Induction Motor Starting Using Soft Starter

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Abstract- **An induction motor has the ability to self start but its starting create many issues to motor as well as power system. The characteristics and performance of induction motor can be changed. This is mainly because of high starting current than rated current. Mechanical and thermal stress can be occur in the motor and load due to high starting current. Many different starters such as Star-Delta Starter, Auto-Transformer Starter, DOL Starters are use for safe starting of induction motor. But these methods cannot rectify the starting problem of induction motor. A soft starter is a new device and is used for smooth starting of induction motor. Soft starter reduces the starting current and torque of the induction motor. Soft starters are particularly used for medium voltage motors. Soft starter uses solid state devices like thyristors to control the supply voltage. Transients during ON and OFF processes of switching are a major concern for the SCR. During transient , the current rise rate di/dt can pass through the thyristor can damage them. The aim of this paper is focused on protection of induction motor during starting, and limiting di/dt to safe level by adding an inductor in to the soft starter circuit.**

Index Terms- Di/dt, Silicon Controlled rectifier (SCR), soft starter, switching transients.

I. INTRODUCTION

An induction motor has the ability to self start but its starting creates many issues to motor as well as power system. The operators must take these into the account while choosing starting methodology of induction motor. The characteristics and performance of induction motor can be changed during the starting of motor. This is mainly because of high starting current than rated current. Mechanical and thermal stress can be occur in the motor and load due to high starting current.High voltage fluctuation, swell and sags, can be present in the power system during the starting of the motor. A soft-starter is a solid-state electronic deviceused for smooth starting of induction motor. Soft starter reduces the starting current and torque of the motor. Soft starters are particularly used for medium voltage motors. Soft starter uses solid state devices like thyristors to control the supply voltage.

The thyristors used in the soft starters are oppositely parallel connected. Soft starter add flexibility in the motor operation. It control starting current, torque, voltage and can be easily adjusted based on the different loadings. It can consist of mechanical or electrical devices, or a combination of both. Mechanical soft starters include clutches and several types of couplings using a fluid, magnetic forces, or steel shot to transmit torque, similar to other forms of torque limiter. Electrical soft starters can be any control system that reduces the torque by temporarily reducing the voltage or current input, or a device that temporarily alters how the motor is connected in the electric circuit.Two types of soft-starters are the voltage ramping and current limiting types.

The voltage ramping soft-starter gradually increases the voltage from present value to the rated voltage, which provides a smooth starting. The current follows the voltage for voltage ramping soft-starters.

The current limiting soft-starter senses the current at the motor so its firing angle is controlled and the voltage is regulated to maintain the desired current. Aim of the soft starters is focused on protection of the motors, pulsating torques, harmonics, and power system.

II. TYPES OF SOFT STARTERS

1. Primary Resistor

It is the first soft starter comes in to operation. A resistor is connected to each phases of motor as shown in fig 1. When the motor comes into operation, the resistors resist the current flow to motor and resulting in voltage drop. When the motor accelerate to pre-determined speed, then the resistors will be disconnected using bypass contactors and supply will be connected directly to the motor.

Primary resistor starter provide smooth starting of the motor. For extra-smooth starting, add additional stages of resistor and contactor.

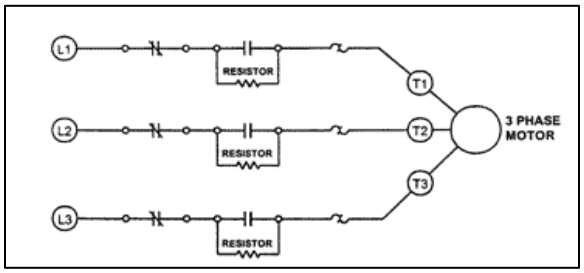

Figure 1: Primary resistance soft starter

2. Auto Transformer

It is the enhancement of Star-Delta starter. The voltage applied to the motor is reduced by using transformer taps. The tapping range of the Autotransformer starter is from 50% to 80% of the supply voltage. The user can select the best taps which is suitable of particular application. Once the taps are selected, it cannot be changed. There are basically two configurations for Autotransformer starter i.e., open transition starter and closed transition starter.During the starting period of an open transition starter, a reduced voltage is applied to the motor until it reaches acceleration determined by the transformer taps. Once it is achieved, the contactor connecting the transformer taps to the motor are disconnected and a bypass contactor is used to connect full supply directly to motor for achieving full speed. During the time of motor is re-connected to supply, current spikes will be generated which can damage the winding of the motor.To overcome this problem, closed transition starters like the Korndorffer starter was developed.

