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Star Delta Starter Using Soft Switch For Low Power Three Phase Induction Motors

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ABSTRACT

The project is designed to provide low voltage start to induction motors. This is achieved by using star to delta conversion. Star/Delta starters are probably the most common reduced voltage starters in the 50Hz industrial motor world. Star delta is used in an attempt to reduce the start current applied to the motor. Thereafter, full load current is applied to the motor. The Star/Delta starter is generally manufactured from three contactors; and electromechanical timer and a thermal overload for operating a 3 phase motor at 440 volt at ac mains supply 50 Hz. A thyristorised star/delta switch is proposed as a soft starter and energy saver for delta connected induction motor drives. A Gate-Turn-Off (GTO) thyristor switch and its gate drive circuit have been developed as a replacement for the relay contact switch.

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INTRODUCTION

This project uses a system to start a 3 phase motor at 440 volt AC mains supply 50 Hz with a set of 12 volt DC Power GTOs in star mode first and then to delta mode by an electronically adjustable timer. A set of Power GTOs are used to shift the motor connections from star to delta with a time delay. The project is supplied with 3 phase 3hp motor i.e., two lamps representing each phase winding of the motor. The interlocking arrangement of the Power GTO and the electronic timer are all wired in low voltage DC of 12 volt fed from an inbuilt DC power supply for safe handling of the starter during the study. It still retains its application for a 3 phase motor starting with single phasing prevention also. During star operation the lamps would glow dim indicating the supply voltage across the coils are 440/√3. In delta condition after the timer operates the lamps would glow with full intensity indicating full supply voltage of 440volts. The timer comprises of a 555 in mono-stable mode the output of which is fed to a Power GTO for changing the mains supply from 3 phase star to delta. The project also has the provision of single phasing protection since 3 phase motors get burnt if any one phase goes missing during running. The output to the lamps shall be completely cut-off in the event of any phase failure.

Types of Three phase Induction Motor starters:

- Direct on Line Starter.
- Stator Resistor Starter.
- Auto Transformer Starter.
- Star-Delta Starter.

Star delta starter:

This starter is used in an attempt to reduce the start current feed to the motor during start as a way of dwindling the disorder and intervention on the electrical supply. The Star/Delta (Wye/Delta) starter is one of the lowest cost electromechanical reduced voltage starters. Voltage reduction during starting the motor windings are connected in star configuration is 230V across each winding; this reduces the torque by a factor of three. Voltage reduction during running the motor windings are connected in delta configuration is 400V across each winding.

Table1: Stator voltage.

Voltage across stator of 3Ø IM	Star (Phase-Neutral)	Delta (Phase-Phase)
	230 V	415 V

The schematic diagram of stator connection of 3Ø IM is shown below Fig 1:

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1.1 ***Existing Electromechanical Star-Delta Starter Consists Following Units****:*

1) Contactors (Main, star and delta contactors).
2) Time relay (pull-in delayed).
3) Three-pole thermal over current release.

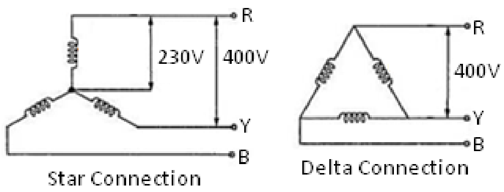

Fig. 1: Star and Delta Connection.

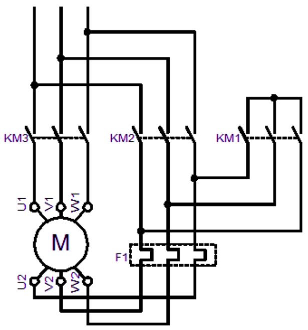

Fig. 2: Electromechanical Star-Delta Starter.

2.2 Principle of operation electromechanical Star-delta Starter:

The main contactor connects the reference source voltage R, Y, B to the primary terminal of the motor U1, V1, W1.In operation, the Main Contactor (KM3) and the Star Contactor (KM1) are closed initially, and then after a period of time, the star contactor is opened, and then the delta contactor (KM2) is closed. The control of the contactors is by the timer (K1T) built into the starter.

2.3 Disadvantages of electromechanical Star-delta Starter:

- Very heavy transients and stresses are produced while changing from star to delta connections and because of these transients and stresses many electrical and mechanical break-down occurs.
- The load torque is low at the beginning of the start and increases with the square of the speed. When motor reaches approximately 80-85 % of the rated speed the load torque is equal to the motor torque and the acceleration ceases. To reach the rated speed, a switch over to delta position is necessary, and this will very often result in high transmission and current peaks.
- The transition from star to delta transition usually occurs once nominal speed is reached, but is sometimes performed as low as 50% of nominal speed which make transient sparks.
- Since electromechanical relays are used control over speed cannot be implemented anywhere in the starter.

Proposed Method:

The proposed star delta starter utilizes GTO instead of electromechanical relays (K. Sundareswaran and B.M. Jos, 2005).

Gate Turn Off Thyristor (Gto):

3.1 What is GTO? How does GTO work?

The Gate turn off thyristor (GTO) is a four layer PNPN power semiconductor switching device that can be turned on by a short pulse of gate current and can be turned off by a reverse gate pulse. Symbol of GTO is shown in fig-3 below.

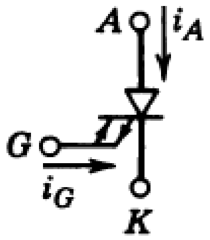

Fig. 3: GTO symbol.

As shown the Symbol has three terminals namely Anode (A), Cathode (K) and Gate (G). The two-way arrow convention on the gate lead distinguishes the GTO from the conventional thyristor.

