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DESIGN OF A SIMPLE MEASURING TECHNIQUE OF THE INSTANTANEOUS POWER IN THREE PHASE SYSTEM

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This paper describes an electronic means of measuring the instantaneous active and reactive power absorbed by any electrical equipment. The measurements are based on the Clark (α-β) and Park (d-q) transformations. The system is useful to teach electrical machines in Park's coordinates and it allows also the study and control of some power electronics converters that are connected to three phase power network, such as static VAR compensator. The principle of the measuring method of the active and reactive power is described and analysed for different tests. The effectiveness of the proposed measuring method is confirmed by experimental investigation employing a test system.

K e y w o r d s: Reactive power, active power, instantaneous power, SVC, power converter

1 INTRODUCTION

Up to now, the reactive power does not really have a physical significance, but it remains recognized as an essential factor in the conception and efficient operating of AC electric networks [1]. The application of Clark (α-β) and Park (d-q) transforms to a three phase system in order to calculate the instantaneous active and reactive powers is a useful tool for study and analysis of many electrical systems [2]. There are many industrial applications that require the knowledge of the instantaneous value of the active and reactive powers. In fact, they are used to manage the economic aspect of their system [1], [3], [4].

The instantaneous active and reactive powers are also used in the control of converters connected to the electric network [5]. These converters can control the flow of active and reactive powers in the power system to improve voltage regulation and increase the transient stability margin [4], [5].

In this paper, an inexpensive electronic circuit that calculates Clark (α- β), Park (d-q) components and the instantaneous active and reactive powers for three phase AC systems is presented and discussed thoroughly.

The effectiveness of the proposed electronic method that calculates the instantaneous active and reactive currents and powers is confirmed by experimental results through a laboratory prototype.

2 THEORY

2.1 α-β transformation

Voltages and currents can be transformed from *abc* system to α-β coordinates as follows:

$$\begin{bmatrix} X_\alpha \\ X_\beta \\ X_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} X_a \\ X_b \\ X_c \end{bmatrix}. \qquad (1)$$

Where X denotes voltages or currents.

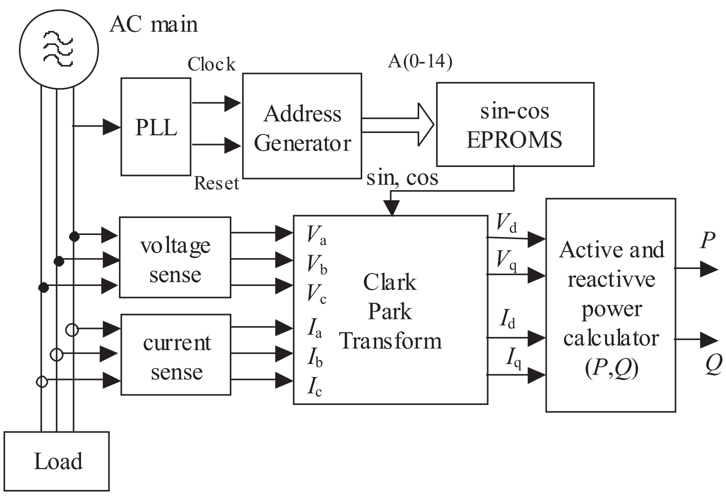

Fig. 1. Proposed measuring system.

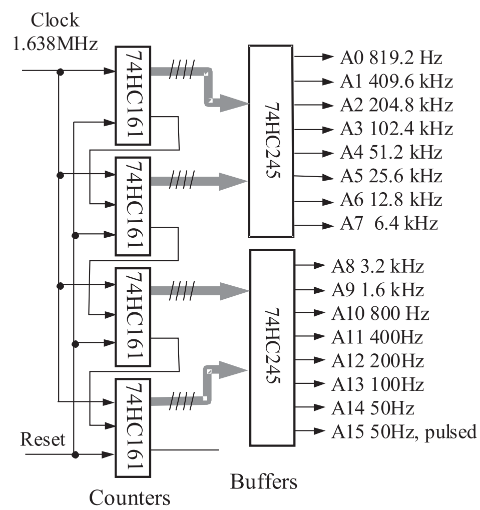

Fig. 2. Address generator.

