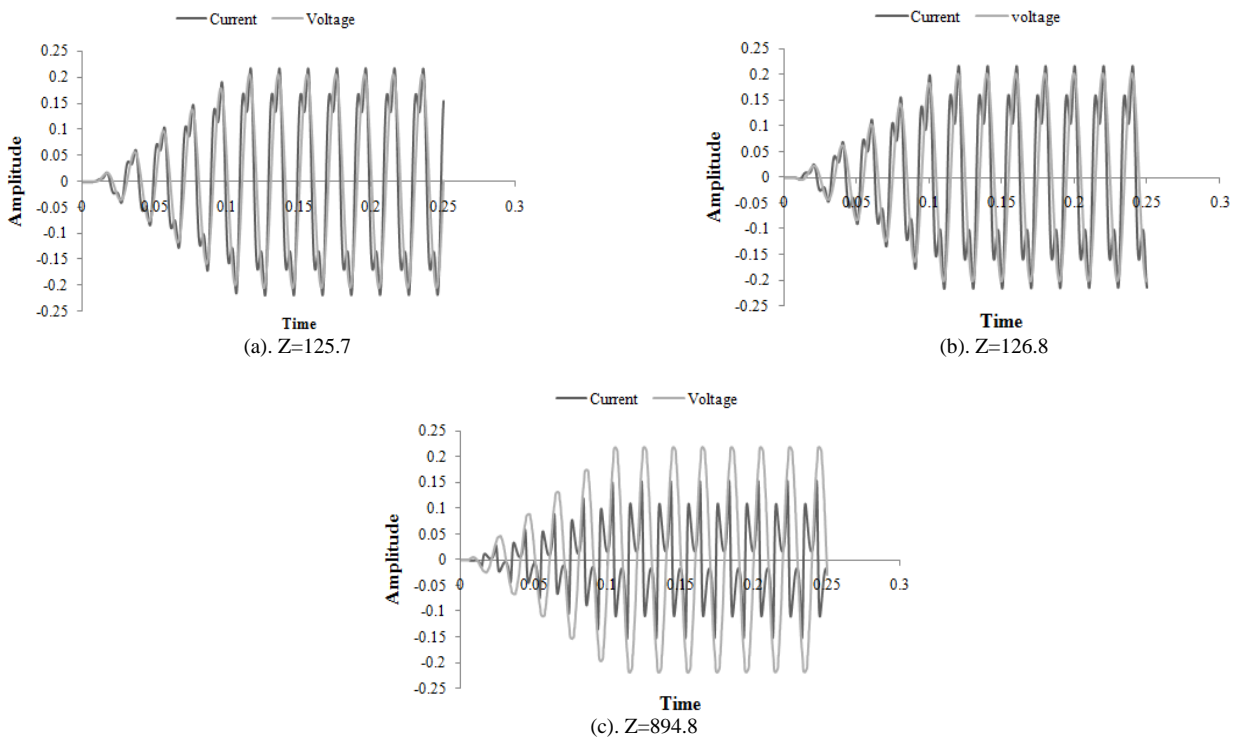


Fig. 2(a-c) Waveform of output current and voltage are recorded at 16,000 sampling rate for three different values of inductance and capacitor keeping resistance (124Ω) constant

