M.Tech. Credit seminar report, Electronic Systems Group, EE Dept,
IIT Bombay, submitted in November 2003.

Micro-controller Based Multi-phase Sequence Detection System.

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ABSTRACT

The report describes various methods for determining the phase sequence of a multi-phase system. The reference phase is chosen random from the multi-phase and is assigned the serial number 1. Then with the help of a general rule and a micro controller, the serial number of any other phase is determined. The discussion starts with the simple three-phase sequence detection and then proceeds towards multi-phase systems. To ensure that the multi-phase sequence detector operates properly, multi-phase supply is needed for its testing. Hence generation of multi-phase sequences becomes a supplementary task. The report also presents various techniques of multi-phase generation along with their merits and demerits. Some experimental results are discussed and conclusions are made related to various methods discussed in the report.

INTRODUCTION

Correct sequence identification of a balanced multi-phase system is quite necessary in scientific experiments. For instance when two 3-phase AC generators are to be synchronized their phase sequences should be matched correctly. The conventional method uses sequence indicator, which generally operates on Induction motor principle. Also when the three-phase induction motor is desired to run in a certain direction, proper phase sequence should be applied to it. Here, an unbalanced 3-phase load is used for the purpose of sequence detection, but with the number of phases increasing, the sequence combination increases for n phases system .The number of wrong sequence combinations is $\{(n-1)!-1\}$, Thus, for $n > 3$ as in case of six-phase or twelve-phase inverters, this method would no more work. The report describes a method, which uses micro controller and a simple the sequence indication method will be general rule to find the proper phase sequence of any balanced multi-phase system. In case of the unbalanced multi-phase system, relative positions of various phases with respect to reference can be determined by measuring the phase angle of each subsequent phase, the phase sequence then can be obtained by rearranging the phase angles in their ascending order. As discussed earlier, the multi-phase sequence detection system needs to be tested for its operation. Hence it is required to have a multi-phase generation unit.

Poly-phase square oscillators supply square wave voltages of an equal amplitude and a suitable phase angle between them. Many times, the oscillator is of variable frequency and its output stage is a switching mode one. Therefore they could perform as a controlled Poly-phase power supply with various applications in power electronics, such as dc-dc converters and electrical motor drivers. A poly phase square wave oscillator that employs only one integrator for any number of generated phases, which uses the multi-hysteresis block as a new circuit component.

A technique for the generation of an adjustable frequency, adjustable amplitude 5-phase reference sine wave is also presented which uses a novel multiplexing method for generation of multi-phase waveform in a common path and the individual waveforms are obtained by subsequent demultiplexing. The technique is quite flexible and can be used to generate periodic waveforms of any shape and for any number of phases. Performance of various techniques for multi-phase sequence detection and multi-phase generations are discussed in subsequent sections.

TECHNIQUES FOR PHASE SEQUENCE DETECTION

A single-phase alternator has only one armature winding. But if the number of windings is increased, then it becomes poly-phase alternator. And it produces as many independent voltage waves as the number of windings or phases [1]. These windings are displaced from one another by equal angles, the values of these angles being determined by the number of phases or windings. In fact, the word 'poly-phase' means poly (i.e. many or numerous) and phase (i.e. windings or circuit).

Phase rotation, or phase sequence, is the order in which the voltage waveforms of a poly-phase AC source reach their respective peaks. For a three-phase system, there are only two possible phase sequences: 1-2-3 and 1-3-2, corresponding to the two possible directions of rotation. Similarly for n phase system the possible number of sequence combinations are $(n-1)!$.

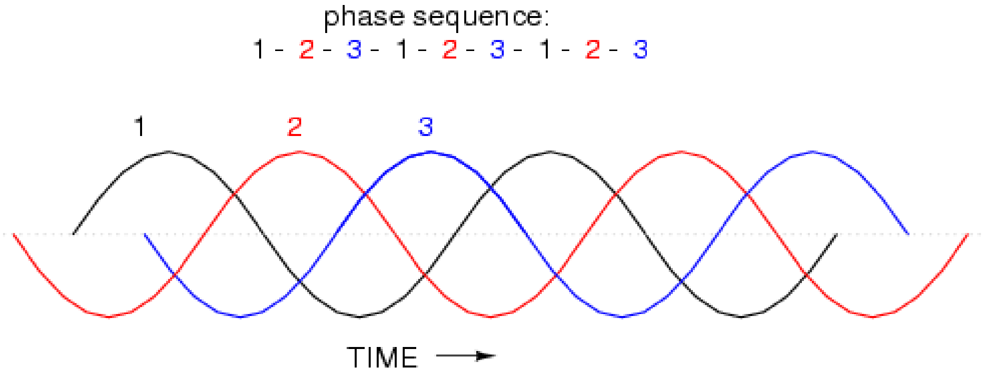


Fig. 1 Three-phase sine wave.

If a poly-phase voltage source is used to power resistive loads, phase rotation will make no difference at all, whether 1-2-3 or 3-2-1, the voltage and current magnitudes will be the same. There are some applications of three-phase power, as we will see shortly, that depend on having phase rotation being one way or the other. Since voltmeters and ammeters would be useless in telling us what the phase rotation of an operating power system is, we need to have some other kind of instrument capable of doing the job.

