Auxiliary Winding Switching Circuit for Single-Phase Induction Motors.

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ABSTRACT

The most common practice for starting a single-phase induction motor is to connect a starting capacitor, in series, with the auxiliary winding. Here, the possibility of using an electronic switch in parallel with the starting capacitor, is discussed. This work relates particularly to a switching device for electrically connecting and removing the auxiliary winding and starting capacitor from the single-phase induction motor's circuitry. The starting capacitor with the auxiliary winding are disconnected by electronic means as the motor gains speed hence leaving only the main winding in the motor circuit for normal operation.

(Keywords: centrifugal switch, auxiliary winding, electronic switch, induction motor, synchronous speed, starting capacitor)

INTRODUCTION

Single-phase motors are probably the most used AC motors today. It is logical that the least expensive, lowest maintenance type of AC motor should be used most often. The single-phase AC induction motor fits that description.

Unlike polyphase induction motors, the stator field in the single-phase motor does not rotate. Instead it simply alternates polarity between poles as the AC voltage changes polarity. Voltage is induced in the rotor as a result of electromagnetic induction, and a magnetic field is produced around the rotor. This field will always be in opposition to the stator field (Lenz's law applies) [1]. The interaction between the rotor and stator fields will not produce rotation, however. Because this force is across the rotor and through the pole pieces, there is no rotary motion, just a push and/or pull along the magnetic lines.

Single-phase induction motors, typically comprise a distributed stator main winding, an auxiliary winding, and a squirrel-cage rotor. An AC supply voltage applied only to the stator winding creates a field fixed in space and alternating in magnitude. The field therefore produces no starting torque on the rotor. This condition, however, prevails only at rotor standstill. If, by some means, the rotor is started in either direction, it will develop a non-zero net torque in that direction and thereby cause the motor to approach its normal operating speed [1, 2].

The typical non-mechanical method of starting a single phase induction motor is to temporarily include a second, auxiliary winding around the rotor to produce a revolving field of constant amplitude and constant linear velocity. This revolving field creates the necessary starting torque needed to start the rotor turning on its axis. To obtain this revolving field, the two windings are displaced in space by 90 electrical degrees. Additionally, the current flowing through these windings is time-displaced by 90 electrical degrees and the windings must have equal magnitude of mmfs [2].

The space-displacement criterion is met by placing the auxiliary winding in the stator with its axis in quadrature with that of the main winding. Typically, the main winding occupies two-thirds of the stator slots, with the auxiliary winding occupying the remaining one-third [1, 2].

The time displacement criterion regarding the currents through the two windings is at least partially obtained by designing the auxiliary winding for high resistance and low leakage reactance [2, 4]. This is in contrast to the main winding which typically has lower resistance and higher leakage reactance. Due to the high-resistance characteristic and the short time power rating inherent in the auxiliary winding, they must be removed from the supply once a sufficient percentage of normal operating speed is reached.

One method for removing the auxiliary winding and starting capacitor from the supply is by a cut-off switch, placed in the auxiliary winding circuit as shown in Figure 1, which by centrifugal action electrically removes the auxiliary winding and starting capacitor from the supply when the motor speed attains a certain percentage of synchronous speed. However, due to the large current flow and the switching action, the centrifugal switch contacts become damaged over time due to arcing [4]. This is disadvantageous because the auxiliary winding could burn itself out if the switch becomes faulty. Additionally, since the switch resides in the motor, it is difficult to miniaturize the overall motor size.

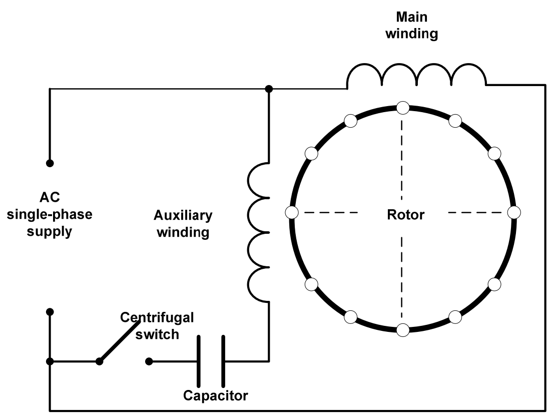

Figure 1: Capacitor-Start, AC Induction Motor.

Another method for removing the auxiliary winding from the supply involves replacing the centrifugal action switch with a 555 timer-based electronic circuit. This method will be fully discussed later in this paper.

CENTRIFUGAL SWITCHING METHOD

A centrifugal switch is an electric switch that operates using the centrifugal force created from a rotating shaft, most commonly that of an electric motor or car engine. The switch is designed to activate or de-activate as a function of the rotational speed of the shaft.

The most common use of centrifugal switches is within single-phase, split-phase induction motors. Here, the switch is used to disconnect the starting winding and/or the starting capacitor of the single-phase induction motor once it approaches its normal operating speed. In this case, the centrifugal switch consists of weights mounted to the shaft of the motor and held near the shaft by spring forces. At rest, levers attached to the weights press a low-friction, non-conductive plate against a set of electrical contacts mounted to the motor housing, closing the contacts and connecting the starting winding and capacitor to the power source. When the motor approaches its normal operating speed, centrifugal force overcomes the spring force and the weights swing out, raising the plate away from the electrical contacts. This allows the contacts to open and disconnect the starting winding from the power source; the motor then continues operating solely using its running winding.

Motors using such a centrifugal switch make a distinct clicking noise when starting and stopping as the centrifugal switch opens and closes. Figure 2 shows a cut-out view of a single-phase induction motor showing the position occupied by the centrifugal mechanism.