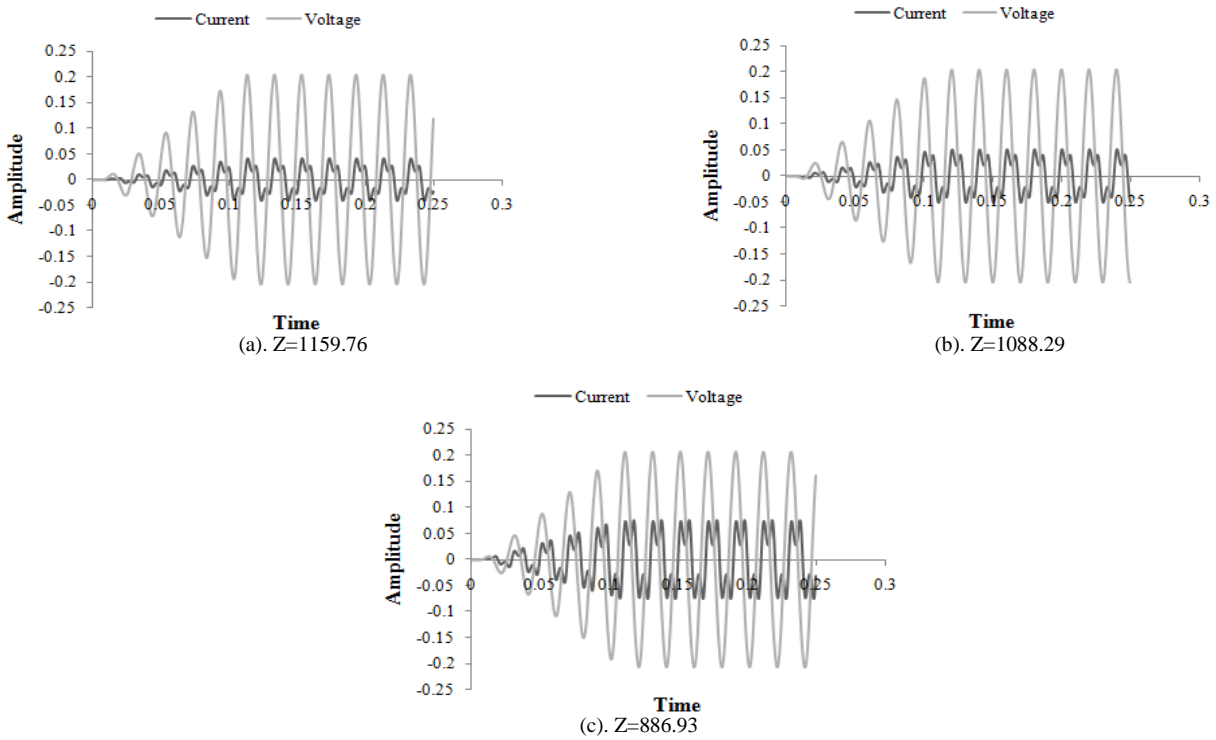


Fig. 3(a-c) Waveform of output current and voltage are recorded at 16,000 sampling rate for three different values of inductance and keeping the value of capacitor ($2.5\mu\text{F}$), resistance (36Ω) are constant

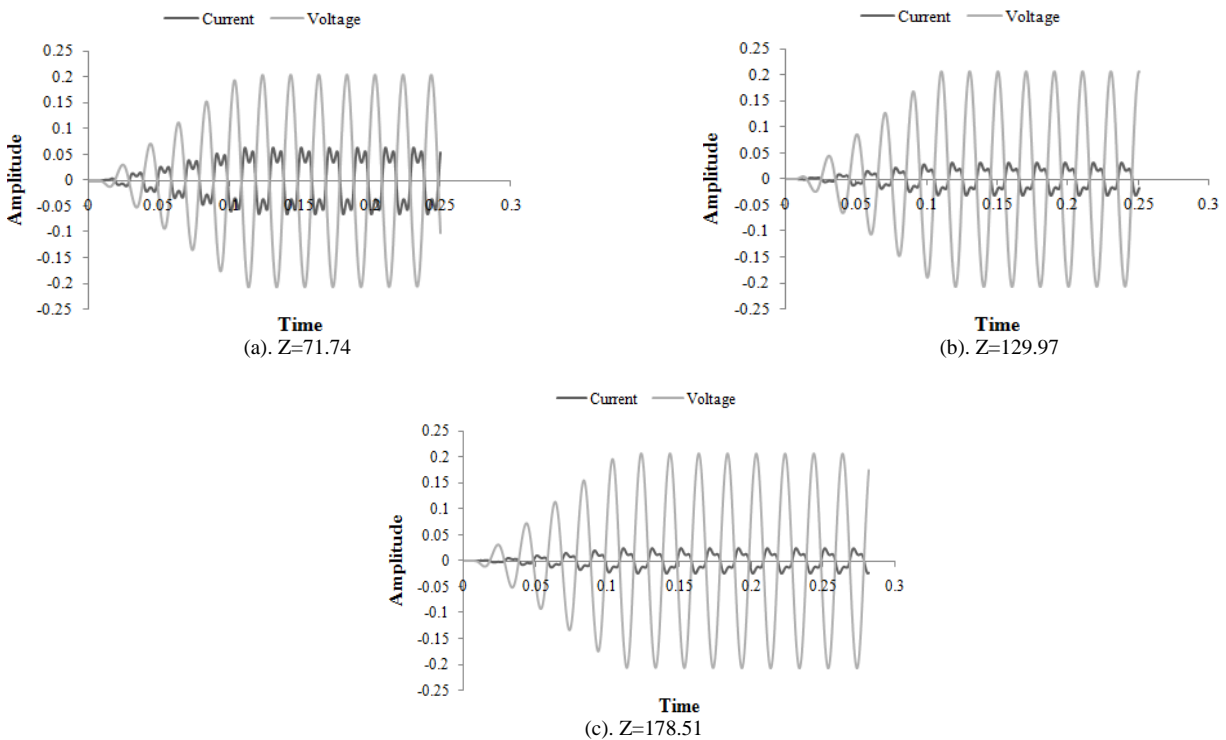


Fig. 4(a-c) Waveform of output current and voltage are recorded at 16,000 sampling rate for three different values of inductance and keeping the value of capacitor ($15\mu\text{F}$), resistance (36Ω) are constant

