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An electronic meter for measuring the saving in electrical power

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Abstract

In electrical installation and building services engineering the power factor is a major consideration in efficient building or system operation. It is the measure of how effectively your equipment is converting electric current from power generation network to useful power output. Your industry can save money and gain other benefits when your power factor is high enough to avoid power factor surcharges on your electricity bills. For this purpose, this work presents an electronic circuit for the measurement of electrical energy. The design is based on a sample and hold method, which generates two DC signals. The first signal is proportional to the peak value of the line voltage, V_m and the second signal is proportional to the instantaneous value of the line current at the instant of peak voltage, $V_{m.}$, i.e. $I_m \cos \Phi$, where Φ is the phase angle between the line voltage and line current signals. Multiplication of the two signals over a predetermined period of time will provide an output proportional to the electrical energy consumed by the load. A voltage to frequency converter, VFC, is used to digitize the electrical energy signal. This signal is then digitally displayed through suitable circuitry. Results are presented to show the effect of a changing power factor on the power available at a constant current and the annual cost savings that can be made.

Keywords: Electrical power measurement; Energy saving; Renewable energy

1. Introduction

Of particular attention to society is the efficient use of electrical energy. An electrical engineer is in a place to improve the efficiency of a system using electrical energy conservation. Power systems engineers generally use a capacitor or synchronous motor to generate a leading reactive power to cancel the lagging reactive power due to inductance [1]. This concept is very logical, for a capacitor or synchronous motor drawing negative Q in parallel with an inductive load reduces the Q which would

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otherwise have to be supplied by the system to the inductive load.

In other word, the capacitance supplies the Q required by the inductive load. This is the same as considering a capacitor as a device that delivers a lagging current rather than as a device which draws a leading current. Therefore, the power factor of the power system utilities can result to: $\cos \phi_R = \cos (\tan^{-1} Q_R/P_R)$ [1].

This formula can be implemented graphically to obtain the overall P, Q and phase angle ϕ for several loads in the power system network. For several loads in parallel the total P will be the sum of the average powers of the individual loads, which should be plotted along the horizontal axis for a graphical analysis.

Fig. 1 illustrates the power triangle composed of P1, Q1 and S1 for a lagging power factor $\cos \phi_1$ combined with the power triangle composed of P2, Q2 and S2, which is for a capacitive load with a power factor $\cos \phi_R$.

In this paper, the results of an investigation are presented in the design of a simple instrument for the measurement of electrical energy. This is not a new idea; in fact, considerable effort has been made in this field because of its special importance to remote monitoring. Thus, there are many designs based on different techniques [1–5,10].

These designs use microprocessors, linear or non-linear analog to digital converters, A/D and binary rate multiplication, etc., and some of them are available in the electronics market. However, all the designs, including the one presented in this work have their advantages and disadvantages.

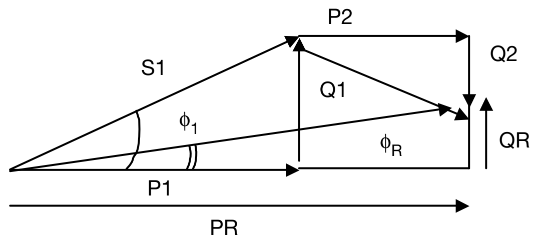

Fig. 1. Power triangle for combined loads.

The approach presented in this paper is based on sampling both the line voltage, V_L and the line current, I_L signals, holding them at the instant of peak voltage V_m, thus two DC levels proportional to V_m and $I_m \cos \Phi$ are provided [6–9].

The product of these signals, when averaged over time, will yield a DC. level proportional to the electrical energy consumed by the load. This signal is then digitized and displayed accordingly.

2. Principal of operation

Consider a normal three-wire system, where the line voltage, V_L and line current, I_L signals under steady state conditions are sinusoidal, as shown in Fig. 2.

The instantaneous voltage *V(t)* and current *I(t)* are given as:

$$V(t) = V_m \sin(\omega t) \quad (1)$$

$$I(t) = I_m \sin(\omega t + \phi) \quad (2)$$

where V_m is the peak value of line voltage, I_m is the peak value of line current, and ϕ is the phase angle between the line voltage and line current.

From Fig. 2: at $\omega t = \pi/2$, then

$$V(t) = V_m \quad (3)$$

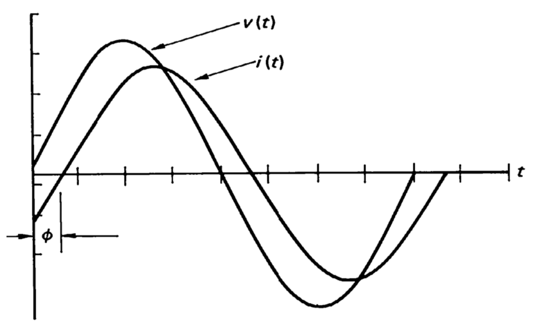

Fig. 2. Voltage and current signals.