Design of a Solid-State Starting System for a Single Phase Induction Motor

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abstract:

A split-single phase induction motor (SSPIM) using a new solid-state starting switch is described. The system uses a thyristor device. Proper control of the thyristor device, thereby cutting out the auxiliary winding from supply before the motor reaches rated speed. The system could be used to replace the centrifugal or the electromagnetic relay switch and have benefits over the existing system. The paper will explore these benefits.

Key words:-Single phase, Split-phase, Centrifugal switch, induction motor, Squirrel-cage.

الخلاصة

يتناول البحث تصميم الدائرة الالكترونية الملائمة لمحرك أحادي الطور نوع منفصل (سبلت). هذه الدائرة الالكترونية قادرة على فتح الملفات الثانوية (ملف البدء) عند وصول المحرك إلى السرعة الملائمة بدل من استخدام مفتاح ميكانيكي (مفتاح طرد مركزي)، ليكون أكثر ملائمة من المفتاح التقليدي. ثم بناء وتصميم الدائرة الالكترونية عملياً. ظهرت كفاءة هذه الدائرة الالكترونية في السيطرة على الملفات الثانوية لمحرك أحادي الطور نوع منفصل.

الكلمات المفتاحية :- احادي الطور –ذو الوجة المشطور – مفتاح طرد مركزي ،المحرك الحثي .

Introduction

A split-phase motor is a single-phase induction motor which is not self-starting and to overcome this drawback and make the motor self starting, it is temporarily converted into a two-phase motor during starting period. For this purpose, the stator of a single-phase motor is provided with a second winding known as starting winding in addition to main (running) winding. These two windings are set **90** electrical degrees apart along the stator of the motor, and the auxiliary winding is designed to be switched out of the circuit at some set speed by a centrifugal or an electromagnetic relay switch. A centrifugal (mechanical switch) is connected in series with the starting winding and is located inside the motor. Typical application for such motors is pumps, air-cooler, and other types of equipment. An electromagnetic type over-current relay which performs the same function can be used instead. As shown in figure (1) (Bhattacharya,2008). The relay has a coil which is connected in series with main winding. The auxiliary winding is connected across the supply through a normally open contact of relay. During the starting period, when main winding current is high, the armature of the relay will be drawn upwards, thereby closing the relay contacts. The auxiliary winding will, therefore, get connected across the supply thus helping the motor to start rotating. As the rotor starts rotating, the line current gradually goes on decreasing. After the motor reaches proper speed, the main winding current drops to a low value and causes the armature of the relay to fall downwards and open the contacts, thereby cutting out the auxiliary winding from the supply. Such relays are located outside the motor so that they can be easily serviced or replaced. Typical application for refrigerate motors (compressor).

(Tian-Hua Liu 1995) presented a single phase induction motor with a two value capacitor. It discuss of the possibility of using an inverse/parallel set of bi-directional electronic switch in parallel with the running capacitor, thereby providing the equivalent of a starting capacitor. The capacitor is shorted during each cycle to vary the effective size of the AC capacitor. This method uses only one capacitor for both the starting and running conditions. It is clear that one can choose an optimal path to control the capacitance to achieve an optimized starting performance. However, due to the difficulty in realizing an adjustable capacitor and the need for a speed sensor for realizing optimal starting.

(Terrance *et.al.*, 1991) work a new electronically controlled capacitor is proposed for single-phase induction motor.The system uses a D.C capacitor switched by transistor H bridge. The proposed system can replace standard single-phase motor capacitor configuration with the aim of improving machine performance. This work is limited and illustration of some of design tradeoffs that are possible.

In this research an electronic starting switch is suggested which is an alternative to centrifugal or relay switch. The system is build so that its feasibility can be determined. It's concluded that the proposed system is simple cost effective and can last longer than conventional switches.