1) Phase sequence detection using unbalanced loads

When a star connected load is unbalanced and it has no neutral wire, then its star point is isolated from the star point of the generator. The potential of the load star point is different than that of the generator star point. The potential of the former is subjected to variations according to the imbalance of the load and under certain conditions of loading [1].

One ingenious circuit design (as shown in Fig. 2) uses a capacitor to introduce a phase shift between voltage and current, which is then used to detect the sequence by way of comparison between the brightness of two identical lamps.

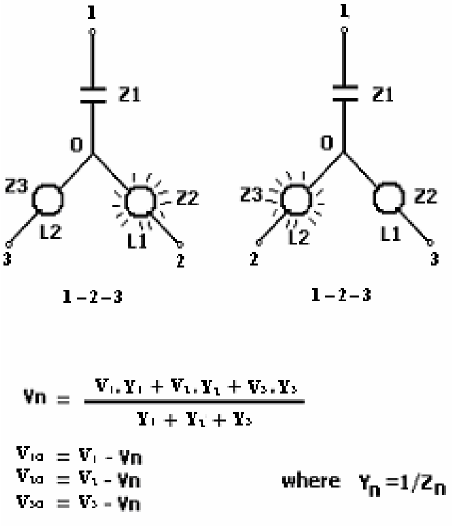


Fig. 2 Three-phase sequence identifier.

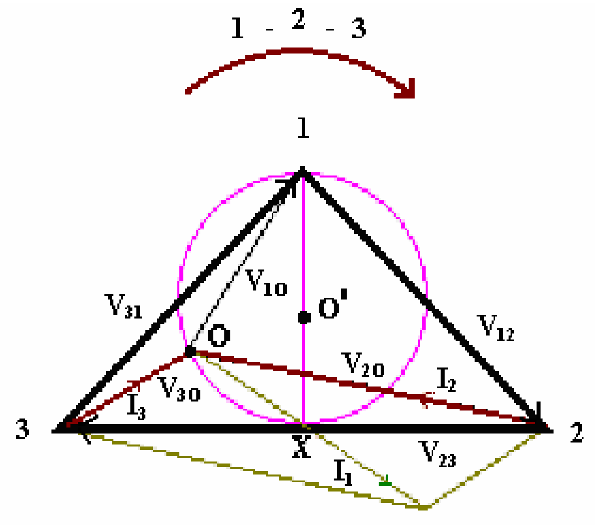


Fig. 3 Phasor diagram of three-phase unbalanced load.

The capacitor is sized to have approximately the same amount of reactance at system frequency as each lamp's resistance. If the capacitor were to be replaced by a resistor of equal value to the lamps' resistance, the two lamps would glow at equal brightness, the circuit being balanced [2]. However, the capacitor introduces a phase shift between voltage and current in the third leg of the circuit equal to 90°. This phase shift, greater than 0° but less than 120°, skews the voltage and current values across the two lamps according to their phase shifts relative to phase 1, which may be considered as reference phase.

Consider the Phasor shown in Fig. 3 ,it shows the condition when the phase sequence is 1–2-3, Here as the three-phase load is unbalanced and the neutral wire is absent, the reference point as seen by each load on star network is O rather than $O^{\prime}$ [3], which would have been the reference, when the load was balanced. In that case load voltages would have been identical, now as the load is unbalanced point O could lie anywhere on the circle depending on the unbalance and the phase sequence of the supply, here the voltage across capacitor i.e. V_{3O} is perpendicular to the current flowing through it i.e. I_1, note that $\angle 1OX = 90°$ where X is the mid point of V_{23}.

When the phase sequence is 1-2-3 then in that condition as shown in the Fig. 3, $V_{2O} > V_{3O}$ and lamp L1 will glow brighter because its phase voltage will be larger whereas L2 will be dimmer because of low voltage across it, and when phase sequence is 1-3-2, opposite conditions develop so that this time L2 glows brighter and now L1 will be dimmer., in this case point O will shift on the other side of the circle. This is a simple method of determining the phase sequence of three-phase supply, but as the number of phases increases the identification is not possible form this method.

2) Sequence detection using 3-phase induction motor

Another method of determining the phase sequences is by the means of a small 3-phase motor [1]. As we know that the direction of rotation of three-phase induction motor depends on the phase sequence of the phases applied, this concept can be applied for phase sequence detection of three phase supplies. Once the direction of rotation with a known sequence is found, the motor may be used thereafter for determining an unknown sequence.

3) Microprocessor based sequence identifier for balanced multi-phase systems

The following method [4] uses 8085 microprocessor and a simple general rule to find the proper phase sequence of any balanced multiphase system.

The principle

Let us consider that we are working with an n-phase balanced ac system. We choose any one phase at random as the reference and designate it to be phase number 1. Then we try to identify the sequential position of any other phase p, $(p\ \varepsilon\ \{2,3,\ldots,n\})$. It is only natural to utilize the zero-crossing property of the ac waveforms and we identify p based upon the time shift of its zero-crossing with respect to phase number 1. To find out a definite pattern of this time shift for a n-phase system, we consider the ac waveforms for n = 3,4,5,6 and these are shown in fig 4.

