Automatic Slip Dependent Rotor Starter for Slip Ring Induction Motor

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Abstract— Most of the industry use automatic rotor starter for large slip ring induction motor like sugar, steel, chemical industries. ARS with dynamic buffer of slip ring induction motor which connected as external resistance is connected into three phase rotor winding through the slip ring shaft. The large motor in many industries are driven by induction motors. These motors create a problem of high starting currents leading to voltage dips, large thrust on motors and jerks on equipment. This paper deals with ARS starter based on the resistance create by using losses that proportional to rotor speed (MAGNA). The use of MAGNA helps in optimizing power system, increase the life of component, reducing the capital cost and enhancing motor efficiency.

Keywords: Rotor Resistance Starter (ARS), Automatic Rotor Resistance Starter with Slip Regulator, RS, FCMA Rotor Starter, ASR & RC (Rotor Controller)

I. INTRODUCTION

Most of the industries use electrical power in large quantities. As such, optimization is needed for reducing the life cycle cost of the entire establishment in term of capital cost, ease of operation and maintenance, energy cost, minimum downtime and maximum availability of scheme. It is also important to avoid disturbances in the power system in term of overloading and others effects such as voltage and frequency dip, so that other users get a stable and clean power supply.

With the advancement of technology there has been a clear trend in the deployment of larger rated motor to improve the mechanical and electrical efficiency, as well as reduce the overall capital cost. Rotor starters are mainly used for the motor starting applications where requiring high-starting torque like loaded belt conveyors in industry. Induction start motors however pose a problem of large starting current (typically four to eight times the full load current/rotor current), which can disturb the power system in terms of voltage and frequency dips. Moreover, sudden uncontrolled acceleration of the motor from standstill may create large reverse thrusts on the mechanical and civil foundations as well as jerks on the drive elements.

This paper deals with an automatic slip dependent rotor resistance starter/controller (ARS) technology based on the principle of losses that proportional to rotor speed (MAGNA) to achieve jerk less starting of large motor with substantially reduced starting current. The ARS are now single drives for sugar, steel, chemical industries and Cane, Chopper, Leveler, Fibrizor applications.

II. GENERAL BENEFITS OF ARS STARTERS FOR INDUSTRIES

ARS starters benefit the industries from the electrical mechanical, and civil aspects in the following manner:

- Reduced starting current limits.
- Control the starting current through an MAGNA.
- Step less and less time duration starting.
- Lower fault level allows economical selection of cables and switchgear.
- Smooth acceleration (In figure 1) to full speed reduces electrical stresses in the motor and mechanical wear.
- It is possible to improve design efficiency of the motor by relaxing the direct online (DOL) starting current limit.
- Magna Start is ideal for inching, reversing and plug braking without any additional controls in the rotor circuit.
- Running motors while limiting the starting voltage dip through an MAGNA.
- Though physically smaller than conventional systems, the large thermal capacity of Magna Start permits the starting of high inertia loads without problems.
- Magna Starter requires only one shorting contactor, reducing overall system complexity, size and cost.
- Magna Starter has no moving parts and does not use liquids or chemicals. Magna Starter will give many years of service without any maintenance or adjustment.
- The robust construction permits heavy usage under the most arduous conditions. Comprehensive thermal protection prevents any possibility of damage.