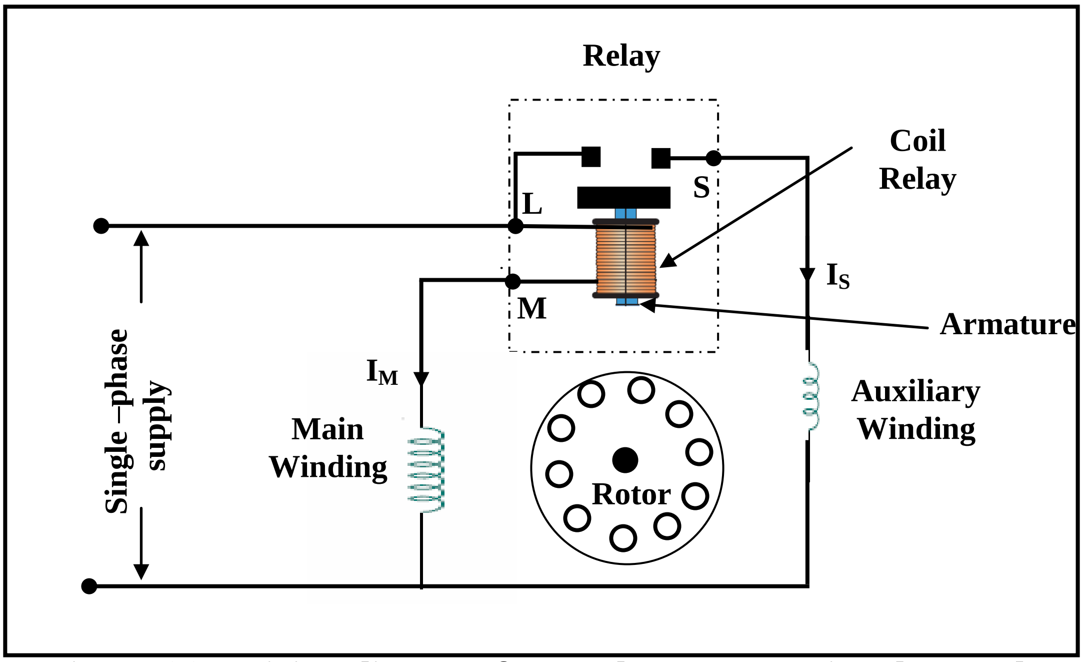


Figure (1): Wiring diagram for an electromagnetic relay used in a split -phase motor (Bhattacharya,2008).

Circuit Description

A schematic representation of the electronically starting switched system is shown in fig. (3), this include electronic driver of two anti-parallel thyristor, and it is a good idea to isolate the lower-power electronic from the high power electronics using what is known as (pulse- transformer) or opto-isolators. The unijunction transistor (UJT) may be used as triggering device in a ramp and pedestal type of firing circuit with a frequency of (**1 kHz**). This (UJT) relaxation oscillator circuit is ideally suited for triggering a thyristor, since (UJT) is capable of generating sharp, high power pulses of short duration whose peak and average power don't exceed the power capabilities of the thyristor gate for which they are intended. [Muhammad H. Rashid 1994] described the oscillator frequency equation as:

$$f_{\circ} = \frac{1}{R.C \ln\left(\frac{1}{1-\eta}\right)} \qquad (1)$$

Where:

η : The intrinsic stand-off ratio.

$f_{\circ}$: Frequency of relaxation oscillator (Hz).

R : Is a resistance (ohm).

C : Capacitor (μF).

The value of (η) lies between $\eta = 0.51$ to 0.82. , $\eta = 0.5$ (Assume)

Substituting the value of (η) in equation (1).

$$f_{\circ} = \frac{1}{R.C\ln\left(\frac{1}{1-0.5}\right)} \tag{2}$$

$$f_{\circ} \cong \frac{1.5}{R.C} \tag{3}$$

An operational amplifier is used to amplify the difference between the voltage proportional to input motor current, (V_S). and the current adjustment, ($V_{ref.}$). Two situations are possible. When $V_S > V_{ref.}$ then V_o is positive, its maximum value being the positive supply, $V_o \cong +V_{cc}$. When $V_{ref.} > V_S$ then V_o is zero, $V_o \cong$ zero. A small change in (V_S-$V_{ref.}$) therefore causes V_o to switch between near $+V_{cc}$ and near to zero, and enables to operational amplifier to indicate when V_S is greater or less then $V_{ref.}$ i.e to act as a differential amplifier.

$$V_{\circ} = A_{\circ}(V_S - V_{ref.}) \tag{4}$$

Where A_o is the open-loop voltage gain

The power supply ($\pm 15V$) should be designed, as shown in figure (2).