(i) We note that taking phase-1 as the reference, phase-2 and phase-3 have their zero crossing after time intervals t_2 and t_3 respectively point O. the reference point has been chosen in such fashion that the reference phase waveforms crosses zero in the positive direction (ie, from low to high) at that instant. As mentioned earlier, phase-2 or phase-3 could have been chosen as the reference phase as well.

(ii) Phase-2 waveforms crosses zero at time t_2 in a positive direction and phase-3 waveform crosses zero in a negative direction at time t_3.

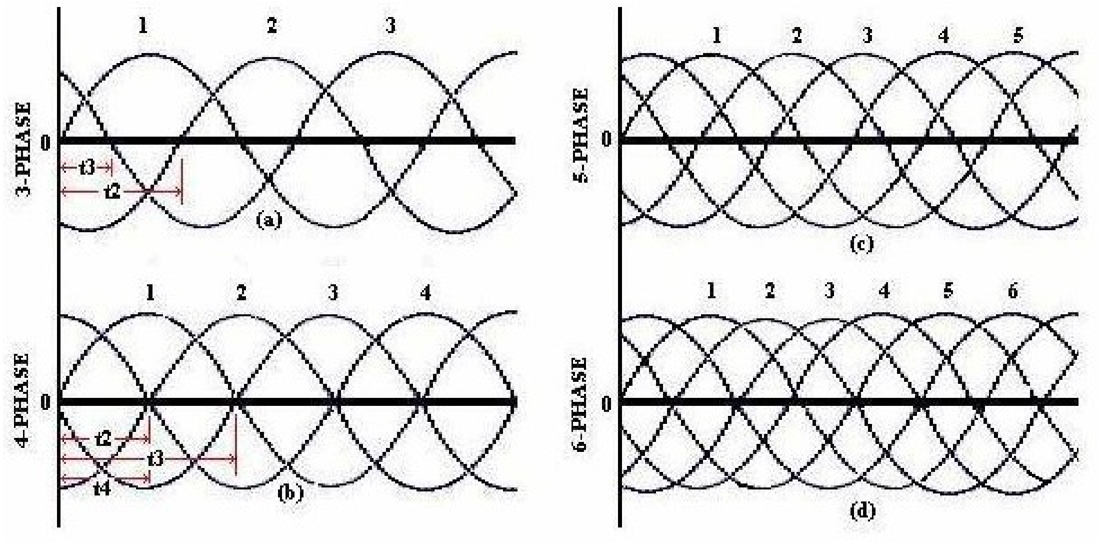


Fig. 4 waveforms for 3,4,5and 6 phase ac systems.

(iii) Phase-2 waveforms crosses zero at time t_2 in a positive direction and phase-3 waveform crosses zero in a negative direction at time t_3.

(iv) The magnitude of phase-2 waveform during the time interval t_2 is negative (low), while the magnitude of phase-3 waveform during interval t_3 is positive (high).

(v) t_2 and the time period T are integral multiples of t_3 ($\pi/3$).

(vi) The pattern described in points (i) to (iv) above is repeated in each cycle. For the 4-phase system, the features noted from fig 4b are:

(i) Designating the reference phase to be phase 1, phase-2 and phase-3 waveforms cross zero at time instants t_2 and t_3 respectively in the positive direction, while phase-4 has a zero crossing at time t_4 (= t_2) in the negative direction.

(ii) The magnitude of phase 2 waveform during the time interval t_2 is negative (low), the magnitude of phase-3 waveform during t_3 is negative (low) and the waveform of phase-4 has a positive (high) magnitude during the time t_4.

(iii) The time interval t_3 and the period T are integral multiple of t_2 or t_4 $(=2\pi/2)$.

(iv) The pattern described above is repeated in each cycle.

For the five phase and six phase systems shown in figure 4c and 4d, similar characteristics are noted. From the above observations, a general pattern emerges for a balanced n phase system and to identify phase p o such a system a following expression can be arrived at:

$p = 1 + n\,(tp/T) + \delta(n/2)$ ………….. (1)

Where, tp is the time instant of zero crossing of phase p (to be identified) Waveform measured from the reference point, T is the time period of the waveforms, δ is a logical operator, $\delta \, \varepsilon \, \{0,1\}$, which takes the value 0 when the magnitude of phase p waveform is negative (low) during the time tp and it assumes the value 1 otherwise Inspection of equation (1) confirms that the second and third terms should always add up to form an integer (p - 1). That is, of δ, the second term has to take up values accordingly, to satisfy the equation. Referring to figure 4 a close scrutiny of waveforms reveals that the time taken by phase p wave for its zero crossing is

$t_p = i\,(T/2n)$ ………. …………… (2)

Where, $i \, \varepsilon \, \{1,2,3,\ldots.\ n\text{-}1\}$ for odd n .And $i \, \varepsilon \, (2,4,6,8,\ldots.,\ n\ \}$ for even n. From equation 1 and 2, we have

$p = 1 + ½\,(\,i + \delta.\ n\,)$ ……………… (3)

Second term of the above equation (3) is always an integer.