3.2 Preference for GTO:

- There is no need for an external commutation circuit to turn it off.
- The device is turned on by a positive gate current and it is turned off by a negative gate cathode voltage.
- This reverse gate current amplitude is dependent on the anode current to be turned off.
- The circuits built by this device are compact and low-cost.

3.3 What are the advantages of GTO?

The prime design goal of GTO devices are to achieve fast turn off time and high current turn off capability and to enhance the safe operating area during turn off. The GTO's turn off occurs by removal of excess holes in the cathode base region by reversing the current through the gate terminal.

- High blocking voltage capabilities
- High over current capabilities
- Exhibits low gate currents
- Fast and efficient turn off
- Better static and dynamic dv/dt capabilities

3.4 What are the disadvantages of GTO?

- On state voltage drop and the associated loss is more.
- Gate drive circuit losses are more.
- Its reverse voltage blocking capability is less than the forward voltage blocking capability.

- Magnitude of latching, holding currents is more than SCR due to multicathode structure.

Reductions Of Using Star Delta Starter:

One major disadvantage of the star delta starting is the reduction in the starting torque from 1038 Nm to 343 Nm (by approximately 67%) (Henk de Swardt, 2007).

The reason for these 67% changes becomes clear when we examine the phase voltage on the motor, we see that the phase voltage when the motor is connected in Delta is 380 Volt. When the motor is however connected in Star, the Phase Voltage will be 219.3 Volt. The relations for star and delta connections are as listed in Table 2:

Table 2: Stator voltage and current during Star and Delta.

	Star	Delta
Voltage	$V_{Line}=\sqrt{3}V_{Phase}$	$V_{Line}=V_{Phase}$
Current	$I_{Line}=I_{Phase}$	$I_{Line}=\sqrt{3}I_{Phase}$

Thus, when the motor is started in the star connection, the phase voltage of the motor is reduced by a factor of √3□ .

The reductions in starting current, starting power and starting torques for a reduced Voltage can each be calculated by using equation 1 (This ignores other factors like saturation, etc.):

Reduction in Value [%]

$$= \left[1 - \left(\frac{Nominal\ Voltage}{Reduced\ Voltage}\right)^2\right] x\ 100\ldots\ldots \quad (1)$$

If we apply this equation for the star delta starting, we see from equation 2 where the 67% reduction comes from:

Reduction in Value [%]

$$= \left[1 - \left(\frac{V_{Line\ Delta}}{V_{Line\ Star}}\right)^2\right] x100\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$= \left[1 - \left(\frac{V_{Phase}}{\sqrt{3}V_{Phase}}\right)^2\right] x100\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$= \left[1 - \left(\frac{1}{\sqrt{3}}\right)^2\right] x100 = 66.66\%$$

Principle Of Operation Of Proposed System Using Gtos:

In this project six GTOs are used G1, G2, G3, G4, G5 and G6. During STAR GTOs G1, G2, G3 are connected to the terminal U1, V1, W1 and G4, G5, G6 are connected U2, V2, and W2 to neutral. During DELTA GTOs G1, G2, G3 are connected to the terminal U1, V1, W1 and G4, G5, G6 are connected U2, V2, and W2 to U1, V1, W1. During Delta all the six GTOs are utilized. When the main is switched on after a time delay of 2 seconds the microcontroller provides gate signal of +5V to turn ON the GTOs G1, G2 and G3 the motor starts running in STAR connection later after a time interval of 20s the microcontroller switch OFF the STAR GTOs by providing -12V, then microcontroller switch ON the DELTA GTOs by providing +5V to the gate of GTO G4, G5 and G6. Therefore the motor is move operated in delta connection. The schematic diagram of proposed starter is shown in the fig 4.

Schematic star delta starter using GTOs:

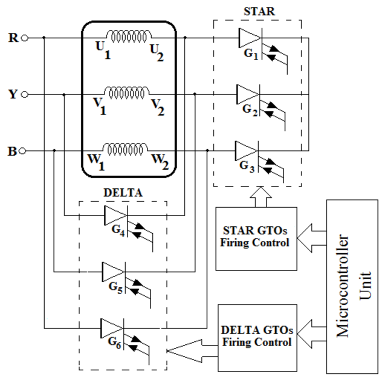

Fig. 4: Proposed STAR-DELTA starter using GTOs.

Hardware implementation of the star delta starter using GTOs:

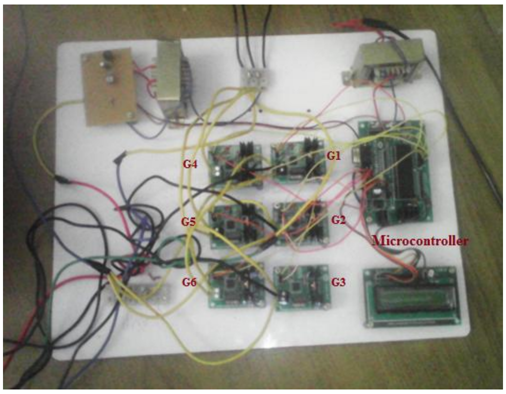

Fig. 5: Hardware implementation of STAR-DELTA starter using GTOs.

Conclusion and Future Scope:

- An automatic voltage fluctuation protector system has been implemented for protection of induction motor.
- The assembly unit is very compact and portable.
- The cost of constructing this project is relatively low as compared to its function.
- It can therefore be easily commercialized.
- In feature the GTO can be replaced with SCR for high power ratings.

- Since semiconductor switches are used ZCS and ZVS in possible.
- Along with this by changing the gate triggering power converter can also be incorporated.
- The parameters can be monitored and controlled will be easy while using the semiconductor switches.

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