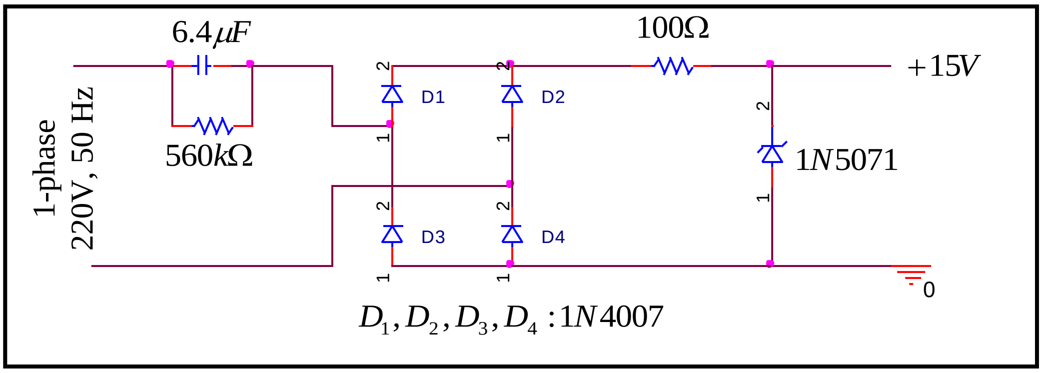


Figure (2): The circuit of Power supply.