The hardware

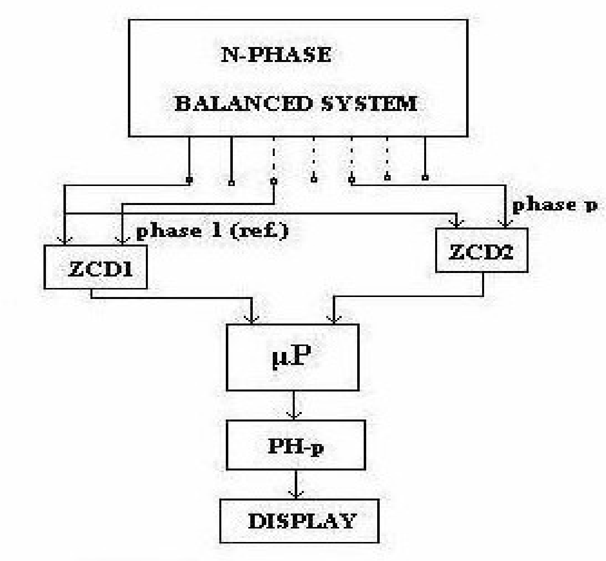


Fig 5 Hardware set up of given system.

The schematics arrangement of the experimental set up is shown in Fig. 5. The signals derived from the reference phase and phase- p, are fed to respective ZCD's (zero crossing detectors) through setup down transformers. The outputs of the ZCD's act as input to the

8085A CPU based microprocessor for the purpose of identification of phase-p with the help of equation 3. To achieve this equation2 is modified to the following form:

$i = 2n\,(C_p/C)$ ………………… (4)

Where C_p and C are the number of counts obtained from the microprocessor, which are proportional to t_p and T respectively. It may be noted that I should always be and integer which may not exactly be satisfied by eq (4) due to value of Cp and C obtained from the microprocessor. To overcome such a situation, the computed value of $2n\,(C_p/C)$ is rounded off to the nearest integer.

The software detects the zero crossing of the rising edge of the reference point. Then it accesses the unknown phase-p. The voltage may be high or low. If it is high, the microprocessor counts number of non-zeros (ie, ones) at the output of ZCD starting from the chosen reference point. This counting goes on until the voltage of phase-p becomes low. This is the count C_p and δ is set to be equal to unity.

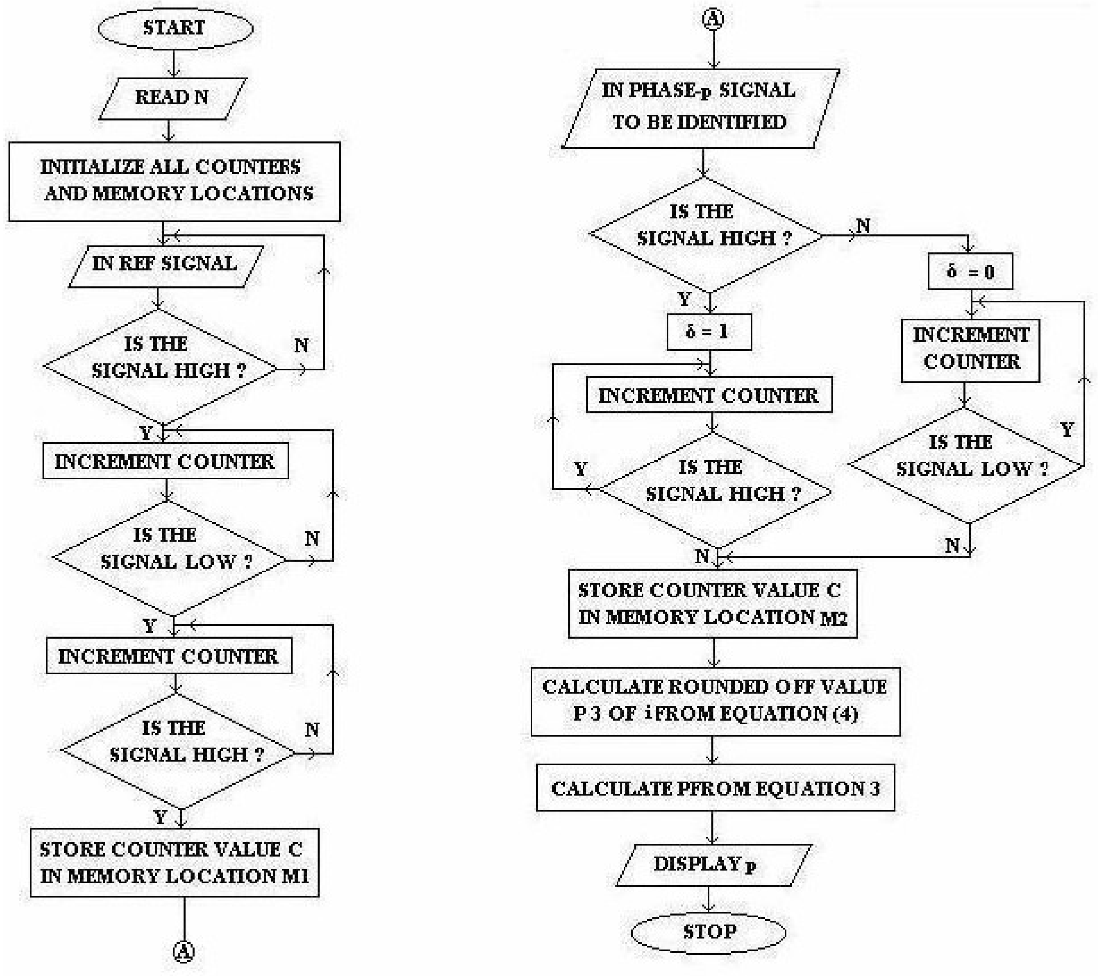


Fig. 6 The flowchart.

