

A COMPARISON OF PERFORMANCES OF ELECTRONIC AND ELECTROMECHANICAL ENERGY METERS

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ABSTRACT

The Ferraris (electromechanical) energy meter has had predominance in the metering of energy consumption using the alternating current supply system. Electronic energy meters are gaining popularity because of the possibility of remote reading and controllable non uniform rate of billing. In this work, an electronic energy meter which does not use a multiplier circuit but uses a voltage to frequency converter with frequency to voltage converter in the feedback loop was designed and built. The performances of this electronic meter were compared with those of the Ferraris meter. It is shown that at light loads, the errors of the electromechanical meter are greater than those of the electronic meter.

KEYWORDS: *Electronic, Energy, Meter, Calibration*

1.0 INTRODUCTION

The metering of the consumption of electric energy in modern power systems generally uses the Ferraris type induction meter. This electromechanical energy meter is preferable over others because it has a higher torque/weight ratio as well as the fact it operates without a commutator which causes friction errors [6]. In general electromechanical energy meters are costly and are also subject to friction errors.

The consequence of friction errors is that a definite starting current is needed to effect the movement of the moving parts of the electromechanical meters. Currents below this value will therefore make it impossible to obtain any registrations with the meter. It becomes important to devise an electronic means of registering energy which would overcome these shortcomings and yet be as reliable as the electromechanical energy meter.

In this work the analogue circuit of an electronic energy meter was designed and built. A comprehensive analysis of the theoretical relationships between the energy

consumed and the indications of the electromechanical and the electronic meters was performed. A digital display was built and incorporated into the meter. While some modern electronic meters tend to use microprocessors and microcontrollers to provide many functionalities such as non uniform rate of billing, reactive power and power factor measurements [7],[8],[9],[10] the present work has concentrated on the construction of a simple meter that provides adequate functions needed to bill consumers.

2.0 ELECTRONIC ENERGY METER REALIZATION

Regardless of type, the computation that is required to be performed by the energy meter is given by

$$E = \int_0^1 V(t)i(t)dt \quad (1)$$

In equation (1) E is the energy while V (t) and i(t) are the instantaneous values of voltage and current respectively. It is thus seen that the voltage and current have to be multiplied and then integrated to obtain the energy. The general scheme used for realizing the electronic energy meter is indicated in figure 1.

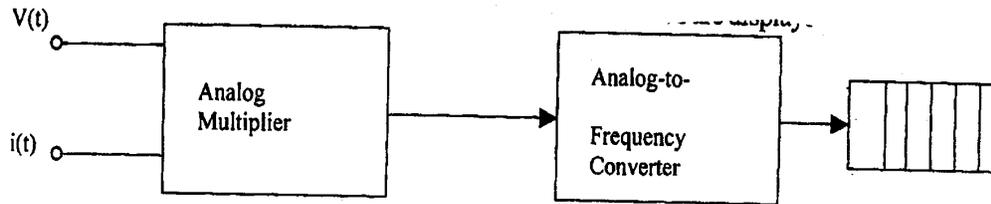


Fig. 1: Scheme for Electronic Energy meter Realization.

Several methods used to realize the general scheme of figure 1 have been reported [1], [2], [3], [4]. The method used in this work eliminates the need for expensive analog multipliers in integrated circuit form. The schematic diagram of the circuit used is given in figure 2 [1].

3.0 SPECIFICATIONS

A circuit following the method described in [1] was designed and built. The following parameters give the specifications for the Circuit.

- i. Rated voltage 230V
- ii. Rated nominal current 1 A
- iii. Rated maximum current 5A
- iv. Rated frequency 50Hz
- v. Rated output frequency 0.17Hz/kW

The first specification gives the mains voltage. For the second and third specifications, it is assumed that a current transformer having a maximum secondary current of 5A will be used. In the last specification, it is noted that an electromechanical energy meter having a speed of 600rev/kWh is to be used for this comparison. This speed translates to 0.17Hz/kW.

4.0 MEASUREMENT AND CALIBRATIONS

The circuit of the electronic meter was built on a prototype board. Its output frequency was measured and adjustments were made so that it corresponded to the desired value specified in the design. The frequency was measured by measuring the time T and T_M under various voltage and current

conditions. The period of the output wave form is then $T = T + T_M$ from which the frequency is calculated. The results of the measurements are displayed in table 1.