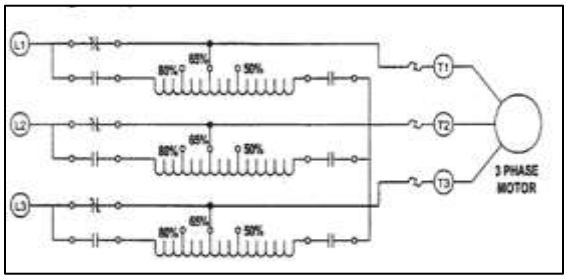

Figure 2: Auto Transformer Starter

3. Part Winding

In this method the winding of the motor is divided into two or more different sets. During the starting of the motor, the power is given to only one set of winding. As motor generates its speed, power is applied to all sets of the motor windings for the normal operation of motor. As a result the windings get energized and produce reduced starting current and torque.

4. Star Delta Starter

It is a reduced voltage starter. In star delta starter, the voltage is applied in star configuration which reduces its voltage to each phase by 58% of the rated voltage. As a result, the starting current and torque are reduced by 33.3%.When the motor reaches 70% of its rated speed, the supply connecting to the motor changes from star configuration to delta configuration. Thus allowing full supply voltage to flow to the motor.

The problem faced in this method is spikes occurs during the transition from star configuration to delta configuration. This is called open transition star delta starter. To rectify this problem, a closed transition starter was developed which uses series resistors to eliminate the current spike. The disadvantage of this starter is the reduced torque and it does not provide speed control. Figure 3 shows the star delta starter.

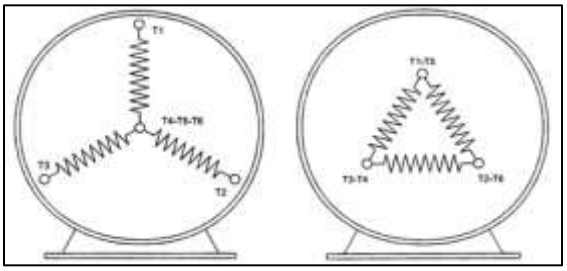

Figure 3: Star Delta Starter

5. Solid State Soft Starter

Solid state soft starter is the latest soft starter that replaces all the mechanical components with electrical components. The solid state soft starter consist of oppositely parallel thyristors connected in each phases of the motor as shown in fig 4. During starting, contactor C2 is open and C1 is closed. Thyristor gradually turn on and control the speed of the motor until it reaches full speed. When the thyristor is fully on, contactor C2 gets closed. Thus full power is applied directly to the motor. Solid state soft starter has the ability to control the starting current and torque. Thyristor has the capability to rapidly switch heavy currents. This provide the smooth starting operation for motor

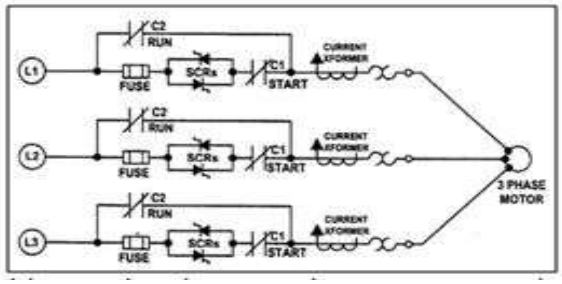

Figure 4: Solid State Soft Starter

III. WORKING PRINCIPLE

Soft starter operate on the principle by adjusting the applied voltage to the motor during starting. It consist of three opposite parallel thyristors as regulators, connected between and supply and the motor stator. While starting the motor, the thyristors output voltage increases gradually. Motor accelerate till the thyristor is fully turned on. The smooth start is achieved by starting the motor at rated voltage. When the motor reaches rated RPM, the startup process is completed, a bypass contactor is used by the soft starter to bypass the thyristor to provide rated voltage to the motor. In order to reduce the thyristor heat loss, extend the soft starter service life and improve efficiency.

