An Improvement in Winding Protection of Three Phase Induction Machine Using Solid State Relays

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Abstract: Now-a –days due to advancement in technologies the various optimization in the induction motor is done but the stator winding in the three phase induction motor remains the vulnerable part due to overloading and low voltage problems. Our project is to reduce the winding melting due to overheating by various problems such as over load, over& low voltage, electro-mechanical relay failure and fuse failure.

Key words: Winding Protection, sensing circuits, Hall Effect, pump load

I. INTRODUCTION

Our main objective is to design a cost effective, reliable and accurate hard ware system to measure the current, voltage and temperature parameters and control the induction motor to provide the maximum protection against winding failures.

II. SYSTEM ANALYSIS

A. Existing System Analysis
The two existing system is analyzed and the proposed system is developed. The existing systems are
- Mechanical system of protection.
- Microcontroller system of protection.

B. Drawbacks:
The electromagnetic relay does not actuate properly due to mechanical faults such as rusting, life span etc., and also this existing system is also not accurate.The microcontroller based starter is not cost effective and if fault occurs cannot in the program may not be serviced.

C. Proposed System:

The proposed system is based on the hardware sensing and control unit using the solid state relay. The proposed system utilizes the low cost dedicated IC's which provide accurate protection to the motor. The proposed system is mainly designed for the agricultural purpose rectifying the faults in the mechanical and microprocessor systems.
The proposed system consist of two major hardware units,
- Sensing unit
- Control unit

III. FAULT DETECTION

In order to protect the induction motor the sensing circuits are necessary to provide the feedback data to the system. A sensor (also called detector) is a converter that measures a physical quantity and converts it into a signal which can be read by an observer or by an (today mostly electronic) instrument. Here we use three sensors,

- Voltage sensor
- Current sensor
- Temperature sensor

The proposed system uses three types of the parameter for the measurement of faults. Hence the faults in the voltage, current and temperature can be identified and each parameter is dependent on one another and hence the accurate fault identification is done.

A. Faults In Induction Motor
The faults in the induction motors are broadly classified into
- Electrical Fault
- Mechanical Fault

IV. MOTOR PROTECTION

Here the motor failure occurs due to the following faults,
- Over voltage
- Under voltage
- Over current
- Over temperature
- Phase faults
- Insulation failure
- Mechanical bearing faults

The proposed system identifies and measure above faults and provides the protection for the induction motor.

V. DESIGN OF SENSOR CIRCUITS

In order to protect the induction motor the sensing circuits are necessary to provide the feedback data to the system. A sensor (also called detector) is a converter that measures a physical quantity and converts it into a signal which can be read by an observer or by an (today mostly electronic) instrument. Here we use three sensors,

- Voltage sensor
- Current sensor using acs712
- Temperature sensor using NTC thermistor

A. *Voltage Sensing*
Voltage sensing is done by comparing the voltage across the bridge rectifier in the power supply circuit. Since the voltage across the bridge rectifier is linear with the input

voltage supply, it can be directly given to the comparator for comparing the signal with the reference signal and if it is lower or higher the comparator will provide the desired output. The design explains the use of LM7805 voltage regulator to obtain a constant 5v power supply from variable power supply. The voltage is stepped down to 12v by step down transformer and fed to bridge rectifier for rectification to DC. The capacitors are used to reduce the ripples in the dc voltage and to provide pure dc voltage. The voltage across the rectifier is linear to the input voltage and hence the over and under voltage detection can be done at the rectifier stage. The voltage is then given to LM339 comparator to obtain accurate measurement of over and under voltages.
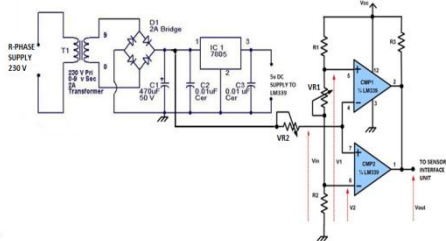

Fig 5.1 voltage comparator using lm339 limit window comparator

To analyze the circuit above; first we assume that the VR2 is equal to 10K; Again the R1, VR2 and R2 will form the voltage divider circuit to both V1 and V2:

$V1 = ((R2 + VR2) / (R1 + VR2 + R2)) x Vcc = 2/3 Vcc$
$V2 = (R2+R1 / (R1 + VR2 + R2)) x Vcc = 1/3 Vcc$

