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Automatic Bidirectional Starter For Induction Motor

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Abstract

In the present scenario the power demand is the main problem to be considered while starting new industries. Almost every industry will be using high power rating motors and for starting the high power rating motors, starters are used. Star-delta starter is the most commonly used starter for starting of an induction motor. In star-delta starter, the motor is started in star and during running condition it is changed to delta connection. In star connection starting current and torque is less compared to delta. In automatic bidirectional star-delta the motor connection can be made both from star-delta and delta-star. In the no load condition the motor requires less power to run. Hence in no load condition motor changes to star connection and in star connection motor can be loaded upto 50% of full load. When motor loading exceeds 50% of full load the connection is made to delta. Thus the conversion from star to delta and vice versa is decided by the motor loading. As current consumed by the motor is directly proportional to the load, by sensing the current to the motor the loading of motor is determined. When the motor is on no load condition, the current drawn by the motor will be less and the connection will be changed to star connection whereas under full load conditions the connections will be changed to delta. With automatic bidirectional starter the power consumption is reduced with star connection with motor operated under no load condition this is not possible with conventional star-delta starter.

Keywords- automatic bidirectional starter, star-delta, delta-star, starting current, torque, motor loading, no load condition, power consumption.

I INTRODUCTION

The aim of this work is to reduce the energy consumption of industry motors by using the Automatic Bidirectional star-delta starters. This type of starter is applicable for different load duty motor. The effects of Motor Starting on Industrial and Commercial Power Systems is explained in [1].

In general star-delta starter, start with star connection and run in delta connection. Conversion of star to delta takes some time delay, set in timer. Once the motor is changed to delta connection it cannot be changed to star in normal starter. The controlled starting of AC induction motors is discussed in [2] and reduced voltage starting methodology for Squirrel Cage Induction Motor is proposed in [3].

In automatic bidirectional star-delta both star-delta and delta-star conversion is possible. In star connection the power connection is $1/3^{rd}$ compared to delta. The current is directly proportional to the load, when the load increases the current also increases. Conversion of star-delta and delta-star is based on the current drawn by the motor. By using the thermal overload relay when the current reaches the set value, the relay operates, changes the contact to a new position from the original position. Thus the star connection is changed to delta connection and the motor can be loaded to full load. When the load is reduced under current relay gets activated and it makes contact connection to change. Thus the delta connection is changed to star and the motor can be loaded to 50% of the load.

The contactors are used to change the motor connection from both star-delta and delta-star. Connections are made in starter terminal. The value of current is set based on the motor rating. Solid state AC motor starters for Pulp and Paper Industry has been discussed in [4].

II AUTOMATIC BIDIRECTIONAL STAR-DELTA STARTER

The conventional way of starting a motor with KW rating more than 10hp is usually done using a star-delta starter. The motor initially starts running with its winding in star form. Once it picks up the speed, when more loading is given to the motor the connection is changed to a delta form, which gives more torque to the motor.

Star-delta starters are generally used in situations where we want to reduce the inrush current to the motor when it starts. When a starter closes on a motor wired in delta, it can draw as much as seven times its running current. This can create heavy stress on the power grid system. When a motor starter starts in star it draws far less inrush current to the motor windings there by reducing the load on the grid. The optimization techniques for three phase induction motor has been proposed in [5].

In delta connection, at no load motor draw more power compared to star connection. At no load condition motor is changed to star connection by using the current sensor relay and at loaded conditions, the connection is changed to delta automatically using overload relay.

The conversion of star-delta and delta-star is based on the current flow in the circuit.

In star connection,

$$V_L = \sqrt{3}\, V_{ph} \quad (1)$$

$$I_L = I_{ph} \quad (2)$$

In delta connection,

$$V_L = V_{ph} \quad (3)$$

$$I_L = \sqrt{3}\, I_{ph} \quad (4)$$

The power diagram of automatic bidirectional star-delta starter is shown in the figure 1.The main circuit breaker serves as the main power supply switch that supplies electricity to the power circuit. The main contactor connects the reference source voltage R, Y, B to the primary terminal of the motor as shown in figure 1.