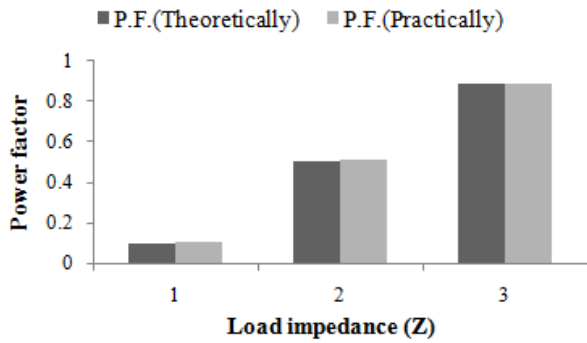


Fig. 5 Theoretical and practical calculated value of power factor for different combinations of impedance (R, C)

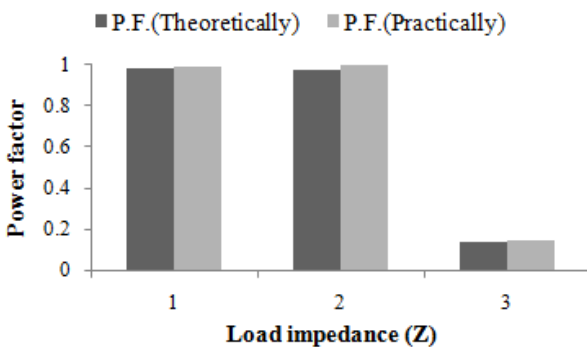


Fig. 6 Theoretical and practical calculated value of power factor for different combinations of impedance (varying inductor and capacitor with constant resistor 124Ω)

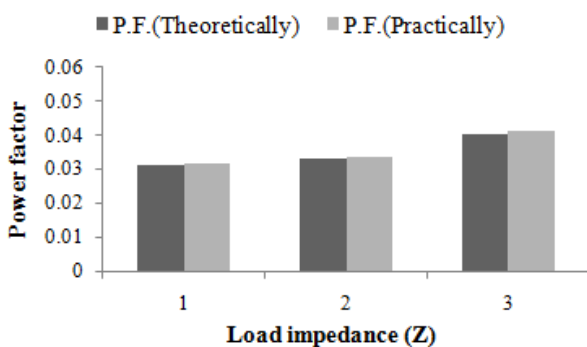


Fig. 7 Theoretical and practical calculated value of power factor for different combinations of impedance (varying inductor with constant resistor 36Ω and capacitor 2.5μF)

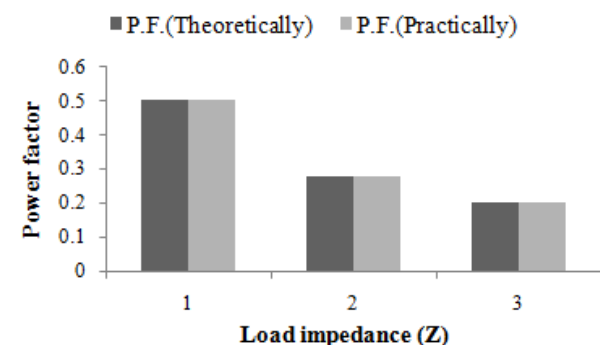


Fig. 8 Theoretical and practical calculated value of power factor for different combinations of impedance (varying inductor with constant resistor 36Ω and capacitor 15μF)

IV. CONCLUSION

In this paper present the comparative study and analyzed the power factor variation due to loading effect. Calculations of the power factor were carried out using digital signal processing algorithms. Different combinations of loads (RC and RLC) were investigated for affecting the performance of the system. The maximum value of theoretical power factor is 0.986 and the maximum value of practical power factor is 0.997. The minimum value of theoretical power factor is 0.0310 and the minimum value of practical power factor is 0.0317. The estimation of the power factor was taken by recording the voltage and current waveforms at 16,000sa/s at 16-bit quantization and processing using digital signal processing algorithms.

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BIOGRAPHIES



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