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Auto Control for Three Phase Induction Motor

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Abstract

Auto Control for Three Phase Induction Motor" is one of the advancements in Electrical Machines. This paper focuses on several advancements that overcome the shortcomings, such as line dropout, single phasing, overload damage and reverse phasing present in the existing systems using 3-Phase Motors. The 3-Phase Motor controller circuit presented here is fully IC based, which is designed to work in difficult environmental conditions. This drive integrates several facilities with built-in protection for current sensing, overload control, under/over frequency cut-off along with auto-starter and off-timer. This controller is possesses major parts viz., phase sequence checker, auto-starter and current sensing circuit, motor on-off timer and power supply circuit**.**
Keyword-Three phase induction motor, Relay, Timer, Flip-flop and ICs.

Introduction

Induction motors widely used in workshops, irrigation pump sets, etc require a 3-Phase supply. Normally, these motors are connected to 3-Phase supply from electricity boards using thermal bimetal relays and relay contactors. Thermal relays protect the motor from overload. Relay coils having hold-on contacts with push-to-'on' and push-to-'off' switches are used for activating and deactivating the relay contacts.

Single-phasing, line dropout and reverse phasing are harmful for 3-phase motors. In the events of line dropout and single phasing, the motor draws a heavy current from the existing phases and during phase reversal the motor simply rotates in reverse direction. Further, an operator (attendant) for switching 'on/off' the motor is always not possible, especially when the motor has to be operated round the clock. Also the protection provided by the thermal relay in the starter assembly is inadequate, since it involves some delay in activation. Thus some damage to the windings of the motor can take place, especially if overload conditions occur frequently.

The circuit presented here incorporated the following features to overcome all the above-mentioned problems:

- Electronic sensing of phase sequence with under-frequency cut-out.
- . Current sensing for overload cut-out.
- Automatic starting/tripping.
- Programmable current sensing for single-phasing prevention.
- Timer with battery backup to count the motor's run time.
- Latching circuit to prevent the motor from frequently starting and tripping.
- Easy operation with just two switches for time set and reset.

The phase-sequence detector protects the motor before starting, while the current-sensing circuit protects it during running. This double protection makes operation really safe.

Circuit Description

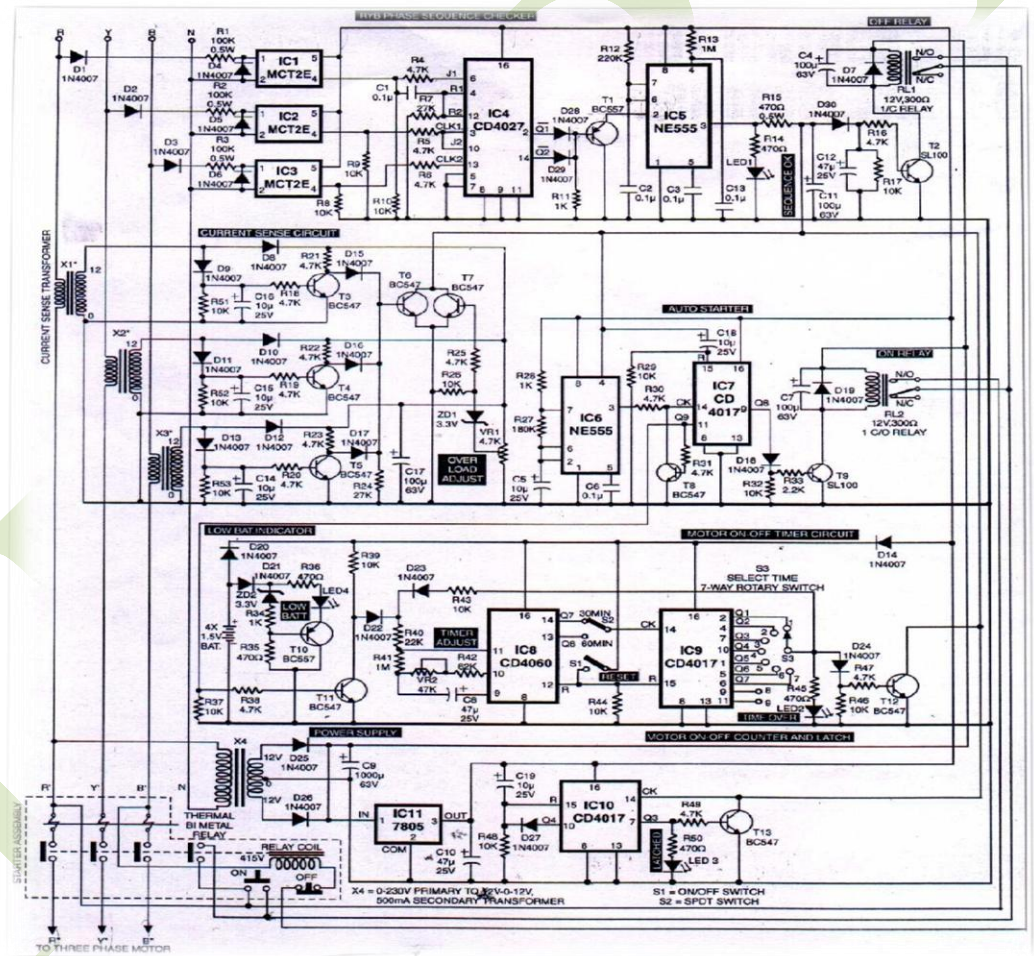

Figure 1: Schematic diagram of auto control for 3-phase [1]

A. 3-Phase sequence checker

The voltage from each of the three phases is connected to optocouplers IC1 through IC3 via rectifier diodes D1 through D3. The outputs from the optocouplers are half-wave rectified DC pulses with phase difference of 120^o (during the conduction period of diodes), which are applied to a positive-edge-triggered, dual JK flip-flop IC4.