If the voltage of phase-p at the time of access is low, the software counts number of zeros instead of non-zeros as in the previous case. The value of δ, in this case, is set to zero and the total count up to the point of low-to-high zero crossing of the voltage of phase-p is stored as C_p. The flow chart for the developed software is shown in Fig 6.

Now one can identify the phase sequence, by measuring tp the time instance of the first zero crossing of the p^{th} waveform negative to positive or positive to negative from the reference point. Where $\delta = 0$, if the first zero crossing happens to be from negative to positive, and $\delta = 1$ if it is from positive to negative. Thus, the equation $p = 1 + n\ (t_p/T) + \delta(n/2)$ shows that p being equal to the sum of the two terms and involves δ, this will result into slightly more complex software.

4) A modified Micro-controller based phase sequence detection

As stated in an earlier technique, p being equal to the sum of the two terms and involves δ, which results into slightly more complex software. To overcome this problem, few modifications are suggested by the given method [5].

Multi phase sequence indicator

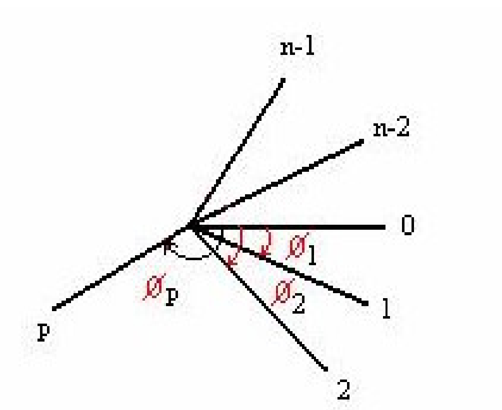


Fig 7 Phasor diagram of balanced n phase system.

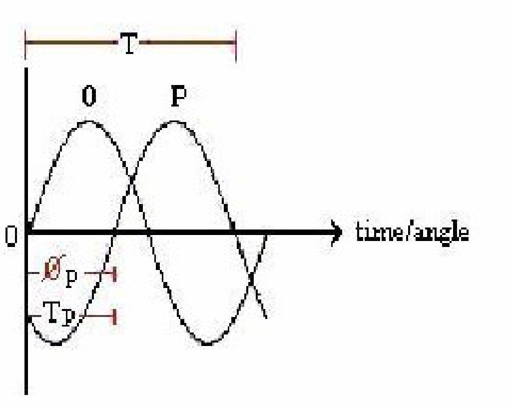


Fig. 8 waveform of the reference and the Pth phase.

Consider the Phasor diagram of a balanced n phase sinusoidal supply shown in figure 7.one of the phasors marked 0, is chosen as the reference, and the others are marked as 1,2,… $p, .., n-1$. The angle between any two consecutive phases is $360/n$ degrees and the angle of lag of the p^{th} phase will be,

$\Phi_p = p\ (360/n)$ ……………… (5)

The waveforms for the reference and the p^{th} phases are shown in figure 8, where Tp is the time instance of the first zero crossing from the negative to positive value of the p^{th} phase measured from the reference point thus,

$\Phi_p = 360*(T_p/T)$ …………………… (6)

From equation (5) and (6) we get,

$p = n\ (T_p/T)$ ……………….. (7)

Equation 2.35 can be used for detecting phase sequence with the help of a Micro-controller (Rathore, 2000) as follows. Measure T, T_p, $p = 1, 2, 3, n-1$, then evaluate p using equation 2.35 since p is an integer, the right hand side of equation (7) must result into an integer. However, it is possible that the calculation by the micro-controller may not result into an integer value. Hence, choose the closest integer value.

Phase measurement can be carried out based on equation $\Phi^0 = 360*(T_p/T)$. Employing a Micro-controller, both t and T can be measured digitally and then the calculation of $\Phi^0 = 360*(T_p/T)$ can be carried out with the help of the micro-controller.

Since t and T appear in the form of a ratio in the expression for Φ , any change in the clk frequency will not affect the accuracy of the measurement.

In case of an unbalanced multiphase system, relative positions various phases with respect to the reference can be determined by measuring a phase angle using above equation.

TECHNIQUES FOR MULTI-PHASE GENERATION

As discussed earlier the sequence detection system requires balanced multi-phase supply for its testing. Hence generation of multi-phase waveforms becomes supplementary task. The following section deals with the various techniques for generating balanced multi-phase waveforms.

1) Multi-phase generation using poly-phase alternator

A single-phase alternator has only one armature winding. But if the number of windings is increased, then it becomes poly-phase alternator. And it produces as many independent voltage waves as the number of windings or phases [1]. These windings are displaced from one another by equal angles; the values of these angles are being determined by the number of phases or windings. Hence to generate balanced n phase waveforms we require n such number of armature windings. This is one of the simplest methods of multi-phase generation, but implementing this method is very inconvenient and will consume large space, hence this method is not practically used.