The input voltage is the dc voltage output from the rectifier

Vcc = voltage after the rectifier bridge

Here we provide the voltage of constant 16v as the supply to the circuit

$V1=((10k + 20k) / (10k + 20k+ 10k)) * 16=12.5v$
$V2=(10k + 10k / (10k + 20k + 10K))*16=8v$

Hence the upper limit is set as 12.5v and lower limit is set as 8v. Here 16 vdc is proportional to the 240v of input ac supply which is kept as upper limit called over voltage condition and 8v dc is proportional to the 181 v of ac supply which is kept as lower limit called as under voltage condition.
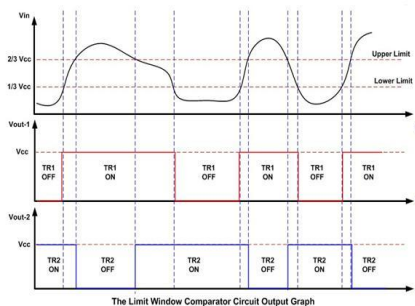

Fig 5.1.2 Output graph for the voltage sensing

B. Current Sensing
Current sensing is the important parameter to be measured in the protection of the three phase induction motor as the major fault in the induction motor causing the winding

damage is the over current faults. ACS712 is the current sensing integrated circuit designed by Allegro Devices. It works on the principle of Hall Effect sensing of current. Here the over current parameter is only measured because the over current only damages the windings of the induction motor. The above parameter is only sufficient for the protection of the induction motor.

Here to measure the over current which means only the upper limit is needed and hence the comparator is kept in the single upper limit comparator mode. The ACS712 current sensor generates **2.5v**vout at the zero current condition hence the output is in the range of **2.5v** to **5v** for the **20A** rating.

$V+= (R2 / (R1 + R2)) x Vcc$
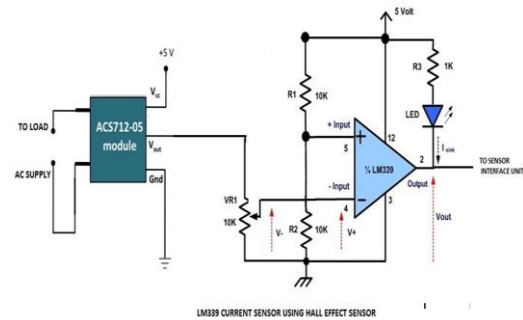$V+ = (10 / 37) x 12 volt = 3.33 volt$

Fig 5.2 Current sensor

Here the current sensor value of **3.33v** represent the over current condition for the given motor load of **5HP** and hence the current flow above the rated **10.8A** for the motor provides the over load condition and comparator provides a fault signal. Here the above circuit provides the protection from the over current condition.
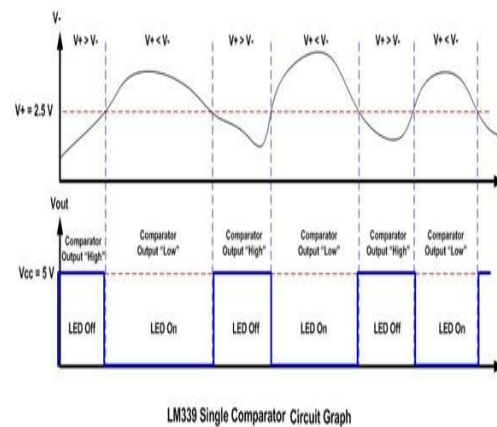

Fig 5.2.1 over current circuit graph

C. Temperature Sensing
The temperature sensing is the important parameter because winding damages is due to the over temperature. The NTC thermistors are made from a pressed disc or cast chip of a semiconductors such as a sintered metal oxide. They work because raising the temperature of a semiconductor increases the number of electrons able to move about and carry charge- it promotes them into the conduction band. The more charge carriers that are available, the more a material can conduct.

Here NTC thermistor resistance decreases as increase in temperature and hence more current flows through the comparator and if the voltage exceeds the reference voltage then the comparator generates logical '1'. Here the comparator is operated in upper limit mode.
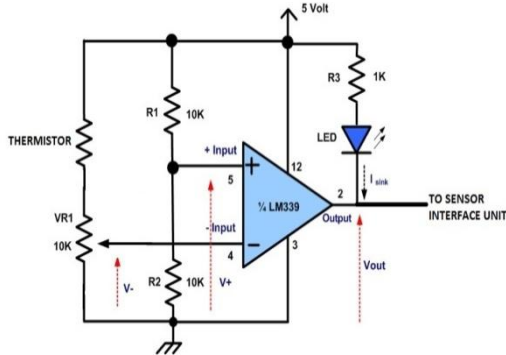

