DESIGN AND IMPLEMENTATION OF A NEW ELECTRONIC METER FOR MEASURING THE FREQUENCY OF POWER SYSTEM NETWORK

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Abstract

In this paper different electronic frequency meters are reviewed and a new method for measuring the 50Hz frequency is adopted. The main feature of this meter is that it is based on analogue manipulations. The meter reading is displayed on a moving coil instrument with a scale of (47.5 Hz to 52.5 Hz). The meter is designed such that it is directly connected to the low-tension line-to-line voltage (380V). It is not affected by line voltage fluctuations and it's reading is qualified with high resolutions.

Introduction

Along the history of measuring instruments, many frequency meters were manufactured and used, like the electromagnetic type, which is based on electromagnetic action. This meter is directly connected to the line or phase voltages. It is the least accurate one.

Another version of frequency meters is a meter based on gated up down counter and is supplied with digital display (2, 3). Its accuracy is mainly dependent on a square wave local oscillator installed in the meter circuitry and on the zero crossing points of line voltage waveform with the horizontal axis. Hence its accuracy is affected by harmonic distortion in the line voltage waveform.

The technique of frequency to voltage conversion (3,4) is also used for manufacturing frequency meters. Where the frequency of the line voltage is converted to a DC voltage and this DC voltage is then converted to digital output. The accuracy of this meter is obviously affected by harmonic component in power system network.

Our proposed meter is somewhat different in its principle of design and operation. It is mainly dependent on analogue computation process, which will be discussed in details in the next section.

The new meter concept

The schematic circuit diagram shown in figure (1) indicates the principle of operation of the adopted meter. The line-to-line voltage is fed to the step-down transformer. This voltage is a sinusoidal voltage in the form:

$$v_L = V_m \operatorname{Sin} \omega t$$

where,

v_L = the instantaneous line voltage in volts.

V_m = the line voltage amplitude in volts.

ω = the power system network angular frequency in radian/second.

t = time in second.

The output of the step-down transformer is K_1K_2 , where K_1 is the constant of the step-down transformer and K_2 the constant of its circuitry. The AC voltage $K_1K_2v_L$ represents the input of the first sample and hold circuit which samples at $\omega t=\pi/2$.

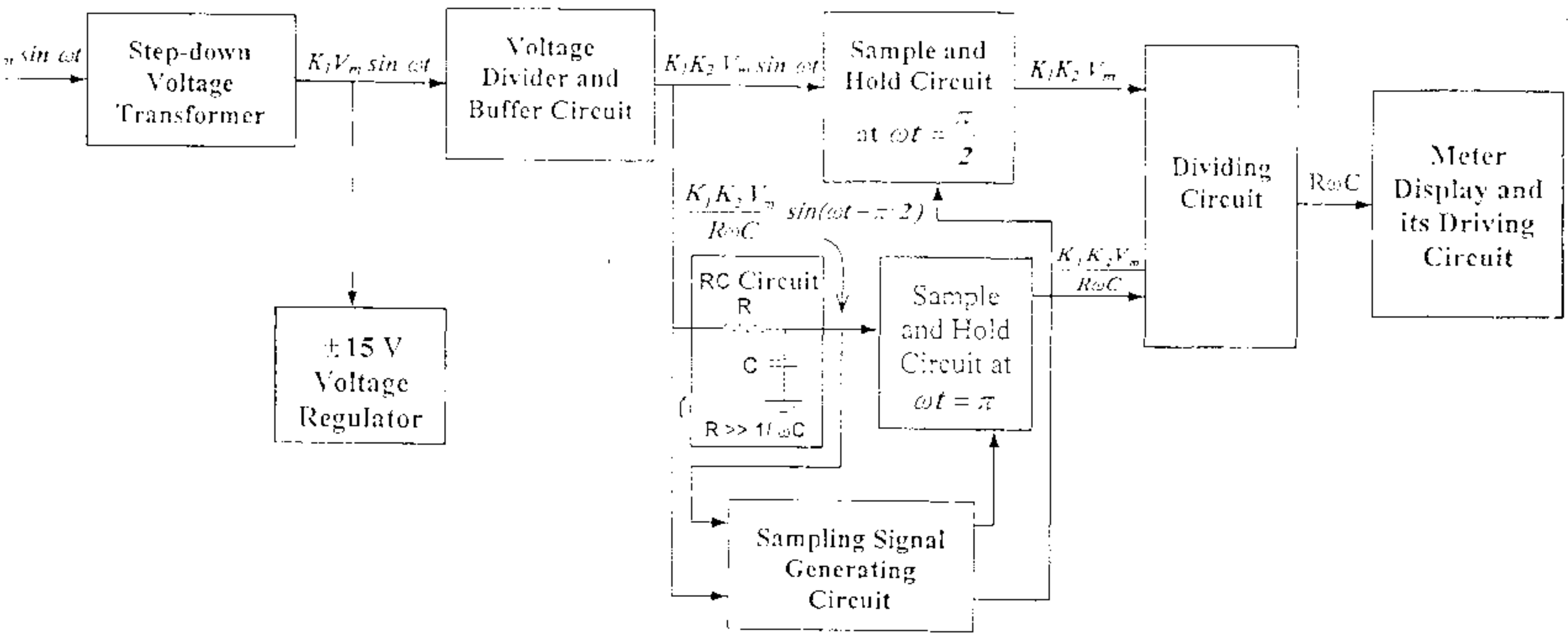
Hence the Output of this circuit is $K_1K_2V_m=V_1$ which is a pure DC voltage. Also the AC voltage $K_1K_2v_1$ is fed to the RC circuit which its parameters are chosen such that the resistance R is very much greater than the reactance ($1/\omega C$) of the capacitor C, i.e. $R>>1/\omega C$. Hence the output of the circuit is closely approximated to $\frac{K_1K_2V_m}{R\omega C}\sin(\omega t-\pi/2)$, which represents an AC voltage lagging the line voltage waveform by ($\pi/2$). The output of the RC circuit is fed to the second sample and hold circuit which is sampled at $\omega t=\pi$. Hence the output of this circuit is $\frac{K_1K_2V_m}{R\omega C}=V_2$, which is also a pure DC voltage.