In operation, the main contractor and star contactor are closed initially, and then after increase in load cause increase in current. When the current reaches to the set value the relay operate and star contactor is opened, and then the delta contactor is closed. The control of contactors is by the current sensor relay built into the starter. The star and delta are electrically interlocked and preferably mechanically interlocked as well.

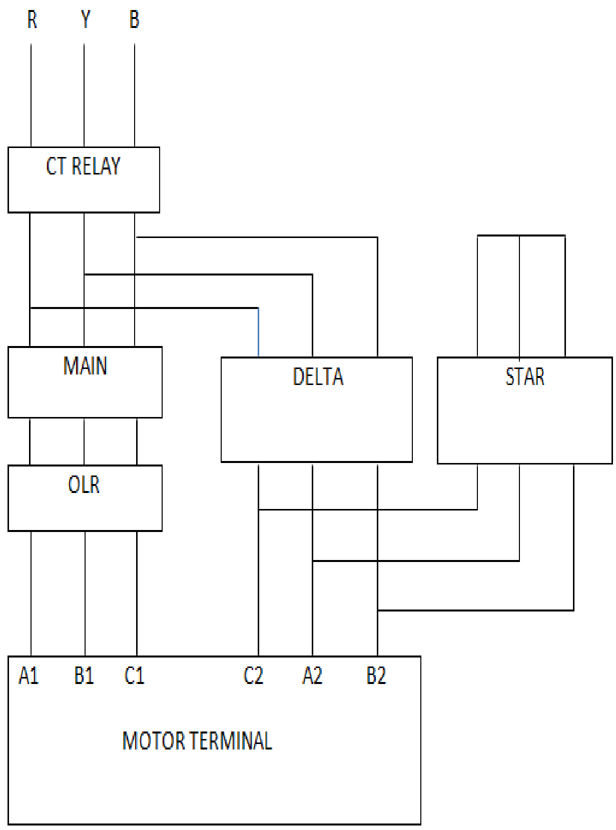

Figure 1 Power diagram of automatic star-delta starter

In load condition motor run in delta connection which produces more current to motor to drive full load. When load is reduced the under current relay sense the level of current and waits for set value of time to change to star.

In no load condition motor run in star connection at 1/3 of delta current. In star connection motor can be loaded up to 50% of full load. Increase in current cause the overload relay to change to delta connection. Based on the loading nature star and delta connection of the motor terminal is changed to reduce the power drawn by the motor. Energy efficient Induction motor design has been proposed in [7].

The star contactor serves to initially short the secondary terminal of the motor for the start sequence during the initial run of the motor from standstill. This provides 1/3 of DOL current to the motor, thus reducing the high inrush current inherent with large capacity motors at startup.Methods and Economics for starting large induction motors is explained in [6].

CONTROL DIAGRAM

Control of interchangeable star connection and delta connection of an AC induction motor is achieved by means of a star delta or wye delta control circuit. The control consists of push button switches, auxiliary contacts and a timer.

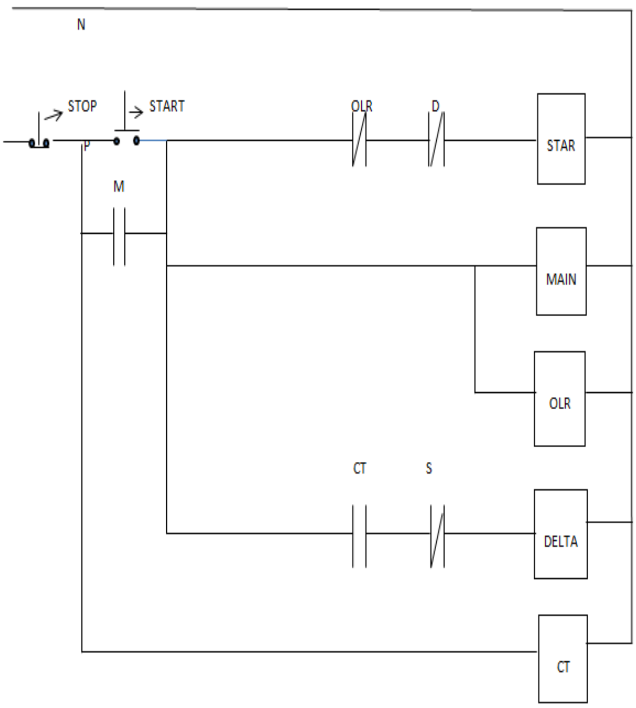

Figure 2 Control diagram of automatic bidirectional star-delta starter.