Fig 5.3 temperature sensing circuit

Consider the R1 and R2 be 10k,
$V+ = (R2 / (R1 + R2)) \times Vcc$
$V+ = (10 / 20) \times 12\ volt = 6\ volt$
the induction motor normal operating temperature is **80 degree centigrade**. The thermistor is **10K ohms**. Hence the temperature of 80 degree produces the input voltage signal of **5.7v** and the reference voltage as 6v is set if the voltage exceeds the reference voltage the comparator produces the logical '1' otherwise swing to logical '0'.
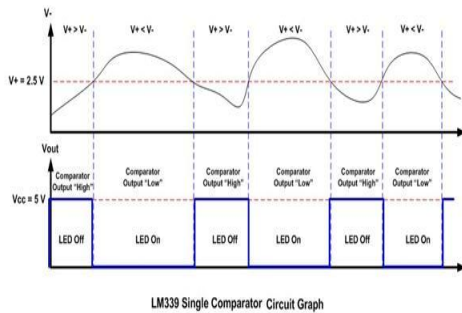

Fig 5.3.1 output graph of temperature sensing circuit

D. Design Of Delay Circuit:
The delay circuit provides then basic timer IC NE555 is used for generating the time delay to switch on or switch off the sensor units.

E. Starting Current Delay:
The induction motor has the higher starting current. This is due to the fact that initial torque to drive the load is larger and hence the induction motor draws 3 to 4 times larger current than the normal load current. During this period the over current sensor shows the fault condition and hence the delay must be given to initiate the starting of induction motor. Here we use the NE555 in the monostable mode to produce the starting delay of 3 seconds. The motor needs only a second to return to normal condition hence we set the three second delay to initialize the motor running.
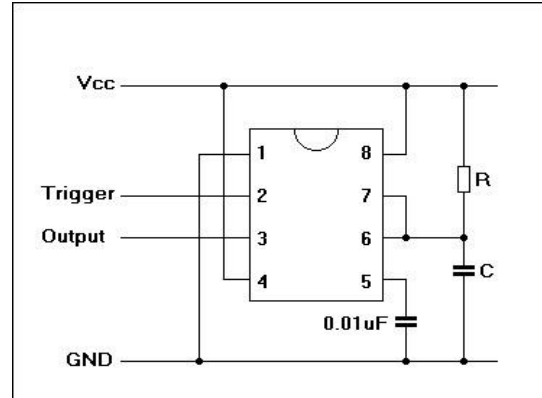

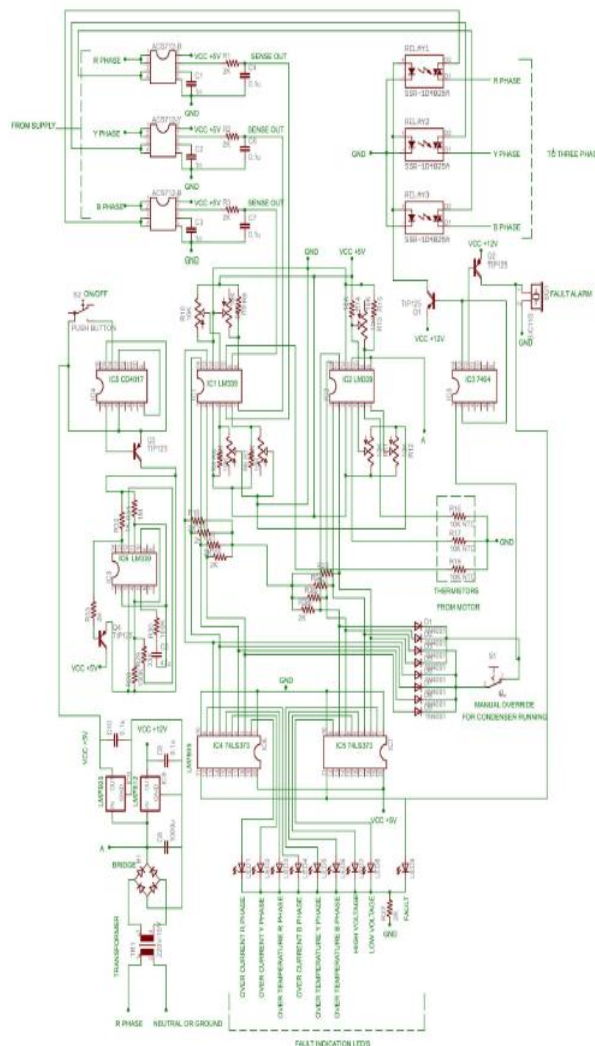Fig 5.4 Monostable mode of NE555

The time delay can be calculated as below,
Time Out Delay (sec) = 1.1 * R * C
Considering capacitor value to be 470uF and delay to be 3 sec,
*3=1.1*R*470, R=173K ohm*
Hence from the above circuit, if trigger is given then the timer provides a logic '1' after three seconds and gets latched until the power supply to the timer is isolated.