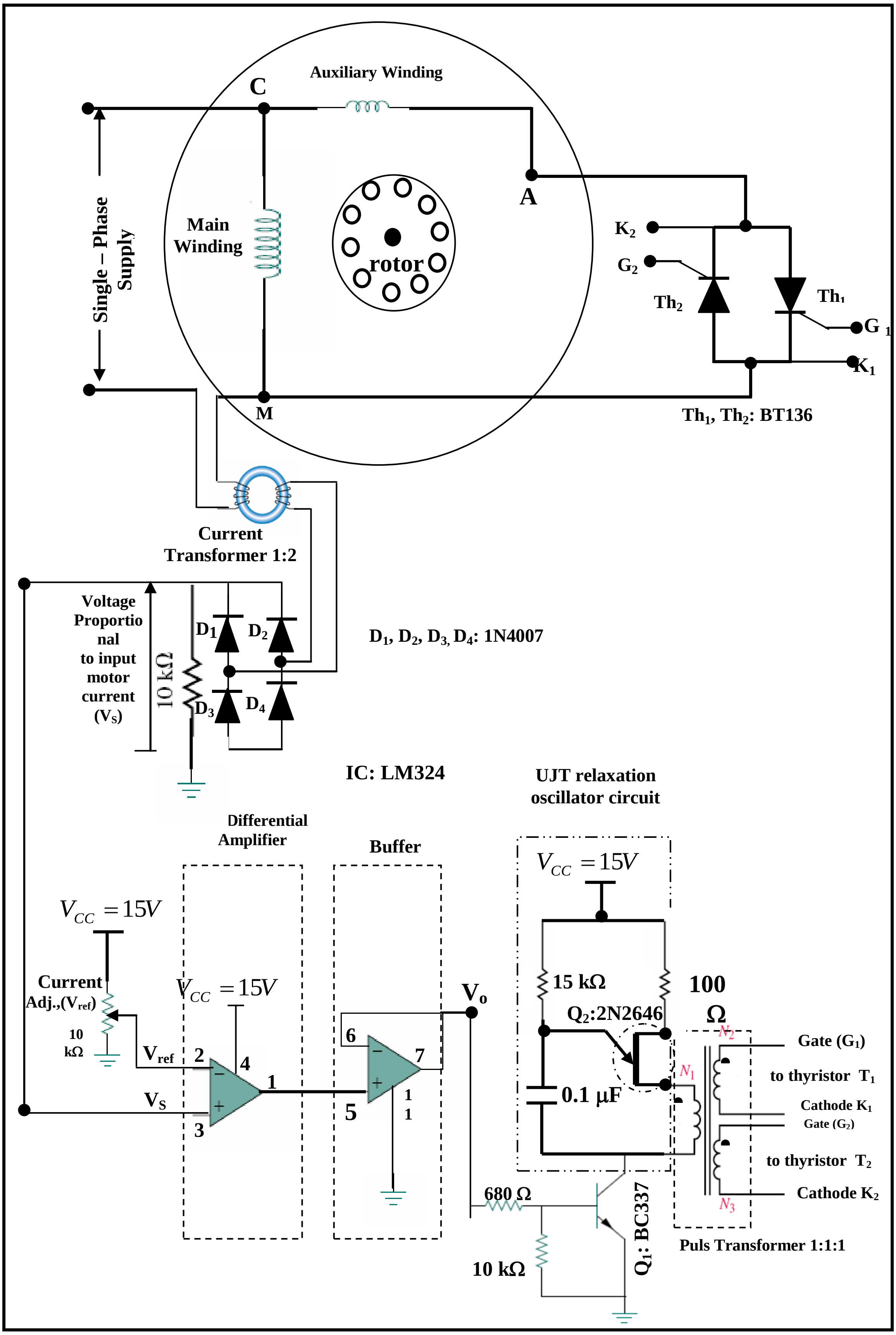


Figure (3): Schematic diagram of electronically starting switch of (SSPIM).

Operation Of Propsed Starting System

A typical torque/ speed characteristic of such motor is shown in figure (4).As seen, the starting torque is **150** to **200** per cent of full-load torque with a starting current of **5** to **6** times the rated current. Thus, the basic mode of operation is comparing the phase of the voltage (**V$_S$**) with the adjustment (**V$_{ref}$**) voltage which is the fundamental control for the system operation. Figure (5), (6) shows the waveform of rated current, starting current and adjustable current. When the starting, phase voltage proportional to input motor current, (**V_S**) is greater than the (**V_{ref}**) level, the output of the op-amp swings is high, due to the auxiliary winding been connected at starting, and when the motor runs the phase voltage proportional to input motor current, (**V_S**) is lower than the (**V_{ref}**) level, the output of the op-amp swing is low, become the auxiliary winding is open-circuit.

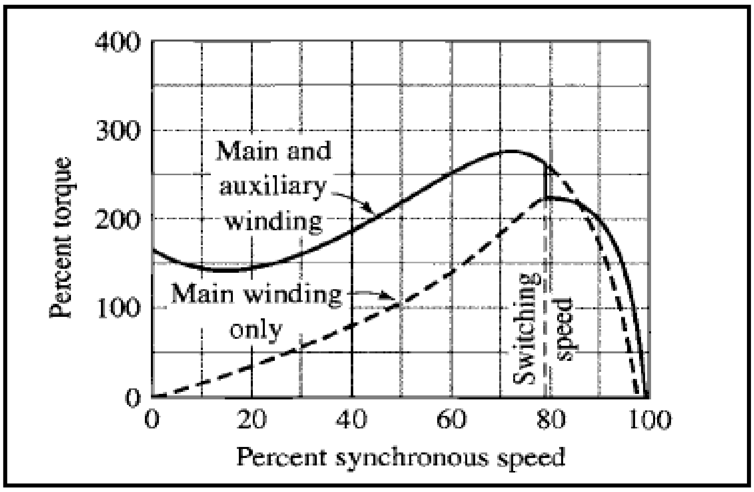


Figure (4): Typical torque/speed characteristic of (SSPIM).
(Fitzgerald *et.al.,* 2003).