V_1 and V_2 are the input of the dividing circuit, which in turn divides V_1 by V_2 and its output, is a DC voltage equal to RωC. It is clear that the DC voltage RωC is proportional to the frequency of power system network. This DC voltage is displayed in recalibrated 10VDC voltmeter to permit a reading from 47.5 Hz to 52.5 Hz.

The meter Circuitry Design

Figure (2) shows the detailed circuit of the proposed frequency meter. The step-down transformation turn ratio $\frac{N_2}{N_1}=0.04$. Hence its output is $0.04\ V_m \sin\omega t$. This voltage is attenuated to ($0.0128V_m \sin\omega t$) and then buffered by the 741 operational amplifier. The output of the buffer stage is sampled at the first sample and hold circuit at $\omega t=\frac{\pi}{2}$. The output of this circuit is $0.0128\ V_m$ which is a DC voltage representing the first input to the dividing circuit. Also the AC voltage ($0.0128\ V_m \sin\omega t$) is fed to the RC circuit and then sample at $\omega t=\pi$ by the second sample and hold circuit. The output of the second sample and hold circuit is a DC voltage equal to $\frac{0.0128V_m}{R\omega C}$ and representing the second input of the dividing circuit. The output of the dividing circuit is RωC which is a DC voltage proportional to the line voltage frequency f. For $R=300\ K\Omega$, $C=0.101\mu F$, and $\omega=2\pi f$, the DC voltage $R\omega C=0.19f$; if $f=50Hz$, then $R\omega C=9.52V$, when $f=52.5Hz$ $R\omega C=10V$, and when $f=47.5Hz$, $R\omega C=9.12\ V$.

A 10VDC voltmeter is used for indicating the frequency readings after its preconnection to a simple summing circuit. The zero reading of the DC voltmeter represents the 47.5Hz ,the 5V reading of the DC voltmeter represents the 50Hz and the 10V represents the 52.5Hz reading of frequency meter. The output of the summing circuit is $V_3= 9.12- 0.19f$. It is clear that when $f=47.5Hz$, $V_3=0V$ and this equation is valid for any frequency in the range (47.5Hz to 52.5Hz).



v_L = line to line voltage or line voltage.
$\omega = 2\pi f$
f = the frequency of the power system network
V_m = amplitude of line voltage
K_1 = constant of the step down transformer
K_2 = constant of the voltage divider

Figure (1) The proposed analogue frequency meter block diagram.