When the red phase rises, the output of IC1 goes from 'low' to 'high', resulting in clearing of both flip-flops FF1 andFF2 through 0.1μF capacitor C1. While the red phase is still 'high', the yellow phase rises, resulting in output of IC2 going 'high' and providing a clock pulse to FF1. As a result, Q output of FF1 goes 'low' (since J1 input of FF1 is already 'high' when the clock pulse arrives at CLK1 pin). Now when the blue phase rises, the output of IC3 goes 'high', while the output of IC2 is already 'high', resulting in the output Q of FF2 going 'low'.

_ The above process repeats once during each 50Hz cycle. If Q outputs of both FF1 and FF2 are 'low', the phase sequence is correct and both diodes D28 and D29 are blocking mode. The base of transistor T1 is pulled towards ground via resistor R11 and transistor T1 start conducting. As result, IC5 is triggered and hence 'sequence OK' LED connected to pin 3 of IC5 via resistor R14, glows.

IC2 is a popular 555 timer wired as a retriggerable mono shot. Its time period is set 25 milliseconds (approx). If the mono shot is not retriggered within 25 milliseconds, the 'sequence OK' signal goes 'low'. The circuit operates smoothly at frequencies up to 42Hz.

If any of the phase fails, the phase sequence is disturbed, resulting in the output of IC5 going 'low' and 'sequence OK' LED goes 'off'. The LED status in relation to the phase sequence is shown in Table 1. The output of IC5 is also used for driving relay RL1 via transistor T2 (SL100).

Table 1

Phase sequence	Sequence OK LED	RL1
Correct	On	On
Incorrect	Off	Off

Normally-open (N/O) contacts of relay RL1 are wired in series with 'off switch of starter assembly as shown in Fig 1. Thus when phase sequence correct and frequency is above 42Hz, the relay is in energized state and it is feasible to switch on the starter by momentary energization of relay RL2, whose N/O contacts are wired in parallel with the 'on' switch of starter assembly.

B. Auto-starter and current-sensing circuit

As soon as the phase sequence is detected to be correct (as explained in previous section), the output of IC5 goes 'high'. This output, via resistor R15, is used to reset IC7 and enable IC6, besides acting as a clock for decade counter IC10.Through transistor T9 (SL100). N/O contacts of RL2 are connected across 'on' switch of starter assembly, as stated earlier and the starter's relay coil energizes. The next clock pulse to IC7 deactivates relay RL2, but starter remains in 'on' state due to hold-on contact (the fourth contact of contactor in starter assembly). When Q9 (pin 11) of IC7 goes 'high', its CK pin 14 is muted due to conduction of transistor T8 (which pulls it to ground) to prevent further counting. The Q9 output of IC7 is also used in motor 'on'/'off' timer circuit.

The supply to starter is connected through primaries of three small current transformers used for sensing the load in each phase. These transformers can be constructed using common E1 laminations generally used for power transformers. Core number 23 or 17 may be employed as per details given in Table 2.

Table 2

			(Primary)			**(Secondary)**	
Motor HP (Max)	Core size	Core area	Max amps	SWG	Turns	SWG	Turns
6 20	17 23	0.25 0.56	10 22	14 11	14 9	38 38	170 110

The secondaries of these transformers are connected to the current-sensing circuit wired around transistors T3 through T5. If any phase goes 'off', it cuts off the corresponding transistor and thereby provides forward bias to transistor T6.

The outputs of transistors T3 through T5 are wired OR via diodes D15, D16 and D17. Any excessive increase in load current (overload) results in forward biasing of transistor T7. The excess current limit can be set with the help of preset VR1.

The conduction of transistors T6 and/or T7 causes their common collector junctions to be pulled low. This 'low' signal is coupled to transistor T2 via diode D30. As a result, relay RL1 deactivates to trip the starter and thus stop the Induction Motor. The above conditions are summarized in Table 3.