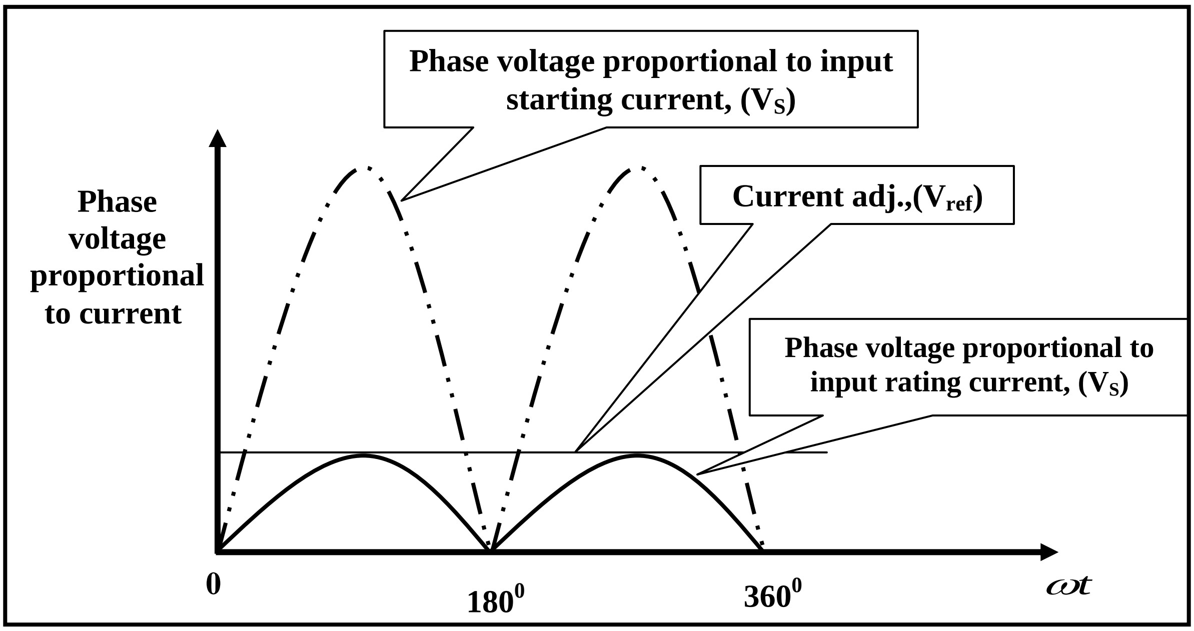
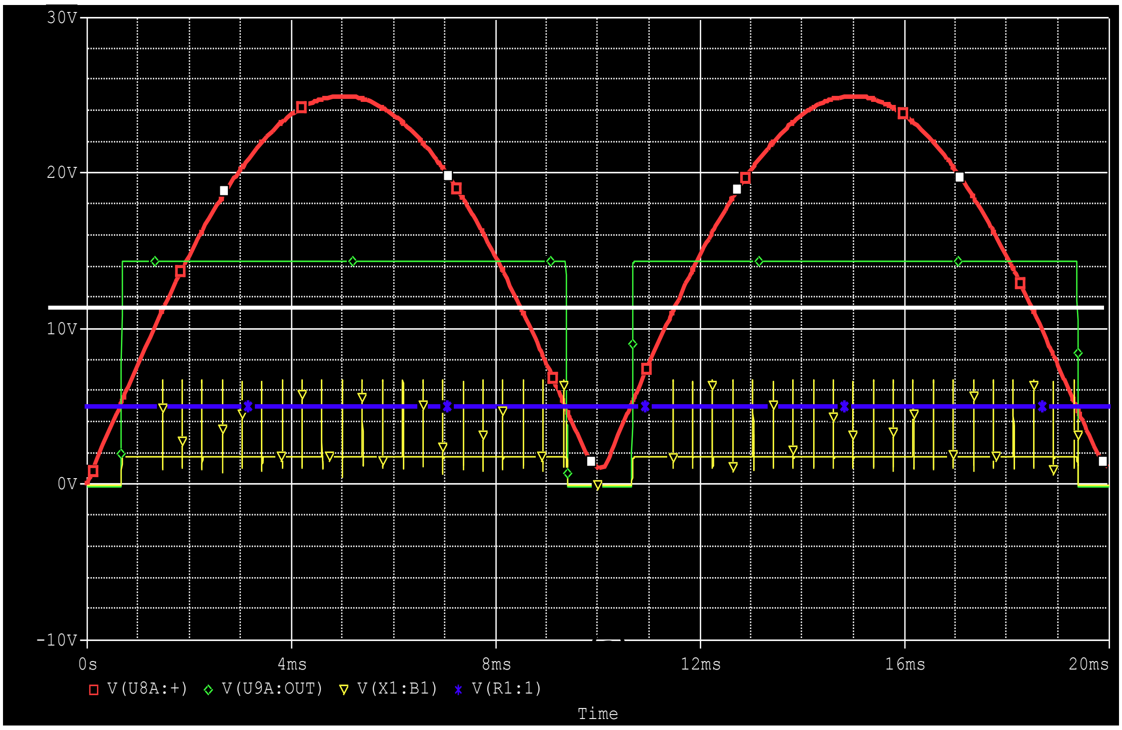