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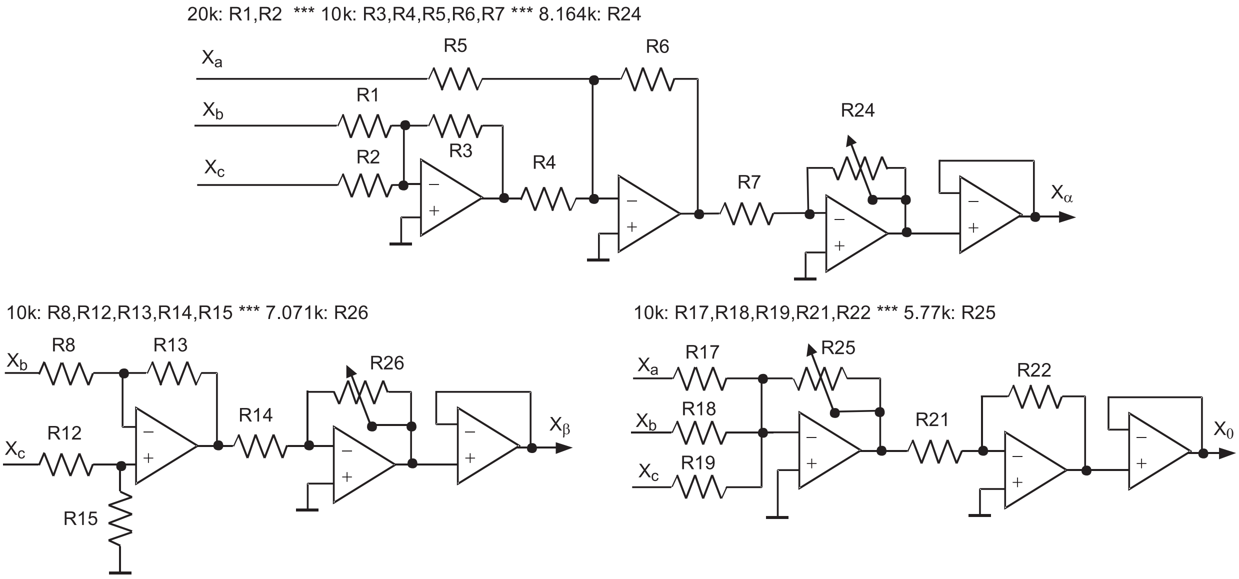

Fig. 3. Clark transform circuit.

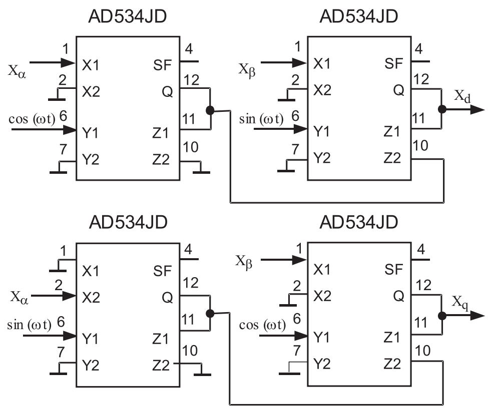

Fig. 4. Park transform circuit

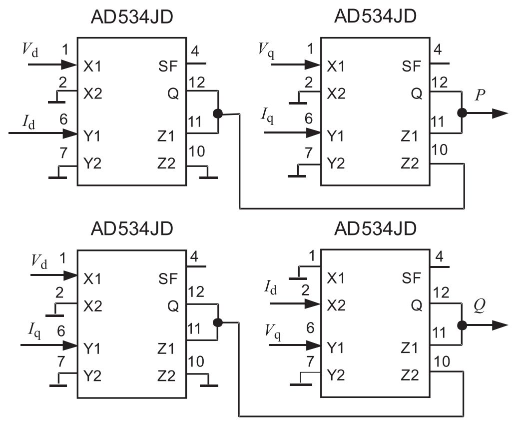

Fig. 5. Instantaneous active and reactive power calculator

2.2 d-q transformation

From α-β Transformation the d-q coordinates are given by:

$$\begin{bmatrix} X_d \\ X_q \\ X_0 \end{bmatrix} = \begin{bmatrix} \cos\omega t & \sin\omega t & 0 \\ -\sin\omega t & \cos\omega t & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_\alpha \\ X_\beta \\ X_0 \end{bmatrix}. \tag{2}$$

2.3 Active and reactive power

The active and reactive powers for the three phase balanced system can be written in d-q coordinates as follows:

$$\begin{aligned} P &= V_d I_d + V_q I_q\,, \\ Q &= V_d I_q - V_q I_d \end{aligned} \tag{3}$$

where V_d, V_q, I_d and I_q are the voltages and currents in d-q coordinates.