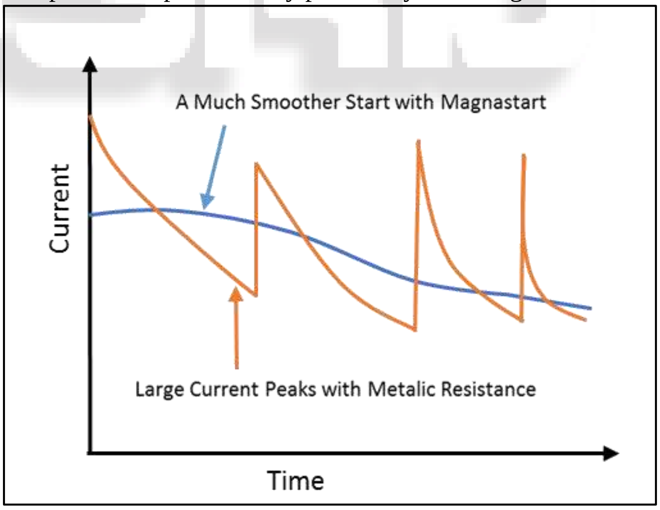

Fig. 1: Acceleration Curve for Current and Time

III. WORKING PRINCIPLE OF ARS

For the optimal performance of the ARS and achieving maximum system benefits several technical considerations are important. The fundamental function of the starter is to accelerate the motor combination smoothly with the least possible starting current value and in the optimum time. When the motor starts from zero speed the rotor frequency equal to supply frequency and rotor starter resistance is maximum. The rotor voltage of the slip ring motor is governed by the following equation.

Vr = s x RVss

Where Vr represents the rotor voltage at slip s, s represents per unit slip, RVss represents the rotor voltage at standstill. With the increase in motor speed the rotor voltage decreases. Thus if the rotor current is to be maintained constant torque, the starting resistance has to be decreased as the motor accelerates.

Rrs/Ph = [(RVss/1.73)/(RA x p.u. Torque)]

Where Rrs/Ph = equivalent star resistance of rotor starter in ohms

RVss/1.73 = rotor phase voltage in volt

RA = rotor current in amps (rated)

p.u. Torque = desired motor torque at standstill per unit value

The reduction in rotor starter resistance with increase in motor speed (decrease in rotor frequency) is automatic and stepless. The MAGNA starter essentially modulates the motor characteristics during starting for system optimization. The starting current is minimized and torque is controlled to ensure correct acceleration in optimum time. The plots in Figure 2 elaborate the starting performance of a typical motor drive.

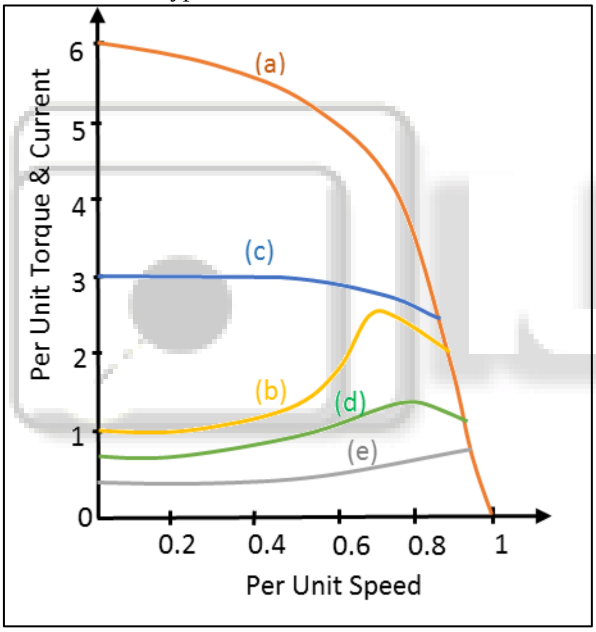

Fig. 2: Acceleration Curve for Current and Time

(a) – Motor current DOL (b)– Motor torque DOL

(c) – Motor current MAGNA (d) – Motor torque MAGNA

(e) – Motor load torque

The curve set which is drawn for a typical application brings out the following criteria:

- It is ensured through MAGNA that the motor torque is always larger than the motor torque demand by 0.1 per unit (10 percent margin) ensuring gradual and continuous acceleration. This criterion is very important to prevent, dwelling at critical speeds and torque.
- The DOL starting current, which is six times full load current, is brought down to 1 to 3 times with MAGNA starter.
- The resultant reduced starting current remains constant in the acceleration range and then drops down to the normal value.
- The DOL current curve shows a drop in the current as the speed increases. The MAGNA starter provides a voltage increment just enough to compensate for this droop and keep the reduced current constant.
- The voltage increment is reflected as a gradual increase in motor torque.
- The transition from starter mode to run mode (MAGNA bypass) is a smooth closed transition and no current kick is observed.