2) Multi-phase generation using phase shift network

Another method of generating multi-phase waveforms is, to generate a periodic single-phase waveform of any shape, and then successively phase shifting the original waveform by using n phase shifters with phase shift of $\Phi_p = 360^0/n$. Generally sine wave oscillator is used to generate the single-phase waveform and this waveform is taken as the reference phase. To have balanced n phases Φ_p of each stage should be accurately adjusted, for proper operation of the ckt, it is desired that the each phase shift network provide the same phase shift Φ_p for all the frequencies.

3) A poly-phase sine wave generator using a multiplexing technique

A new technique for generation of adjustable frequency and adjustable amplitude, 5-phase sine wave is presented [6]. Fig. 9 shows the block diagram of sine wave generator using a multiplexing technique. M1 is a 2K*8 bit erasable programmable memory (EPROM). It is programmed to certain values of sin (x) between 0˚ and 360˚ for 360 steps and for all the five phases.

The sine values are programmed with an offset so that 10000000 correspond to zero values of sine wave. Each step has five successive memory locations, in which sine values of the five different phases at respective instants of time are programmed. The values contained in the first five address locations of M1 are shown in table1. It can be seen that the sine values of all five phases do not correspond to the same instant of time. This is done to account for the time delay corresponds 0.2˚. The sine values for the next step will be programmed in a similar manner. This means that address locations 0, 5, 10, etc. will contain sine values of phase-1 and address locations 1, 6, 11; etc will contain sine values of phase-2 and so on. Thus 1800 locations are used to store 5-phase sine wave values in

360 steps. This corresponds to a resolution of 1° for the o/p of the waveform. The memory is addressed by a 12 bit binary counter which is driven by an o/p of voltage controlled oscillator vco the counter is reset after every 1800 clk cycles so that one cycle of the 5-phase o/p is generated in 1800 clk period.

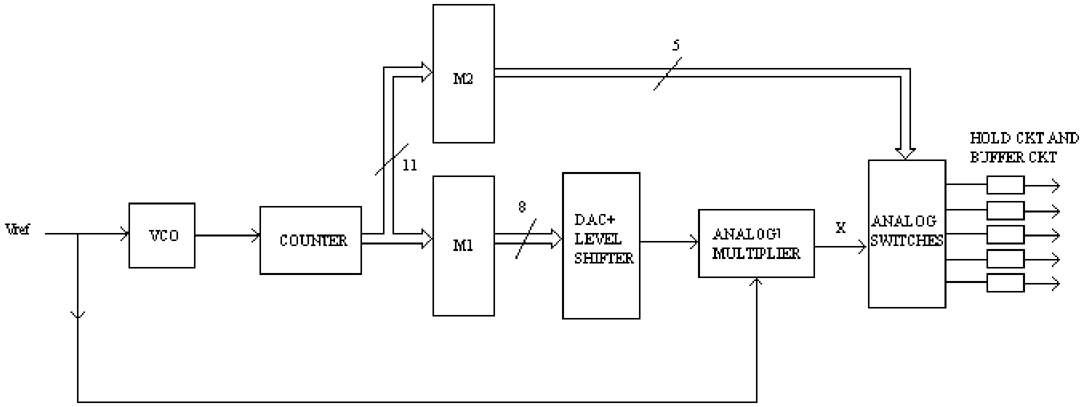
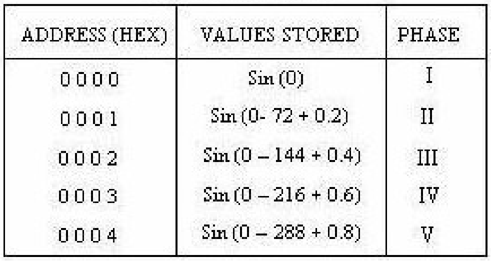


Fig. 9 Block diagram of 5-phase sine wave generator.

The cyclic incremental addressing of the memory results in multiplexed 5-phase digital o/p, which is converted to analog quantity using a unipolar DAC. The DAC o/p is level shifted to facilitate the generation of bipolar o/p waveforms. The o/p amplitude is controlled to be proportional to the frequency using a single analog multiplier. This arrangement produces a multiplexed analog 5-phase o/p of adjustable frequency and adjustable magnitude. The 5 individual sine waves are obtained by demultiplexing these using a second memory M2 (2k*8-bit) and a set of five analog switches for every address location in a step in M1, the corresponding location in M2 is programmed to contain an identification bit. Table 2 shows the identification bits programmed in the first five address locations M2 for phase decoding this pattern will be repeated in M2 for all the 360 steps.

TABLE 1

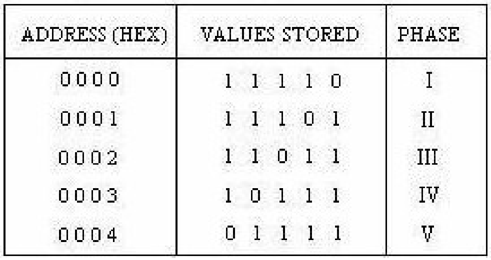
Values Stored In First Five Address Locations of M1



ADDRESS (HEX)	VALUES STORED	PHASE
0000	Sin (0)	I
0001	Sin (0- 72 + 0.2)	II
0002	Sin (0 – 144 + 0.4)	III
0003	Sin (0 – 216 + 0.6)	IV
0004	Sin (0 – 288 + 0.8)	V