3 PROPOSED MEASURING SYSTEM

3.1 General description

The block diagram of the proposed measuring system is presented in Fig. 1.

The whole system is divided in three subsystems connected in cascade.

The function of subsystem 1 is to synchronize all of the system to the AC mains using PLL and to generate the adequate addresses to generate sine and cosine functions which are stored in two EPROMS.

In subsystem 2, the measured voltages and currents are transformed from *abc* to Clark and Park coordinates.

In the third subsystem the instantaneous active and reactive powers are calculated.

3.2 Detailed description of the proposed system

Subsystem 1 is a frequency synthesizer. The clock frequency is $16 \times 16 \times 16 \times 8 \times 50\,\text{Hz} = 1638$ MHz synchronized to the AC mains supply. This clock frequency is

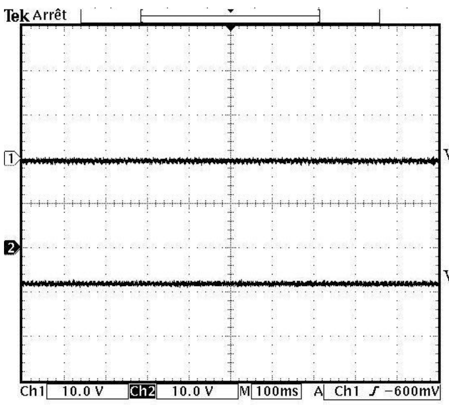

Fig. 6. Direct and quadrature voltages of the AC mains.

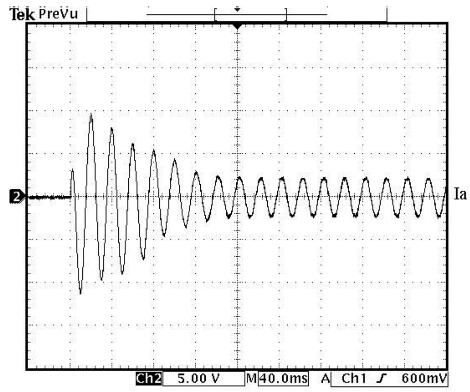

Fig. 7. AC current of induction motor in transient starting.

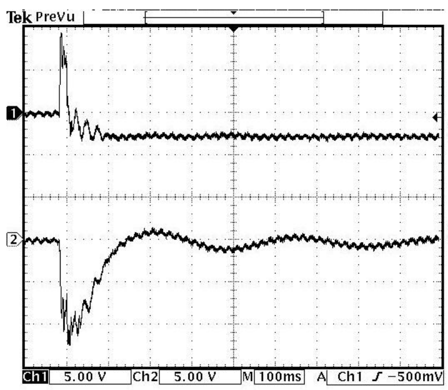

Fig. 8. Direct and quadrature currents of induction motor in transient starting.

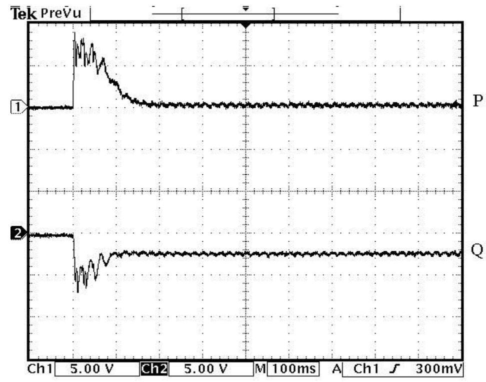

Fig. 9. Active and reactive power absorbed by induction motor in transient starting.

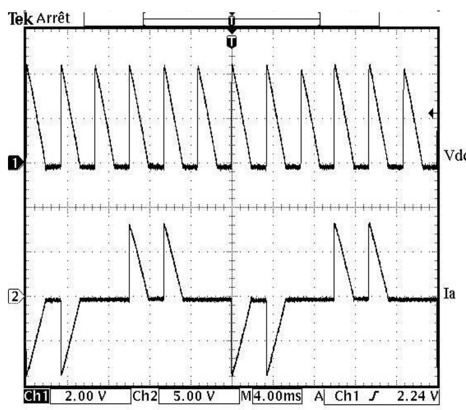

Fig. 10. Output DC voltage and input current of three phase symmetric rectifier with $\alpha = 80^\circ$.