IV. ELECTRICAL CONNECTIVITY OF THE ARS STARTER

The ARS starters can be easily integrated into new electrical schemes. The MAGNA to be connected in the rotor side of the motor as shown in Figure 3. The operational sequence of the connections is as follows:

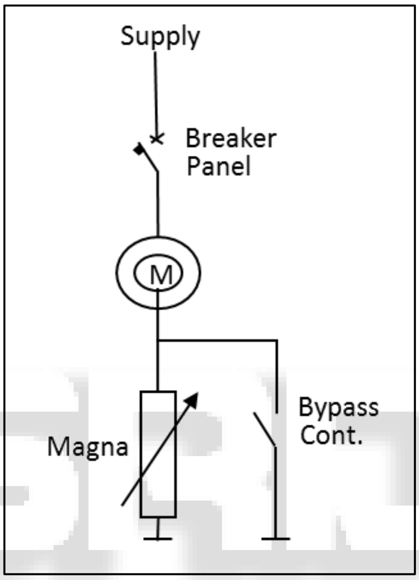

Fig. 3: SLD of Rotor Starter

- The motor is started by MAGNA circuit.
- The MAGNA provides high impedance to limit the
- motor starting current to a low value.
- As the motor accelerates, the built-in run mode contactor automatically bypasses the MAGNA through a time, speed, or current signal in a step less manner thus providing incremental manner thus providing incremental voltage and torque to the motor while keeping the current constant at reduced value. The motor voltage is incremented from the initial low value (typically 50 percent) to approximately 95 percent as the motor speed.
- The entire starting sequence is monitored by a supervisory control and interlocked with the main circuit breaker.
- The motor now operates at full rotor voltage.

V. DESIGN CONSIDERATION OF THE MAGNA

MAGNA starters work on the principle of impedance control by eddy currents in these cores are reflected in the windings as impedance, which is dependent on rotor frequency. When power is applied to the motor, the frequency in the rotor is the same as that in the stator. As the motor accelerates, the rotor frequency and the inducer impedance decrease. This results in a smooth acceleration to full speed at which point the slip-rings are short circuited.

$$r \alpha f$$

where r represents the resistance, f represents the rotor frequency. As the motor speed increases the resistance of magna base ARS reduces slip to keep the constant current & torque so that the load is accelerated. The Magna Start inducer consists of 3 coils wound on specially shaped mild steel (MS) cores/plates. The heavy mass of core material allows the inducer to absorb a considerable amount of heat. The advanced thermal insulation protects the coils that remain relatively cool and several consecutive starts may be obtained on drives with high inertia loads.

A. *Electrical Characteristic and Performance*

Magna Starter design ensures that a high power factor (0.8 or more) is maintained in the rotor circuit in order to prevent excessive starting currents being drawn. Magna Start also provides a good linear characteristic of impedance against frequency (a graph of impedance v/s slip is shown in Figure 4) so that a constant current is drawn and the same torque is delivered during the run-up. This enables the fastest possible run-up time within a given current limit. Any current lower or in excess of the above value will give lesser torque.

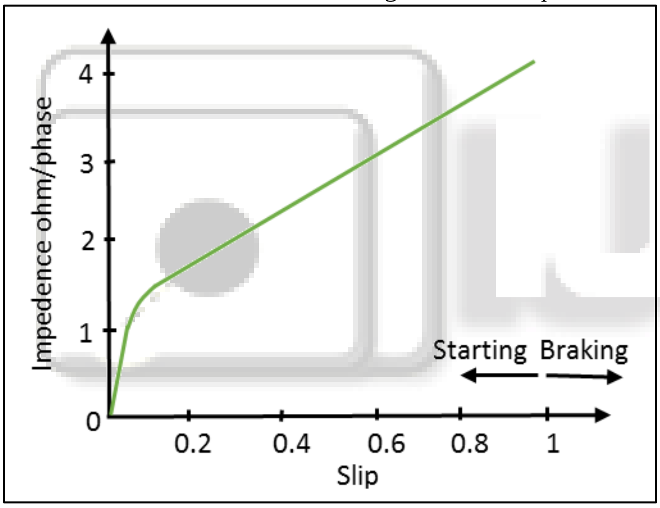

Fig. 4: Curve of Impedance and Slip.