F. Block Diagram

VI. FAULT LATCHING CIRCUIT

A latching switch is a switch that maintains its state after being activated. A push-to-make, push-to-break switch would therefore be a latching switch - each time you actuate it, whichever state the switch is left in will persist until the switch is actuated again.

Fault latching is very important in the above circuit since when the fault occur the motor should be disconnected before the fault increases causing damages. The latch circuit prevents the motor to restart until the fault condition is cleared. The latch circuit provides the protection to the motor during faults.

Here the timer IC NE555 is used for the latching of the FAULT latching. Here NE555 is kept at bi-stable mode. When the trigger is given then the latch is set until the reset or power off is done. Hence this circuit is suitable for latching.
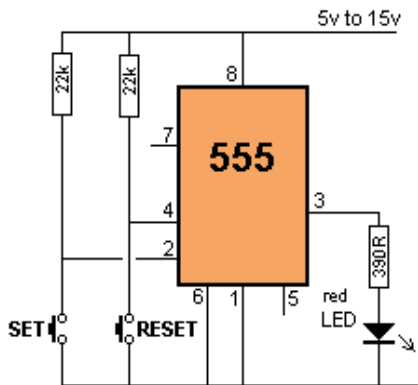

Fig 8.1 Latching using NE555

A. *Fault Indication Circuit*:

Fault indication is important in case of trouble shooting during faults. The type of fault should be known before trouble shooting for the faults. The output from the comparator is given to latch IC 74373 and given to the led's for fault indication. The buzzer is additionally added to alert about the occurrence of the fault. The fault indication is important for the trouble shooting.

VII. SOLID STATE RELAY CONTROL CIRCUIT

Solid state relay is best preferred to the mechanical and electromagnetic relay. A **solid-state relay (SSR)** is an electronic switching device in which a small control signal controls a larger load current or voltage. It consists of a sensor which responds to an appropriate input (control signal), a solid-state electronic switching device which switches power to the load circuitry, and some coupling mechanism to enable the control signal to activate this switch without mechanical parts. The relay may be designed to switch either AC or DC to the load. It serves the same function as an electromechanical relay, but has no moving parts.

The control signal must be coupled to the controlled circuit in a way which isolates the two circuits electrically. Bi-directional solid state relay with opto-isolation. Many SSRs use optical coupling. The control voltage energizes an LED which illuminates and switches on a photo sensitive diode (photo-voltaic); the diode current turns on a back-to-back thyristor, silicon controlled rectifier, or

MOSFET to switch the load. The optical coupling allows the control circuit to be electrically isolated from the load.

Tip 122 is the darling pair power transistor driver used for switching of the loads such as dc motors, lights etc., Tip has the low output impedance and high current driving capacity. The TIP122 is silicon epitaxial-Base NPN power transistor in monolithic Darlington configuration mounted in TO-220 plastic package. It intended for use in power linear and switching applications.

Darlington transistors or Darlington pair is two transistors connected together so that the current amplified by the first is amplified further by the second transistor. The overall current gain is equal to the two individual gains multiplied together.

VIII. PCB DESIGN

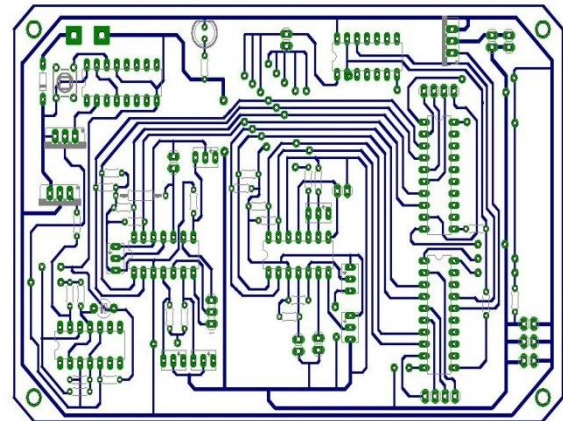PCB design for the complete hardware is done using eagle 5.6.0.
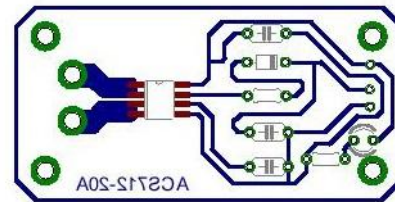