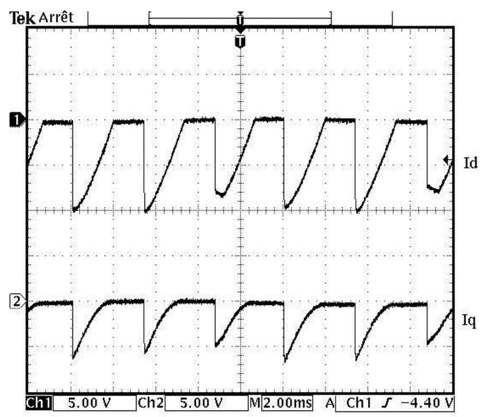

Fig. 11. Direct and quadrature currents of the three phase symmetric rectifier with $\alpha = 80^\circ$.

used to drive the address generator. The address generator is composed of four 74HC161 synchronous presetstable binary counters and two 74HC245 buffers. The addresses obtained are suitable to read in parallel two EPROMs of $\left(2^{15}/1024\right) = 32\,Koctets$, where sine and cosine functions are stored. Hence the obtained address generator is shown in Fig. 2.

Subsystem 2. The measured voltages and currents in *abc* frame are transformed into Clark and Park coordinates. The Clark transform given by equation (1) is obtained using simple operational amplifiers as shown in Fig. 3.

Park coordinates are obtained from Clark coordinates by using equation (2). The sine and cosine functions generated by the address generator and synchronized to the AC mains supply are used to obtain the Park coordinates by using the analog multiplier AD534JD as shown in Fig. 4.

Subsystem 3. The instantaneous active and reactive power calculator is also obtained using the analog multiplier AD534JD as shown in Fig. 5

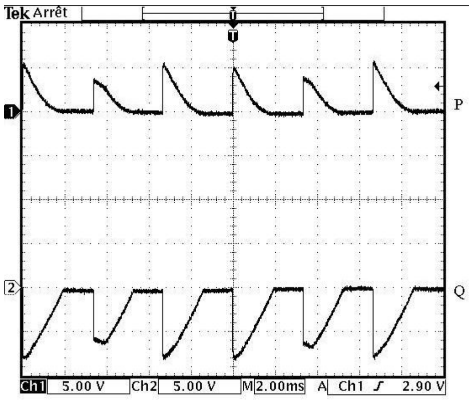

Fig. 12. Active and reactive power of three phase symmetric rectifier with $\alpha = 80°$.

4 EXPERIMENTAL RESULTS

To confirm the effectiveness of the proposed measuring method of the instantaneous active and reactive units, a prototype has been designed and some experiments were carried out employing a test system with various loads.

Figure 6 shows the direct and quadrature Park's voltages of the AC mains supply. A transient starting test of an induction motor was carried in the laboratory with the proposed system.

Figure 7 shows the AC current absorbed by the induction motor at transient starting.

Figure 8 shows the direct and quadrature currents of the induction motor starting.

The active and reactive powers absorbed by the induction motor in transient starting are depicted in Fig. 9.

The measurement system was tested with induction motor without load, it is clear that the active power absorbed by the motor is negligible but there is a little amount of reactive power necessary to create the three phase rotating magnetic field in the stator of the induction motor.

Another test was also carried out in the laboratory with the three phase symmetric thyristor rectifier.

Figure 10 shows the output DC voltage and input current of the rectifier for the phase angle control $\alpha =$ 80 degree.

Figure 11 shows the direct and quadrature currents absorbed by the three phase symmetric rectifier for the phase angle control $\alpha = 80°$, and the active and reactive power are depicted in Fig. 12.

5 CONCLUSION

In this paper, an electronic measurement method of the instantaneous active and reactive powers has been presented. The proposed measuring system has thoroughly been tested in steady and transient states. The measuring method can be used to study different electrical equipment in laboratory as induction and synchronous machines and some converters.

The steady state and transient measurement results obtained have confirmed the applicability of the proposed scheme to design a simple and fast controller for active and reactive power applications.

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