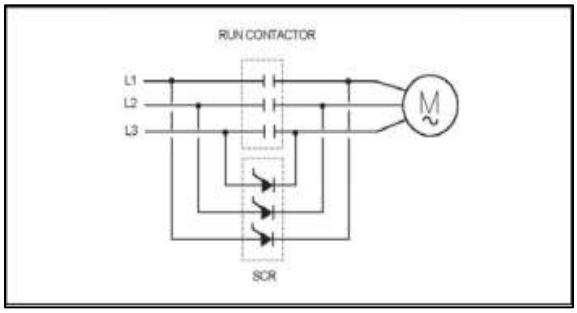

Figure 5: Circuit Diagram of Soft Starter

IV. SCR PROTECTION IN SOFT STARTER

The major concern for the SCR driven soft-starter are the switching transients during "on" and "off" processes i.e., current rise rate di/dt during switching "on", and over voltages dv/dt during switching "off". Due to inherent capacitance, high current rise rate is present. When current rise rate di/dt passing through the SCR it can damage them. When the SCR is on, then the current through the SCR is controlled by external impedance connected to the circuit and applied voltage. At the beginning period of turning-on, only a small area near the gate conducts the current. If the current increases too fast, overheating will be taken place and resulted in damaging of the SCR. Switching on transient current on soft starter is shown in figure 6.

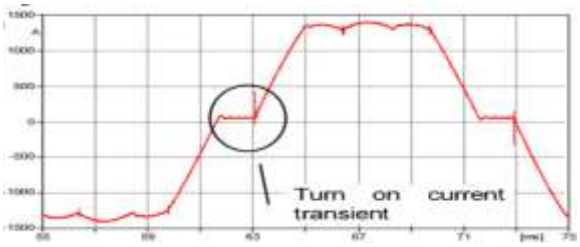

Figure 6: Switching on transient current of Soft Starter

V. SCR PROTECTION METHODS

SCR may face different types of threats during its operation due to over voltages, over currents etc. There are different types of thyristor protection schemes available for satisfactory operation of the device like

1. Over voltage protection

Over voltage protection scheme is very important because thyristors are very sensitive towards over voltages. Over voltage transients is the main reason for thyristor failure. By inserting a non-linear resistor can limit over voltage to some extent. During normal operation it offer very high impedance but when voltage exceed the rated value then it offer low impedance path to protect thyristor.

2. Over current protection

The fault occurs in the circuit are responsible for the generation of over current. Due to the presence of over current, iron losses are increasing which resulted to heating of the thyristor and finally burns the device. Circuit breakers are used to protect the SCR against over current. During high surge current, fast acting fuses are used to protect SCR.

3. High dv/dt protection

When the thyristor is in forward blocking mode, the junction J2 will be reverse biased. The leakage current through the J2 increases with increase in dv/dt i.e. rate of change of applied voltage across the thyristor. This leakage current can turn on the thyristor even in the absence of gate pulse. This is called dv/dt triggering and it can be limited by using snubber circuit in parallel with the device.

4. High di/dt protection

When a thyristor is turned on by gate pulse then charge carriers will rapidly spread through its junction. But if di/dt i.e. rate of change of anode current is greater than the spreading of charge carriers then local hot spots are generated. It can damage the thyristor. To prevent high rate of change of current and to limit local hot spots an inductor is connected in series with the device.

5. Thermal protection

When the temperature in the junction is increasing, it can affect the insulation. So proper steps has to be taken to limit the temperature rise. This can be achieved by mounting the thyristor with high thermal conductivity metals like Aluminum, Copper etc. Aluminum is mainly used because of its low cost. The different types of mounting techniques for SCR are – Lead-mounting, stud-mounting, Bolt-down mounting, press-fit mounting, press-pack mounting etc.