4.1 CALIBRATION OF THE ELECTRONIC METER

A display unit using a divide-by-600 counter, decoder, and light emitting diode (LED) display was built and interfaced to the main meter circuit. An electromechanical or Ferraris-type meter was obtained from the office of the National electric Power Authority and this was supplied at the same voltages and currents as the electronic meter. The electromechanical meter obtained is a single-phase 2-wire type having the following ratings:

Nominal voltage 230V
 Current rating 5-25A
 Frequency 50Hz
 Meter constant 600rev/kWh
 Accuracy class 2.0

This meter was deliberately chosen since it has the same constant (600rev/kWh) as the electronic meter that has been designed. The number of complete revolutions of this meter would ideally be the same as the number of counts displayed on the electronic meter. It was desired to compare the registrations of the two meters under the following conditions:

- i. Light and heavy loads at unity power factor.
- ii. Variation of current from 10 to 200% of nominal value

- iii. Variation of voltage between 10% of nominal value
- iv. Test for creep at 250volts
- v. Determination of starting current for the meters.

It is desirable to compare the actual readings of the two meters with the ideal or true readings expected so that the errors of the meters could be evaluated. The true readings of the meters can be calculated by reasoning as follows. Let us suppose that the load voltage is V volts and that the load current is I amperes.

The power expended in the load is $P = V.I = y$ (kW)(2)

If the power is expended in t seconds or $\frac{1}{3600}$ hour, then the number of kilowatt-hours is given by $kWh(m) = \frac{yt}{3600}$ (3)

Equation (3) gives the true reading of the electromechanical meter.

The electronic meter is designed to have a frequency of 600rev/kWh or 1/6Hz/kW. This means that for every kilowatt, a pulse (or

count) occurs in every 6 seconds or alternatively put, for every kW in 6 seconds a count occurs.

∴ for every kW in t seconds, $\frac{t}{6}$ counts occur or for every y kW in t seconds, $\frac{yt}{6}$ counts occur.

The true reading of the electronic meter is then given as

$$\text{Reading (E)} = \frac{yt}{6} \dots\dots\dots (4)$$

This analysis shows that the registration of the electronic meter is 600 times as fast as the registration of the Ferraris meter. In order to make the registration of the electronic meter to be in kilowatt-hours, it is necessary to pass the output from the electronic circuit through a divide-by-600 counter [5] before the pulses are counted and displayed.

The two meters were connected to the same supply and load as shown in the set up of fig.3. The current transformer (CT) used in this measurement.

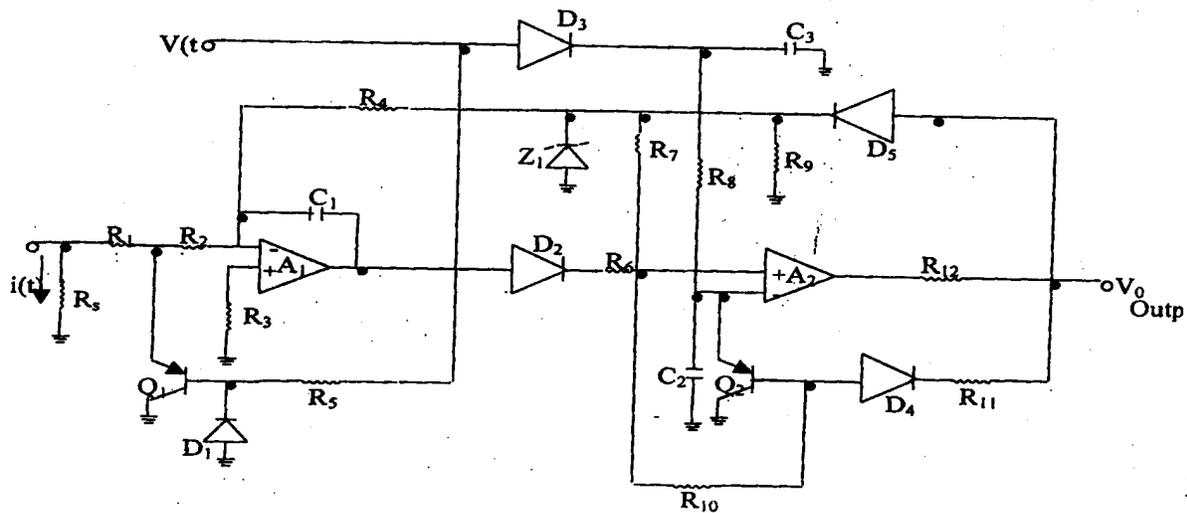


Fig. 2: Schematic diagram of the Electronic energy.