After pushing the ON push button switch, the auxillary contact of the main contactor coil which is connected in parallel across the ON push will become NO to NC, thereby providing a latch to hold the main contactor coil which eventually maintains the circuit active even after releasing the ON push button switch. When main contactor closes it connects the motor in star until the current reaches the set value. As when the current reaches the set value the OLR contacts in the star coil circuit will change its position from NC to NO and at the same time auxiliary contactor in delta circuit change its position from NO to NC. Now the motor terminal connection is changed from star to delta connection.

A normally close auxiliary contact from both star and delta contactors are also placed opposite of both star and delta contactor coils, these interlock contacts serves as safety switches to prevent simultaneous activation of both star and delta contactor coils, so that one cannot be activated without the other deactivated first. Thus, the delta contactor coil, cannot be active when the star contactor coil is active, and similarly, the star contactor coil cannot be active while the delta contactor coil is active. During delta connection when the current goes below the set value then the current sensor activate and its timer get to start. Over load relay and under current relay get activated based on the current to motor and change the connection of motor to either star or delta based on the load.

The control circuit shown in the figure 2 also provides two interrupting contacts to shut down the motor. The OFF push button switch break the control circuit and the motor when necessary. The thermal overload contact is a protective device which automatically opens the STOP control circuit in case when motor overload current is detected by the thermal overload relay, this is to prevent the burning of the motor in case of excessive load beyond the rated capacity of the motor is detected by the thermal overload relay.

III SIZE SPECIFICATIONS FOR OVER LOAD RELAY AND CONTACTORS

For a star-delta starter there is a possibility to place the overload protection in two positions, in the line or in the windings.

Overload relay in line:

Overload relay in line is same as putting the overload relay before the motor as with a DOL (Direct On Line) starter.

The rating of overload relay (in line) =Full Load Current (FLC) of the motor.

Overload relay in winding:

Overload relay in the winding is the case where the overload relay is placed after the point where the wiring to the contactors are split into main and delta. The overload relay measures the current inside the windings.

The setting of overload relay (in windings) =0.58*Full load current (line current).

Size of main and delta contactor:

There are two contactors that are close during the run, often referred to as the main contactor and the delta contactor. These are auxiliary contactors rated at 58% of the current rating of the motor.

Size of main contactor = (Full load current) *(0.58)

Size of star contactor:

The third contactor is the star contactor and it carries star current while the motor is connected in star. The current in star is 1/√3= (58%) of the current in delta. The star contactor is the auxiliary contactor rated at one third (33%) of the motor rating.

Size of star contactor = (Full load current)*(0.33)

IV ANALYSIS OF AUTOMATIC BIDIRACTIONAL STAR-DELTA STARTER

For the purpose of analysis a three phase induction motor with 5hp, 7.5A, 415V, and 0.8pf is taken into consideration. The no load voltage and current are determined and is tabulated in table 1 as below.

Table 1 No load voltage and current for star and delta connection

S.No	Parameters	Star connection	Delta connection
1.	No load voltage	1.5 A	4.5 A
2.	No load current	415 V	220 V

In star connection,

$$V_L = \sqrt{3}\, V_{ph} \tag{1}$$

$$I_L = I_{ph} \tag{2}$$

In delta connection,

$$V_L = V_{ph} \tag{3}$$

$$I_L = \sqrt{3}\, I_{ph} \tag{4}$$

$$\text{Power } P = \sqrt{3} V_L * I_L * \cos\phi \text{ watt} \tag{5}$$

Computations:

For star connection,

$$I_L = I_{ph} = 1.5A$$

$$V_L = \sqrt{3}\, V_{ph}$$

$$V_L = \sqrt{3} * 415 = 719\,\text{V}$$

Power P = $\sqrt{3} V_L * I_L * \cos\phi$ watt

$$P = \sqrt{3} * 1.5 * 719 * 0.8 = 1496\,\text{watts}$$

For delta connection,

$$V_L = V_{ph}$$

$$I_L = \sqrt{3}\ I_{ph}$$

$$I_L = \sqrt{3} * 4.5 = 7.8\,\text{A}$$

Power P = $\sqrt{3} V_L * I_L * \cos\phi$ watt

$$P = \sqrt{3} * 220 * 7.8 * 0.8 = 2378\,\text{watts}$$

Table 2 Comparison of Power Consumption by Induction motor with conventional starters and bidirectional starters under lightly loaded condition

S.No	Power consumption by Induction motor with conventional starters under lightly load condition	Power consumption by Induction motor with bidirectional starters under lightly loaded condition
1.	2378 W	1496 W

Table 2 gives the comparison of Power consumed by the induction motor with conventional starters and bidirectional starters. Power consumed by the motor with conventional star-delta starters is **1496** watts under lightly loaded condition and the power consumed by the motor with bidirectional starters is **2378** watts under lightly loaded condition. From the power consumption figures we infer that under lightly load conditions the power consumed by the motor in star connection is less compared to motor running under delta connection. Hence under no load condition the power consumption can be reduced by changing the connection from delta to star. Optimized control of high efficiency Induction motors in CT and HVAC applications is explained in [8] and Energy Efficiency of Induction Machines has been proposed in [9].The bidirectional starters serves for the purpose of reduced power consumption under lightly loaded conditions, less power dissipation under light loaded conditions and increased life time of the motor.

V HARDWARE SETUP OF AUTOMATIC BIDIRECTIONAL STAR-DELTA STARTER

NO LOAD STAR CONNECTION

The figure 3 below indicates the contactor connected in star. The figure 4 represents ammeter and voltmeter readings that gives the value of current and voltage observed during lightly loaded and no load condition with the contactor connected in star. Methods for the control of large medium voltage motors have been proposed in [10].

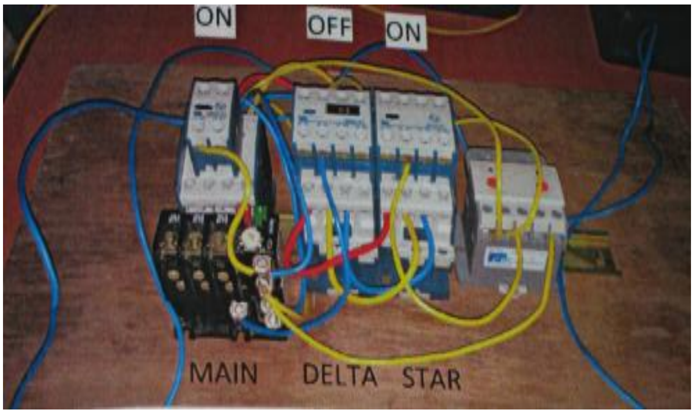

Figure 3 Contactor connected in star connection

Figure 4 Ammeter and Voltmeter records the voltage and current under lightly loaded and no load condition

NO LOAD DELTA CONNECTION

The figure 5 below indicates the contactor connected in delta. The figure 6 represents ammeter and voltmeter readings that gives the value of current and voltage observed during lightly loaded and loaded condition with the contactor connected in delta.