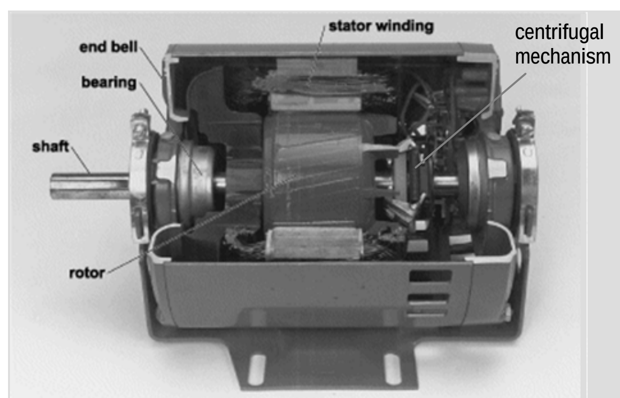

Figure 2: Motor Interior View.

ELECTRONIC SWITCHING APPROACH

The circuit diagram for the electronic switching circuit is as shown in Figure 3. This is divided into 5 units namely: the power supply, timer, amplifier, and relay circuits.

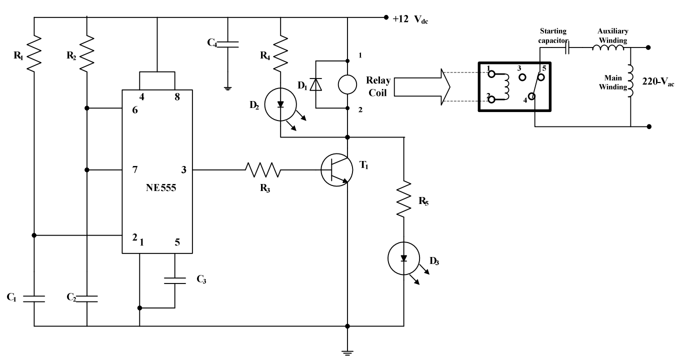

Figure 3: The Electronic Switching Circuit.

Power Supply Circuit

A 12-V transformer is used to deliver a regulated DC supply to the electronic switching circuit. Rectification was achieved with integrated circuit IN4001, a full-wave bridge rectification of the AC supply; and a 7812 three terminal integrated circuit for regulation with capacitors present for filtering and transient compensation purposes as shown in Figure 4. Diode D_2 is a power supply light emitting diode (LED) indicator with characteristic voltage drop in the forward biased condition of 2V and sinks a maximum current of 15mA. The current limiting resistor R_4 is calculated using equations 1 and 2 [3].

$$V_R = V_S - V_D \qquad \textbf{(1)}$$

$$R = \frac{V_R}{I_D} \qquad \textbf{(2)}$$

where V_s = DC supply voltage
V_D = Diode voltage drop
V_R = Voltage across resistor, R_4

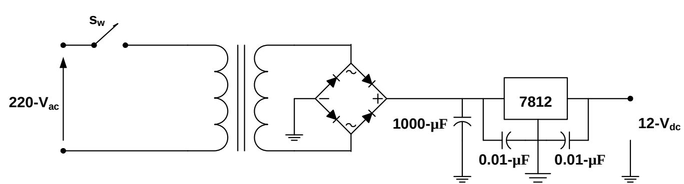

Figure 4: Power Supply Circuit.

Timer Circuit

The timer circuit designed for the cutting-out process is a monostable multivibrator circuit, and when the trigger input signal at Pin 2 goes negative, it triggers the 555 timer IC with its output pin 3 going high for a period given by Equation 3 [3].

$$T_{high} = 1.1R_2C_2 \qquad \textbf{(3)}$$

Choosing a value for C_2 and with a period of 2 seconds chosen for the cut-out time, the value of R_2 is obtained.

Amplifier Circuit

A TIP 41C transistor is used for the amplification of the output signal at pin 3 for the switching action of the amplifier circuit. By Kirchoff's law, the base limiting resistor R_3 is calculated using Equations 4 and 5 [3]. When the output of the multiviabrator goes low, the transistor switch is turned off and thus initiates the toggling action of the relay contacts. The transistor switching action is indicated by LED D_5 (this comes ON and OFF when output pin 3 goes high and low respectively).

$$I_B = \frac{(V_{CC} - V_{BE})}{R_3} \qquad \textbf{(4)}$$

$$I_B = \frac{I_C}{\beta} \qquad \textbf{(5)}$$

where the transistor gain ß = 15 and V_{BE} = 0.7 (silicon type).

Relay Circuit

Here, the switching action of the relay disconnects the starting capacitor and the auxiliary winding away from the main winding. The relay contact as shown in Figure 3 simply toggles away to contact position 3 after the relay coil has been energized. The diode D_1 ensures reverse current flow when the output of transistor goes high

CONCLUSION

With this method of switching, the possibility of arcing at the relay contacts is completely eliminated and as such ensures a smoother motor operation as compared to the centrifugal switching method. The outer frame of the single-phase capacitor start induction motor as shown in Figure 5 indicates the positions for the electronic switch and the capacitor compartments.

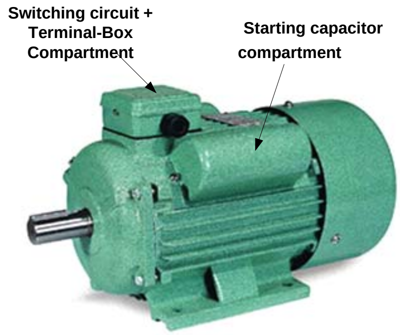

Figure 5: The Proposed Outer Frame Construction of the Single-phase Induction Motor.

The electronic switching process will lower maintenance cost as the centrifugal mechanism is completely replaced. Smaller motors are also made possible as the space usually occupied by the mechanical switch will be no more. Hence, the smaller an induction motor is, the lower the cost of constructing it.

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