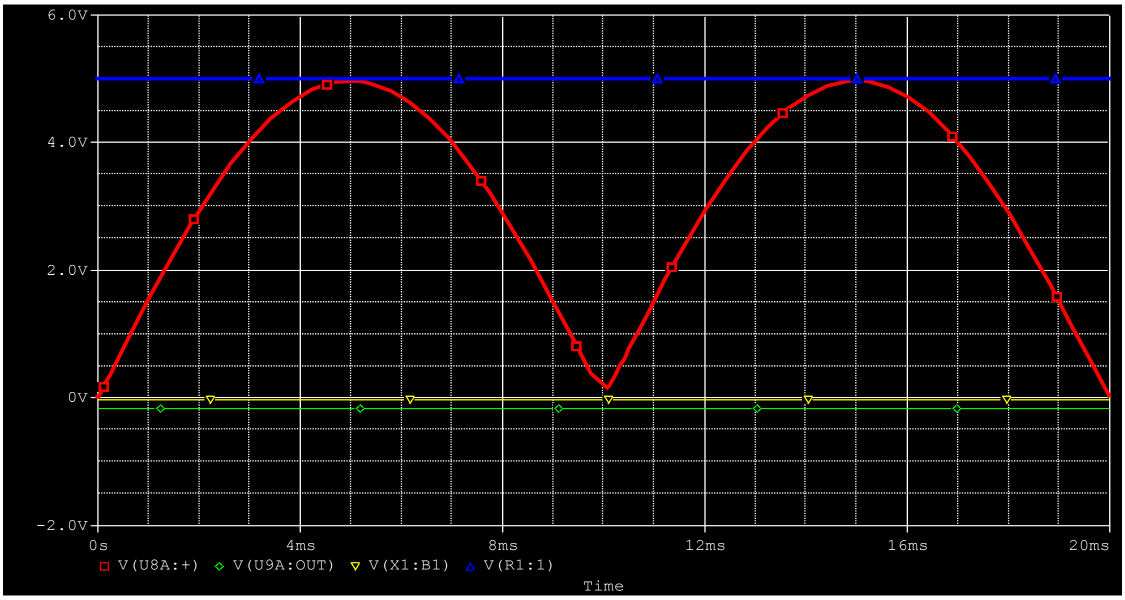