Table 3:Truth Table of Current Sensing Circuit

Phase R	**Phase Y**	**Phase B**	**T6**	**T7**	**RL1**
(ON)	(ON)	(ON)	RB	RB	Energized
(ON)	(ON)	(OFF)	FB	RB	De-energized
(ON)	(OFF)	(OFF)	FB	RB	De-energized
(OFF)	(OFF)	(ON)	FB	RB	De-energized
(OFF)	(ON)	(OFF)	FB	RB	De-energized
(ON)	(OFF)	(ON)	FB	RB	De-energized
(OFF)	(ON)	(ON)	FB	RB	De-energized
In case of overloading in any phase			X	FB	De-energized
Note: RB=Reverse bias; FB=Forward bias; X=Don't care					

C.Motor on/off Counter and Latch Circuit

Frequent start and stop operations subject the motor to lot of fatigue due to heavy currents, which may damage the motor. In this circuit, automatic restarting of motor is limited to three attempts for each power 'on', by using another decade counter CD4017 (IC10). It monitors each 'on-off' cycle of the motor by advancing the count of decade counter by on every start.

The clock for IC10 is obtained from the output of IC5 via resistor R15. This point i.e. the junction of resistor R15 and diode D30 is also used as supply point for transistors T6, T7, T12 and T13 as also for reset pin of timer IC6. On the third start, pin 7 (Q3) goes 'high' and transistor T13 gets forward biased. As a result, CK pin 14 of IC10 is pulled low to stop any further clock to the decade counter, which thus gets latched and LED3 glows to indicate the latched state of the counter. Simultaneously, this 'low' signal causes transistor T2 to cut off and de-energize relayRL1. Thus the motor cannot restart automatically and only complete resumption of power can reset the latch.

D.Motor on-off timer

A timer is provided to run the motor for a predetermined time. It counts run time of the motor and thereafter switches off the motor automatically. The signal from pin 11(Q9) of IC7 is connected to the base of transistor T11 via resistor R38 (as referred in 'auto-starter and current-sensing circuit'). Thus the collector of transistor T11 goes 'low' to activate the oscillator circuit of CD4060 was inactive because its pin 11 was at logic '1', being connected to +ve rails via resistors R39, R40 and diode D22. The frequency of oscillation is set by R-C network comprising 47µF capacitor C8 and resistor R42 in series with preset VR2.

A timing of either 30 minutes or 60 minutes can selected with the help of switch S2 for the output of 'on/off' timer to go from 'low' to 'high' state. The output from the pole of switch S2 is connected to the clock input of decade counter IC9. The outputs of IC9 go 'high' sequentially after 30/60 minute time intervals, depending on the selection mode via switch S2. Thus multiples of 30/60 minute basic timing can be selected with the help of 7-way rotary switch S3. (The 7-way rotary switch may be substituted with decade thumb-wheel switch, if desired.)

The output available at the pole of rotary switch S3 goes 'high' after the selected duration of forward bias transistor T12, which in turn, causes de-energisation of relay RL1. Also, when the selected run time is over, the oscillator of IC8 (CD4060) gets inhibited because oscillator pin 11 of IC8 goes 'high' due to feedback from the pole of switch S3 via resistor R43 and diode D23. LED2 glows to indicate that run time is over. To restart the motor, IC8 and IC9 can be manually reset by closing and then opening switch S1. The timer may be bypassed by keeping switch S1 closed.

The timer section requires very low power in standby mode and is powered by four 1.5V cells as standby supply. A battery low indicator is provided to warm the user about the low battery condition.

E. Power Supply

The normal DC power supply for the circuit is provided by a small step-down transformer X4 connected between R (red) phase and neutral, followed by rectifier and filter capacitor. The unregulated voltage is used for operation of the relays, while the 5V regulated supply is used for remaining circuit.

Constructionand Testing

Before connecting the circuit to starter assembly, a bench test is required for the adjustment of timer. Apply 3-phase power to the circuit. Observe pin 3 of IC5 (NE555), which should go ‘high’, provided the sequence is correct. Else, interchange any two phase wires. As ‘sequence OK’ signal at pin 3 of IC5 goes ‘high’, relay RL1 energizes and IC6 (NE555) is activated. As a result, relay RL2 energizes after a delay of 15 seconds for one second.

Now adjust preset VR2 such that 30-minute duration pulse train (time Period 60 minutes) is available at pin 14 of IC8 (CD4060). Flip switch S2 to 30-minute position. Select the required run time using rotary switch S3. On completion of the selected run time, ‘time over’ LED should glow and the timer should stop. Relay RL1 should de-energise.

After resetting the timer with the help of switch S1, relay RL1 should energise once again. Then after a delay of 15swconds, relay RL2 should again energise for one second. Now short momentarily pin 14 of counter CD4017 (IC10) to ground thrice. On the third touching, Q3 of IC10 will go ‘high’ and LED3 will glow, followed by de-energisation of relay RL1. The mains should be interrupted completely to reset IC10.

Over-current adjustment can be done only after connecting the load. Connect all the wires to the starter point and the load. Keep wiper contact of VR1 towards ground side and switch on the 3-phase supply. Relay RL1 activates. After 5 seconds, relay RL2 also activates and the motor Starts running. Now slide the wiper of VR1 and mark the position just before the motor trips. (Reminder that such trips will be counted with bare hands).

Caution

Some parts of this circuit contain live 3-phase voltages. So avoid touching the circuit with bare hands.

Conclusion

This paper provides protection schemes for three phase induction motor from the faults such as phase failure, phase reversal, over voltage and over load with the help of IC’s.

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