VI. SOFT-STARTERS BASIC CONFIGURATIONS

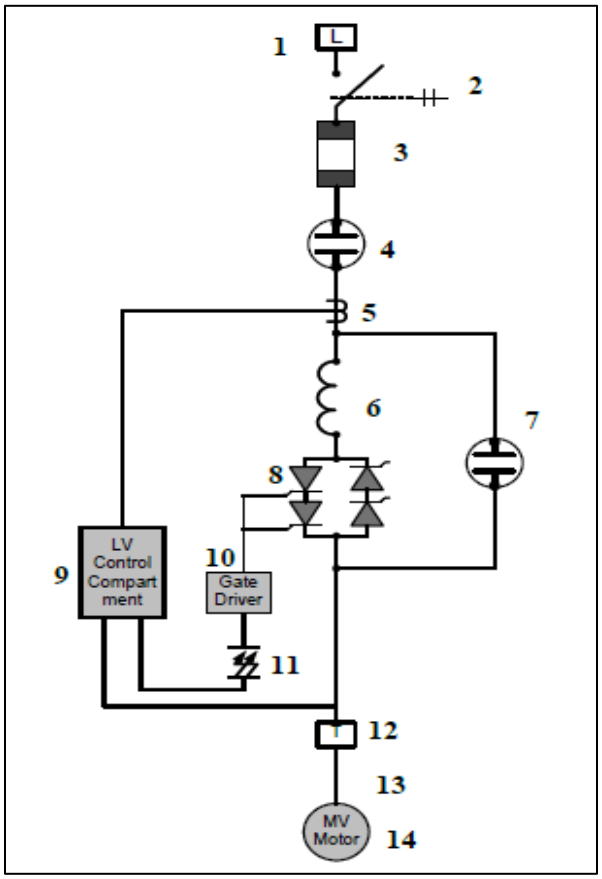

Figure 7: Soft Starter Basic Configurations With Inductor

Fig. 7 shows basic configurations of the medium voltage soft-starter comprising of power grid, load break switch with grounding bar, motor fuse, line isolation vacuum contactor, voltage transformer, inductor, bypass contactor, SCR, low-voltage control compartment, gate driver (isolation transformer), optic fibre cable, motor starter output terminals, power cable, and medium voltage motor.It consist of parallel thyristors connected in reverse configuration to each other. An inductor can be inserted to limit the di/dt to the level that is safe for the SCRs operation. The inductor can be connected before or after the thyristors, and must be inside the bypassing loop of the contactor.

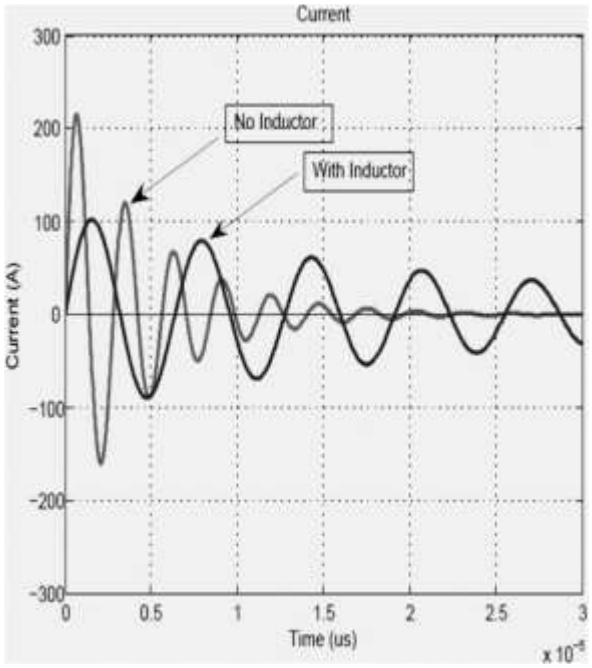

Figure 8: Switching on transient current with and without Inductor

VI. CONCLUSION

An induction motor has the ability to self start but its starting creates many issues to motor as well as power system. The characteristics and performance of induction motor can be changed. This is mainly because of high starting current than rated current.Mechanical and thermal stress can be occur in the motor and load due to high starting current. A soft starter is a new device and is used for smooth starting of induction motor. Soft starter reduces the starting current and torque of the induction motor. Soft starters are particularly used for medium voltage

motors. Soft starter uses solid state devices like thyristors to control the supply voltage.The soft starter consist of parallel thyristors connected in reverse configuration. The aim of the soft starter is focused on protection of induction motor during starting, and limiting di/dt to safe level by adding an inductor in to the soft starter circuit.An inductor is inserted to limit the rate of rise of current di/dt to the safe level. The inductor can be connected before or after the thyristors, and must be inside the bypassing loop of the contactor.It can be concluded that the best and most suitable starter to be used in fixed speed applications is the Soft Starter because of low inrush current at starting thus minimizing maintenance cost when compared to conventional starters.

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