TABLE 2

Phase Identification Bits Programmed In First Five Address Locations of M2



ADDRESS (HEX)	VALUES STORED	PHASE
0000	1 1 1 1 0	I
0001	1 1 1 0 1	II
0002	1 1 0 1 1	III
0003	1 0 1 1 1	IV
0004	0 1 1 1 1	V

When M1 and M2 by the same counter the phase identification bits in M2 activate the appropriate analog switches to produce demultiplexed o/p, each analog switch o/p is passed through the hold ckt and a buffer amplifier stage. The components of the hold ckt are chosen to be identical. The waveform in the common signal path is of a switched multiplexed type and this necessitates the use of high slew rate opamps for the DAC and the level shifter. A bipolar DAC can be used to replace unipolar DAC and a level shifter .the phase decoding can also be carried out by using a 5-bit shift register instead of a separate memory chip (M2).

Results:

The distortion of the given technique is less than 0.8 percent throughout the frequency range (1 – 50Hz).The developed ckt provides balanced 5-phase sine waves of adjustable magnitude for the designed frequency range. One important feature of the ckt is the novel amplitude control method of the five output phases in a single analog multiplier. The multiplexing technique results in substantial reduction in overall component count and ensure perfect amplitude symmetry among the five different outputs. The technique is quite flexible and can be used to generate periodic waveforms of any shape and for any number of phases.

4) Generation of Poly-phase square wave using multihysteresis block

This technique introduces a new circuit component, the multihysteresis block. It consists of several hysteresis elements having the same input signal. Here only one integrator is required for any number of phase generations [7]. In conventional poly-phase square wave generator we require n integrators and n comparators for the generation of n phases. The fig 10 shows one such, two-phase square wave generator.

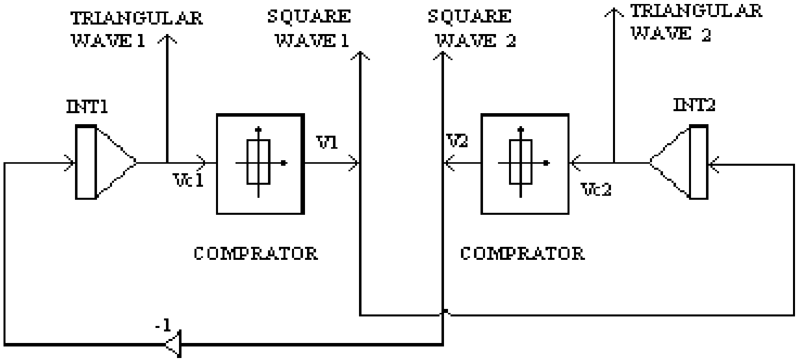


Fig. 10 Conventional 2-phase oscillator. The square waves (1) and (2), as well as the triangular waves (1) and (2), are in quadrature.

The Multihysteresis block:

The multihysterises block has only one input signal vc, but several output, v_0, v_1, etc. The component characteristic consists of several hysteresis curves, the input signal of which, for all of them, is the same wave vc. The output levels are also the same for all the curves, i. e., -V and +V. However, each hysteresis curve has its own “coercive” values, e.g., -Vc_1, -Vc_2, etc., for the input signal. When the input signal arrives at one of the “coercive” values, the corresponding output signal switches from -V to +V levels, or vice versa. Another feature of the new block is that each one of the hysteresis loops can be followed counterclockwise or clockwise. It is desirable to name the hysteresis of the first type as a direct-type hysteresis. Hysteresis of the second type is, then, inverse-type hysteresis.

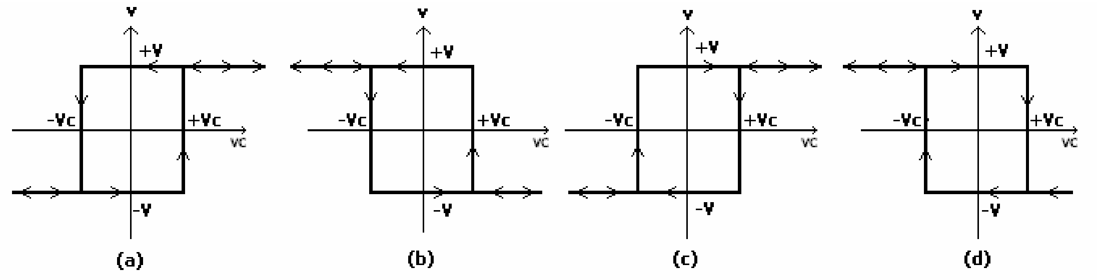


Fig no 11 The four types of hysteresis elements. (a) Direct up. (b) Direct down. (c) Inverse up. (d) Inverse down.