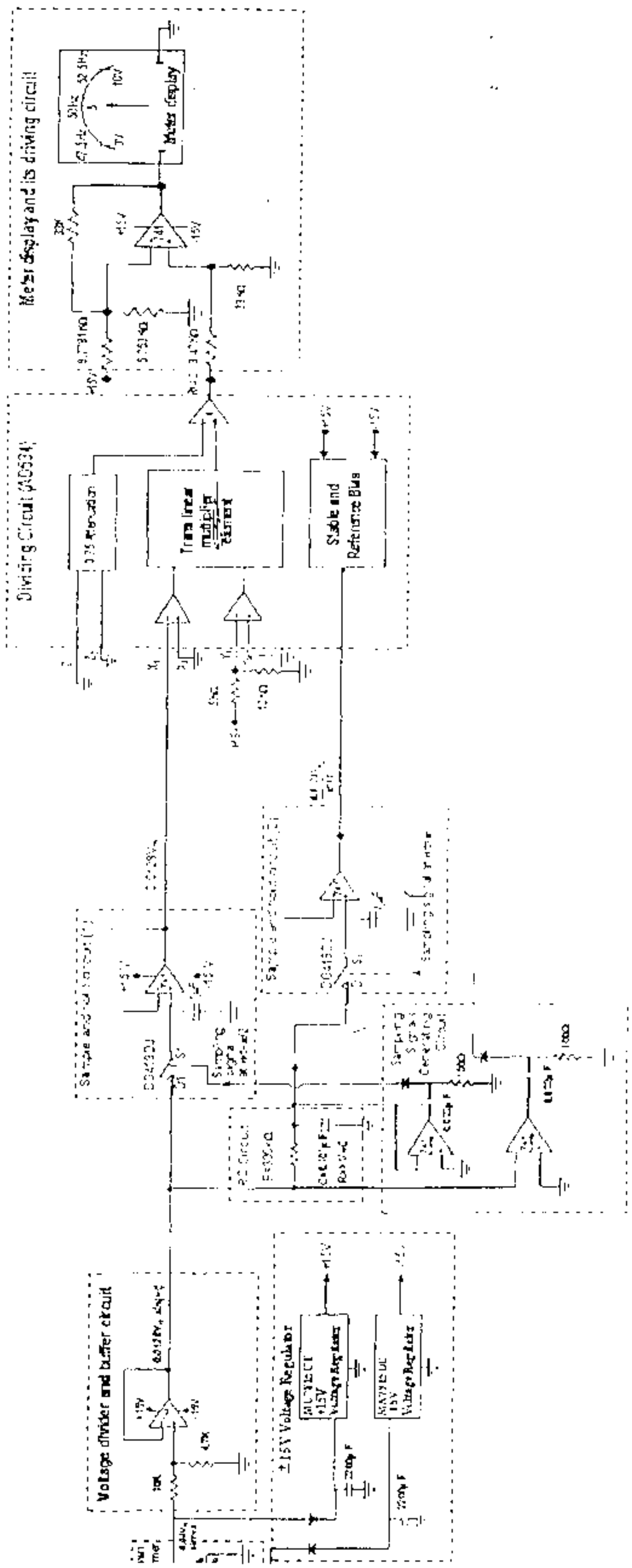


Figure (2) The Complete Meter Actual Circuit Diagram

Conclusion

The above meter is less sensitive to harmonic components in the power system network, since it is mainly dependent on the amplitude of the power system voltage and not on it's zero crossing points with the horizontal axis. The meter is somewhat cheap and its components are commercially available. The meter is directly connected to the line voltage, permitting wide range voltage fluctuations for line voltage amplitude. Since the line voltage amplitude is at last cancelled in the computation circuit output.

References

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تصميم وتنفيذ مقياس جديد لقياس تردد شبكة منظومة القدرة الكهربائية ذات التردد 50 Hz

الخلاصة

في هذا البحث تم استذكار ومناقشة انواع مختلفة من اجهزة مقياس التردد وكذلك تم تبني طريقة جديدة لقياس تردد منظومة القدرة الكهربائية ذات التردد 50Hz. أهم ميزة في هذا الجهاز الجديد هي اعتماده المباشر على الحسابات التماثلية الالكترونية. الجهاز مزود بأداة مقياس مغناطيسية ذات مؤشر يقرأ بين 47.5Hz و 55.5Hz. وايضاً الجهاز مصمم للربط المباشر على منظومة القدرة الكهربائية (380v). جهاز القياس هذا لايتأثر بتغيرات الجهد الكهربائي ويمتاز بقراءات ذات دقة عالية.