Circuit is rated at 5VA. Thus its secondary is terminated in a burden (R_s) equal to 0.2Ω [6]

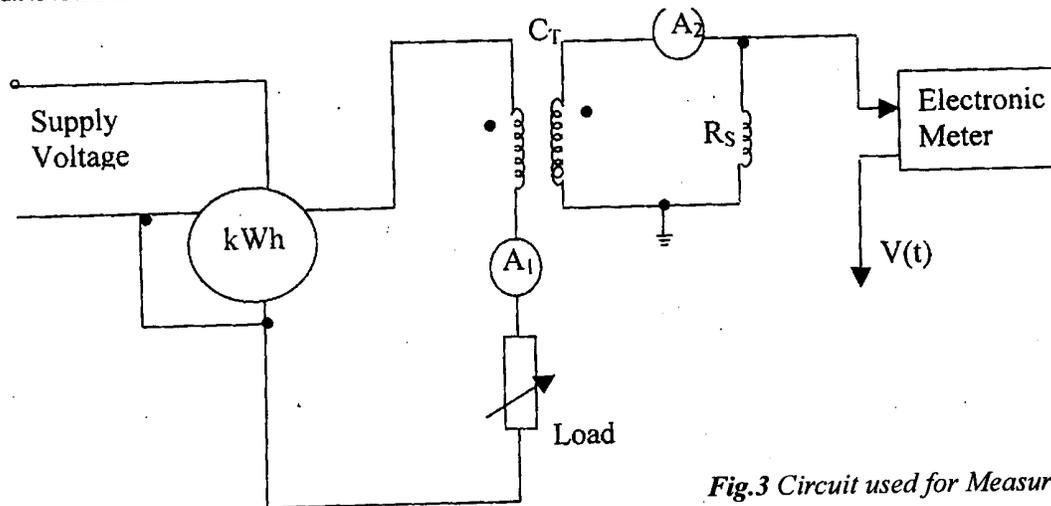


Fig.3 Circuit used for Measurements

4.2 MEASUREMENT ESULTS

The actual readings of the Ferraris and the Electronic energy meters were obtained at different voltages and load currents. The errors of the meters were computed by comparing the true readings of the meters given in equations (3) and (4) with their respective actual readings. A single measurement period was made long enough so that at least 40 displays of the LED are counted. At the same time, the number of complete revolutions of the disc of the Ferraris meter is also counted. Figures 47 give graphs which relate the percentage errors of the Ferraris and the electronic meters.

5.0 CONCLUSIONS

The test for creep was carried out at 250 volts with zero loads current and no registration was noticed in both the Ferraris and the electronic meter. It will be seen from the tables that the electronic meter has a very high accuracy even at very light loads when the errors of the electromechanical meter become intolerable. The graphs show that the errors of the electronic meter are comparatively much lower than those of the Ferraris meter. It was also found that at a load current of 0.2A where the disc of the Ferraris meter no longer revolved, the electronic meter still gave registrations. This means that the electronic meter has a smaller starting current.

Table 1: Measurement for the output frequency of the Electronic Meter

V (V)	I(A)	T_1 (s)	T_M (s)	$T=T_1+T_M$ (s)	$f = \frac{1}{T} (H_z)$	f/kW(Hz/kW)
200	1.0	28	3.3	31.3	0.032	0.16
220	1.5	16	3.0	19	0.053	0.16
230	2.0	11	2.9	13.9	0.072	0.16
240	0.5	49	2.7	51.7	0.019	0.16
240	2.5	8	2.7	10.7	0.093	0.166