Figure (5): Phase voltage proportional to current waveforms.



(a)



(b)

Figure (6): The output waveform when
(a) V_S is greater than the $V_{ref.}$
(b) V_S is lower than $V_{ref.}$

So, if this value of rated current is known for all machine conditions, the phase of (**V_{ref}**) level can be adjusted to give the proper starting switch at all time. Finally, electronically starting switch of a single phase induction motor with solid-state drive package are designed as shown in figure (7).

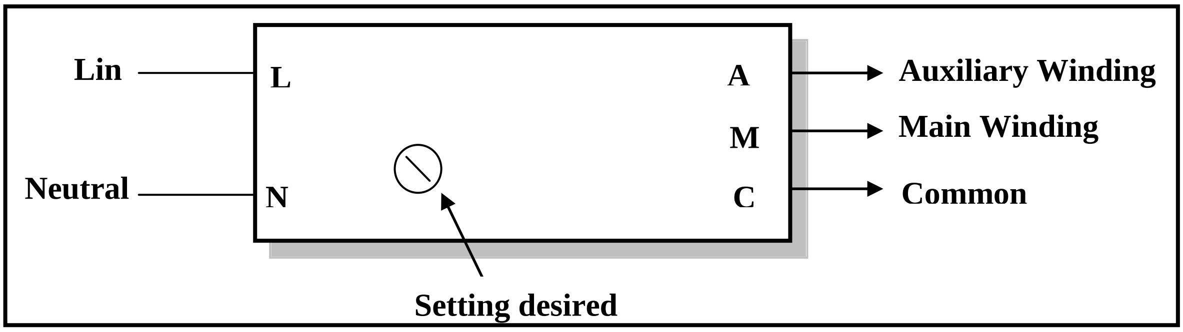


Figure (7): Package drive of (SSPIM).

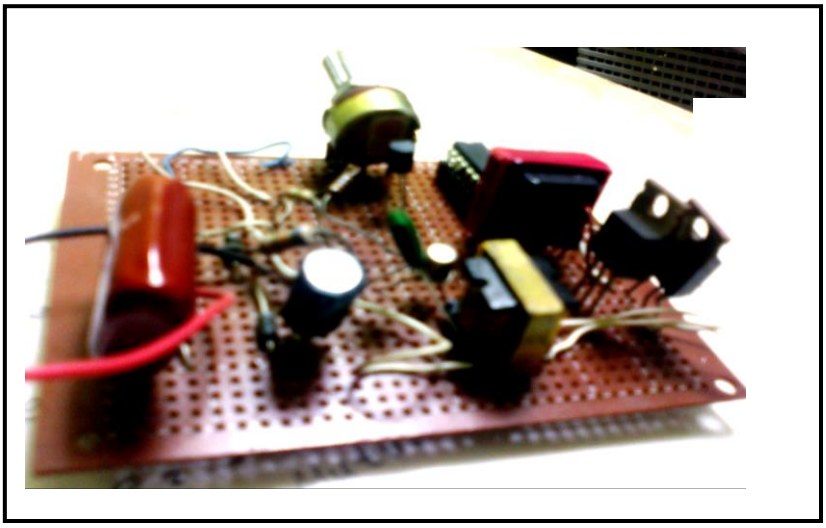


Figure (8): Photograph of electronic circuit.

Conclutions

A new scheme for starting split-phase motor has been presented and compared with already existing methods for starting the motor.

Further, the paper showed that the new scheme poses the following benefits as compared with the existing schemes,

1) More reliable.
2) Easily serviced or replaced, since located outside the motor.
3) For any number of poles can be used if rated current is known, but mechanical switch (centrifugal) used only for specific speed.
4) Split-single phase induction motor using solid-state starting can placed in a hazardous or explosive environment, since the risk of sparking is eliminated by the absence of mechanical contact.

References

Bhattacharya S. K. ,2008, "Electrical Machines" McGraw- Hill, book.

Fitzgerald, A. E., Charles Kingsley and Stephen D. Umans 2003, "Electric Machinery" McGraw-Hill, book.

Muhammad H. Rashid 1994, "Power Electronics" New Delhi, book.

Terrance A. Lettenaier, Donald W. Novotny and Thomas A. L.ip 1991," single-phase induction motor with an electronically controlled capacitor" IEEE Transaction on industry Application , vol. 27, no.1, January/ February.

Tian-Hua Liu 1995," A maximum torque control with a controlled capacitor for a single-phase induction motor" IEEE Transaction on industry Application , vol. 42, no.1, February.