Fig 8.1Main Board design using EAGLE
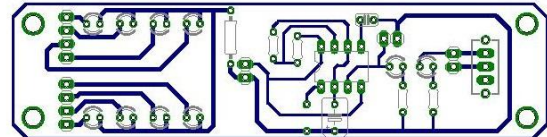

Fig 8.2 Current Sensor Board design using EAGLE

Fig 8.3 LED fault indication board using EAGLE

IX. OPERATION

Initially the project kit is powered ON. The starting current delay circuit is switched on which provides a delay of 3 seconds. The output of the circuit is provided to the driver circuits of control circuit and latch circuit. The latch circuit becomes online after three seconds of power on if the fault exists the latch circuit operates to latch the fault and to disconnect the power supply to the remaining circuits. The control circuit containing comparators of voltage, current and temperature sensors will only be switched on after a initial delay of 3 second. If any prevailing fault occurs the control circuit sends the faults signal to fault indication circuit. The fault indication board

consists of led fault indicators and fault alarm circuit to enable alarm to alert of the incoming fault. When the fault occurs the relay driver isolates the relay from switching ON the motor. Hence the motor is isolated in case of any fault including temperature, over current and voltage faults.

Since this project is based on agricultural pump motors , if motor is needed to be operated on the two phase using condenser or at the low voltage conditions, an additional provision of manual override which isolates the current and voltage sensors alone but the temperature sensor still be always online hence the winding protection is ensured. The manual override system provides additional provision in case of emergency operations. The reset circuit operates when any fault occurs. If the fault occurs in the voltage or current sensors during emergency operations the manual override can be enabled to reset the circuit and operates under voltage and current faults. In case of over temperature fault the motor cannot be operated since the latch circuit latches even in the manual override enabled condition since this has the higher risk of winding failure

X.   TESTING

The testing of the system in which the motor is connected to the kit which is given three phase supply and the test result shows absolute positive results in the operation of the induction motor. Three motors are taken as sample for testing. The load is provided in the form of pump load used for the irrigation purpose.

A. Test Motor Specification And Without Fault Condition

Table I
Test Motor Specification

RATED VOLTAGE	415 V
RATED CURRENT	11A
FREQUENCY	50Hz
PHASE	3 PHASE
HP	5HP
RPM	1420
WINDING INSULATION	CLASS B
WINDING WIRE	1.40mm-WIRE, 0.40mm-INSULATION
BEARING TYPE	ROLLER THRUST BEARING

Table II
Result Of Test On Sample Motor Without Fault

RPM	1426
VOLTAGE	211.6 V
STARTING CURRENT	24.1 A
RUNNING CURRENT	12 A
FREQUENCY	49.9 Hz
TEMPERATURE BEFORE STARTING	31.6℃
TEMPERATURE DURING RUNNING	52℃
LOAD	PUMP LOAD
FAULT	NO
MOTOR HEALTH	GOOD

Table III
Result of Test on Sample Motor with Fault

RPM	1376
VOLTAGE	181 V
STARTING CURRENT	35.3 V
RUNNING CURRENT	16.3 A
FREQUENCY	50.1 HZ
TEMPERATURE BEFORE RUNNING	72 DEGREE C
LOAD	PUMP
FAULT	PHASE TO PHASE IN WINDING CAUSING OVER CURRENT AND DROP IN VOLTAGE
EFFECT ON MOTOR	WINDING FAILURE
MOTOR HEALTH	BAD

From the above test it shows that any fault in the induction motor has its effect on motor's input voltage, input current and motor temperature. Hence measuring the above parameters provide the detection of all types of faults in the induction motor

XI.   ADVANTAGES

1. The life span of the motor increases up to three years.
2. Applicable for all types of induction motors and wide ratings.
3. Easily installed for agricultural motors and provides maximum protection.

I.   CONCLUSION

Hence our project aims at protection of motors used in agriculture. It uses the very low cost IC's for the temperature and current sensing and operation and our project is cost–effective and it is immense use to the farmers and servicing can be done easier in case of any faults. Our project provides maximum protection to the motor and hence the life span of induction motor is increased. This project reduces the winding faults in motors use for agriculture and hence reducing the risk to the farmers.

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BIOGRAPHIES

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