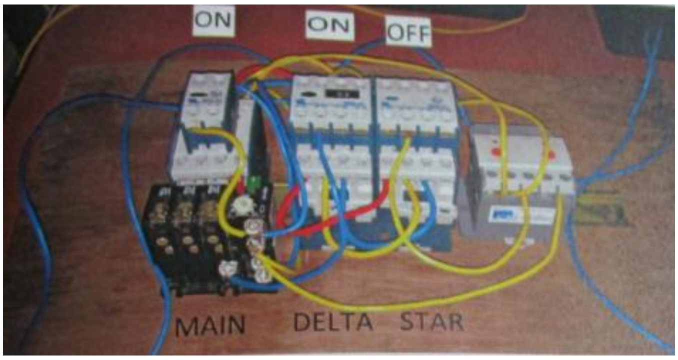

Figure 5 Contactor connected in delta connection

Figure 6 Ammeter and Voltmeter records the voltage and current under lightly loaded and loaded condition

HARDWARE MODEL

The figure 7 represents the hardware setup of the automatic bidirectional star-delta starter. Three phase supply connections are given to the contactor as shown in figure 7.The hardware setup is checked for its working under lightly and heavily loaded conditions as proposed in figures 3, 4, 5 and 6 respectively. Starting of high Inertia loads and Efficiency improvement with Thyristor controllers is proposed in [11] and [12] respectively.

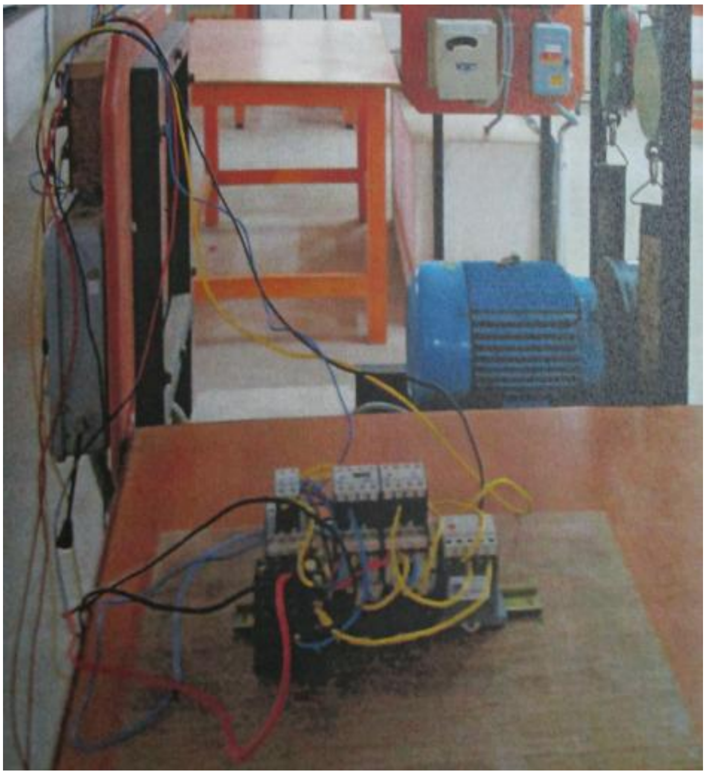

Figure 7 Hardware setup of the automatic bidirectional star-delta starter

RESULT

From the proposed work we infer that the bidirectional transformation is made on motor connections from star to delta (under full condition) and from delta (under lightly loaded condition or no load condition).

In conventional unidirectional star-delta starters motor keeps on running on the delta connection once if the transformation is made from star to delta irrespective of the loading condition whether. This means that motor will consume 3 times the current as the case with star connection even for light load condition which is not acceptable because of energy wastage and excessive heating effects. This signifies improper use of power for its loadability.

The bidirectional starter provides a solution to this problem. The bidirectional transformation prevents the energy wastage of the motor and excessive heating by shifting the motor connections back to star connection under lightly load condition or no load condition. Through bidirectional transformation of motor connections from star to delta under heavily load conditions and from delta to star under lighly loaded condition with serve for optimum utilization of the motor power for its loadability. The optimum utilization of the motor capacity will result in benefits like energy savings, cost benefits and increased lifetime of the motor. The benefits of motor starting and operation with medium voltage AC adjustable speed drives is proposed in [13].

SCOPE FOR FUTURE WORK

Automatic Bidirectional star-delta starter for variable load application is proposed in this work. This work can be extended with electronic devices and PLC can be tested for varying load condition for industrial applications.

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