R_8 is adjusted to be approximately $137k\Omega$

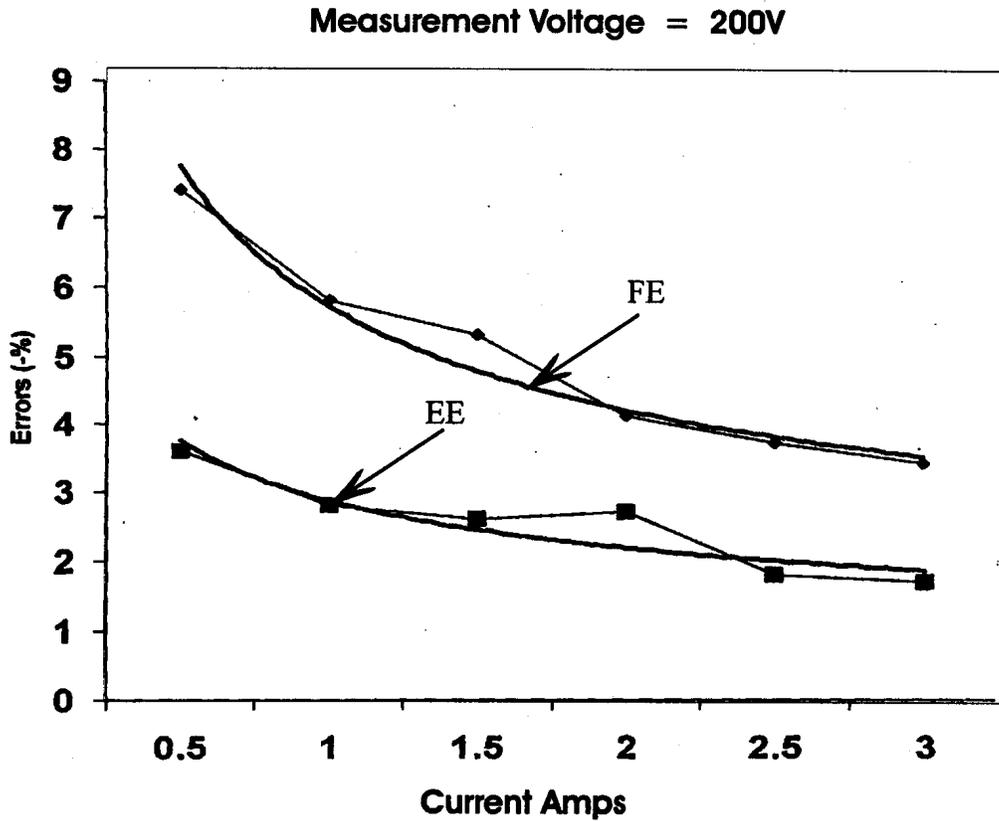


Fig. 4: Errors of the Ferraris and the Electronic Meters.

Note: In the graphs FE denotes the error of the Ferraris meter while EE denotes the error of the Electronic energy meter.

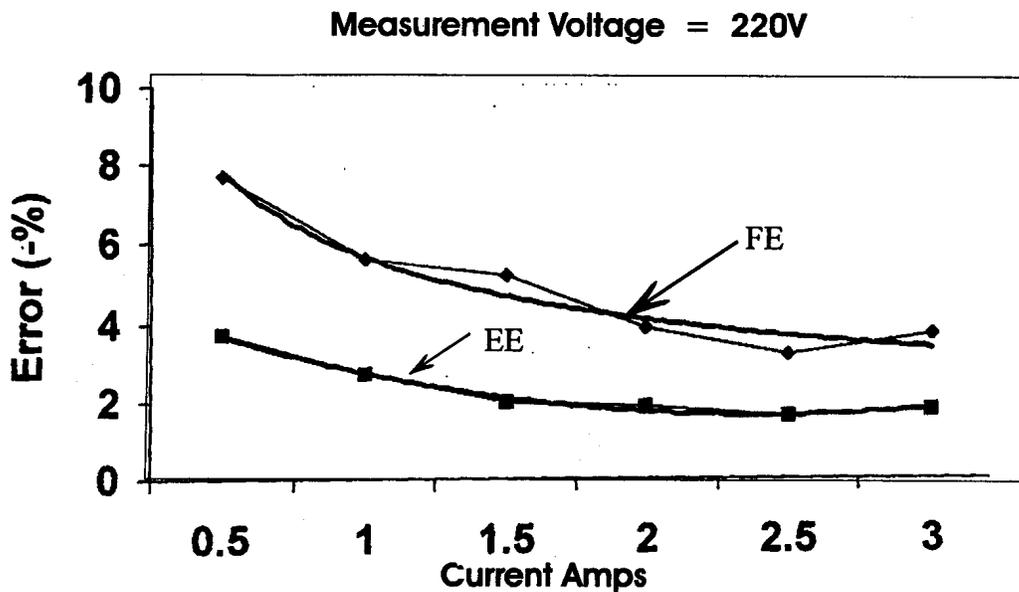


Fig. 5: Errors of the Ferraris and the Electronic Meters.