The direct-type hysteresis can be expressed as [see Fig. 11(a), direct up hysteresis]:
$v = V + \text{sign}(vc - Vc)$ when vc increases ……….(1)
$v = V + \text{sign}(vc + Vc)$ when vc decreases ……….(2)
or as [see Fig. 2(b), direct down hysteresis]
$v = -V + \text{sign}(vc + Vc)$ when vc increases …….. (3)
$v = -V + \text{sign}(vc - Vc)$ when vc decreases …….. (4)
Where v is the output signal of the hysteresis element, vc is its input signal, and Vc is the "coercive" value of the hysteresis curve.
The inverse-type hysteresis can be expressed as [see Fig. 11(c), inverse up hysteresis]:
$v = V + \text{sign}(vc + Vc)$ when vc increases ……….(5)
$v = V + \text{sign}(vc - Vc)$ when vc decreases ……….(6)
Or as [see Fig. 11(d), inverse down hysteresis]
$v = -V + \text{sign}(vc - Vc)$ when vc increases ……… (7)
$v = -V + \text{sign}(vc + Vc)$ when vc decreases ………(8)
Where v, vc and Vc have the same meaning as in (1)–(4).
The following section shows how the multihysteresis block may be used to obtain a poly-phase square-wave oscillator.

Poly-phase square-wave oscillator

The starting point of a poly-phase square-wave oscillator is a classical one-phase square- and triangular-wave generator. It contains an integrator and a single-hysteresis block of the direct type. The triangular wave, which is the integrator output, is the input signal to the hysteresis block, while the square wave, which is the hysteresis block output, is connected to the integrator input. It is straightway that if a multihysteresis block replaces the single hysteresis one, a poly-phase square-wave oscillator is obtained. The triangular wave now constitutes the joint input signal to several hysteresis elements, each one with its own "coercive" value. Only one integrator input is connected to the output of the hysteresis element with the highest "coercive" value. Its characteristic is the reference hysteresis curve. This element will produce at its output the reference square wave, with zero phase. All other hysteresis curves are included in the reference one. They will produce the other phases of the poly-phase square-wave oscillator. For example, a direct up hysteresis element could produce square waves with a phase difference between 0° to 90° relative to the reference square wave, while a direct down element could give a phase difference between 0° to -90°, an inverse up element, a phase difference between 90° to 180°, and an inverse down element, a phase difference between -90° to -180°. If the input signal to the multihysteresis block changes linearly in time, it is relatively easy to choose the “coercive” values of the hysteresis curves to obtain the desired poly-phase system. The phase difference (in degrees) Φ_N of the phase N wave relative to the reference wave is

$$\begin{gathered}\mathbf{..}\cdots \boldsymbol{up}\downarrow\cdots\downarrow \boldsymbol{direct}\\ \boldsymbol{\Phi_N = \pm 90(1 \mp \frac{Vc_N}{Vc_1})}\\ \mathbf{..}\boldsymbol{down}\uparrow\cdots\uparrow \boldsymbol{inverse}\end{gathered}$$

Where Vc_1 is the “coercive” value of the reference hysteresis curve and Vc_N is the “coercive” value of the N hysteresis curve (Vc_N - Vc_1): However, the input signal could also be of other forms, e.g., sinusoidal.

This technique introduces an apparently new circuit component, the multihysteresis block. This block could be immediately implemented by several conventional, single-hysteresis blocks, all of them having the same joint input. Furthermore, different types of the hysteresis elements are defined. The multihysteresis block could save integrators in poly-phase square-wave oscillators, because only one integrator is needed for any number of phases.

CONCLUSIONS

The following section concludes our discussion on various techniques used for sequence detection and generation of multi-phase systems. It is seen that the sequence indicator method using 3Φ induction motor provides simple and basic technique for sequence detection of 3Φ supplies, so as the 3Φ unbalanced load sequence detection method, these techniques find their applications in 3Φ supplies, but if we have more number of phases for detection the given method fails.

The microprocessor based sequence detection system suggested by Gautam Sarkar (1996) provided an efficient means for sequence detection of balanced n phase supply, It uses a processor for calculating the phase number of any given phase with respect to the reference phase. This method can be extended for sequence detection of any number of phases in a given supply, the given method uses ZCD to detect the first zero crossing instant of a given phase, and the direction of transition of the given phase during zero crossing was required to calculate the phase number. This resulted into slightly complex algorithm. Also the ZCD used could be affected by noise signals around the ground level, which may affect the final result of the system.

A modification was suggested (T.S Rathore, 2000) to the above system, that instead of finding the zero crossing time instant ant the direction of transition, we will just measure the time T_p of the first zero crossing from negative to positive with respect to the reference point and then calculate the phase number using the equation $p = n$ (T_p/T), where p is the phase number, n are the total number of phases in given supply and T is the time period of the reference phase, it is clear that p should be an integer value, however it is possible that the calculations performed by the micro controller may not result into an integer value. Hence, choose the closest integer value.

Among the various techniques used for multiphase generations, poly-phase sine wave generation using multiplexing method and poly-phase square wave generation method were found to be efficient for generation of higher order balanced phases, out of which multiplexing method was capable of generating waveforms of desired size and shape, the basic disadvantage of the method was that, both the frequency and the amplitude of the sine wave was controlled by single parameter (Vref), thus individual control of these parameters was not possible, also the frequency range of operation was only 1-50Hz, which was limited due to the processing time and the desired resolution of sine wave required, also as the no of phases goes on increasing the memory space required goes on increasing and maximum operating frequency reduces. Whereas the poly-phase square wave generation method using hysteresis block proved to be efficient to generate any number of phases, without putting any constrains on resolution and frequency of operation. Also this method uses only one integrator for any number of phases, hence results in reducing total number of components in poly-phase square wave oscillators.

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