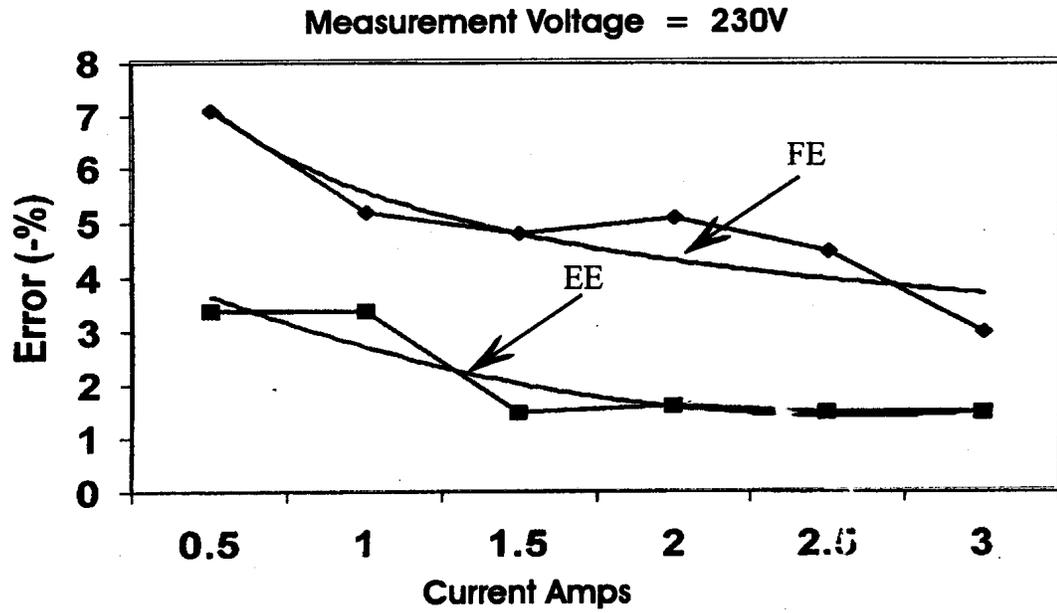


Fig. 6: Errors of the Ferraris and the Electronic Meters.

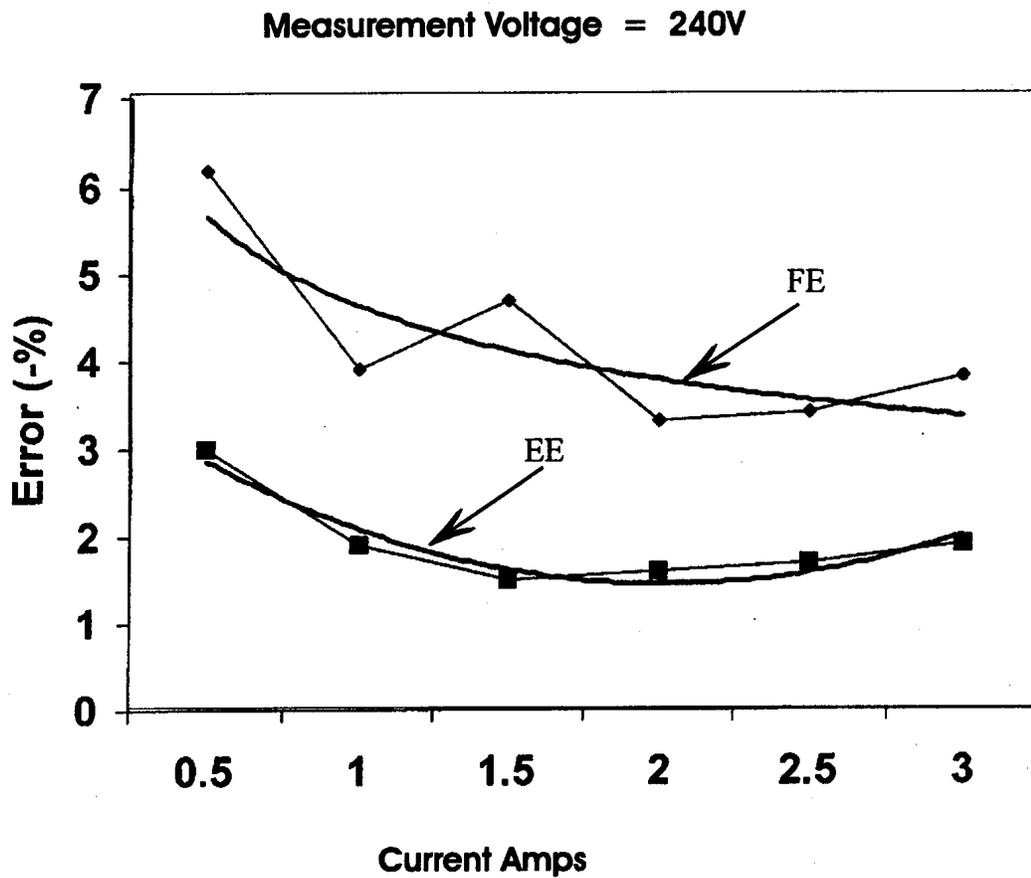


Fig. 7: Errors of the Ferraris and the Electronic Meters.

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