B. *Physical Properties of Mild Steel*

Mild steel is a type of low carbon steel. Carbon steels are metals that contain a small percentage of carbon (max 2.1%) which enhances the properties of pure iron. The carbon content varies depending on the requirements for the steel. Low carbon steels contain carbon in the range of 0.05 to 0.25 percent. There are different grades of mild steel. But they all have carbon content within the above-mentioned limits. Other elements are added to improve useful properties like corrosion resistance, wear resistance and tensile strength. Some mild steel's physical properties are as follows:

- High tensile strength
- High impact strength
- Good ductility and weld ability
- A magnetic metal due to its ferrite content
- Good malleability with cold-forming possibilities
- Not suitable for heat treatment to improve properties

As copper is an excellent conductor of heat, it's good for heat exchangers, heat sinks, and even saucepan bottoms and steel is a poor conductor of heat, it's good for high-temperature environments. Below some parameters of MS plate are as follows:

1) Resistivity of MS (ρ) = 0.00000014 ohm-meter
2) Density at 20˚C (δ) = 7.85 gm/cm^3
3) Specified Heat (S) = 477.1 J/Kg ˚C
4) Conductor Length (l) = 1 mtr. (assumed)
5) Width of MS plate (W) = 100 mm (assumed)
6) Thickness of MS plate (T) = 6 mm (assumed)
7) Area of Conductor (a) = W*T = 600 mm^2
8) Resistance of MS rod/ mtr. (R) = 0.0002333 ohm
9) Volume (V) = a*l = 0.0006 m^3
10) Mass (m) = V* δ = 4.71 Kg

VI. COMPARISON TABLE OF STARTER

Comparison Table between Automatic Slip Dependent Rotor Starter and Liquid Resistance Starter.

Parameter	ARS	LRS
Operating principle	Resistance create by eddy current loss dependent on rotor frequency	Resistance create by resistive liquid, independent on rotor frequency
Starting current	Independent and constant starting performance for every start independent of temperature	Vary between starts depends on temperature of liquid for same concentration and distance between electrode
Starting over current	No possibility of over current, because resistance in circuit until motor reach full speed	In case of counter load on motor is more, than possibility of over current bypass due to independent movement of electrodes
External resistance variation Vs. motor speed	By design principle itself resistance is inverse proportional to motor speed	Independent of motor speed
Life time of the starter	Independent and same as motor life	Depends on no. of start, corrosive nature of atmosphere
Moving parts involve in operation in power circuit	No moving parts	Yes-moving electrodes
Time between starts	Independent and no limitations on between starts	Depends on previous start & ambient conditions

Table 1: Parameters of ARS and LRS

VII. DATA REQUIRED FOR DESIGNING ROTOR STARTER

- Motor data sheet with details of: - Kw, I, V, f, N, pf, effi., etc.

- Driven equipment.
- Motor rotor voltage (RV) & rotor current (RA).
- Motor thermal withstand curve.
- Motor current – speed curve.
- Motor torque – speed curve.
- Load torque – speed curve.
- Motor rotating inertia (GD2).
- Load rotating inertia (GD2).
- Motor no. of starts per hour.
- Ambient condition

VIII. CONCLUSION

Magna start system provides load sensitive starting and smooth time current characteristic. Magna start system has advantage of size, simplicity and no maintenance. Required impedance can be achieved by adjustment of tapping of the inducer. We can also conclude that by using the ARS the starting losses will be reduced by 50%, so that heating of the motor can be avoided and at the time it will result in the increased life of the motor. A simple technique to control IM electromagnetic torque during starting has been presented. Using this technique the motor can be tailored according to load torque and acceleration can be maintained constant over the entire starting period. The proposed strategy eliminate the shaft torque pulsation during the starting process.

REFERENCES

[1] Sourabh Chourasiya, Shivangi Singhal & Md Irfan Ahmed, “COMPARISON & POWER QUALITY IN DOL & SD STARTER OF IM”, IJMRME Volume 3, Issue 1, 2017.
[2] Mohammad Reza Feyzi Mehran Sabahi — Meysam Farrokhifar “A NEW SOFT STARTING METHOD FOR WOUND ROTOR INDUCTION MOTOR” Journal of ELECTRICAL ENGINEERING, VOL. 62, NO. 1, 2R011, 31–36.
[3] T.K. Nagsarkar, M.S. Sukhija, “Basic Electrical Engineering”, OXFORD university press.
[4] Dr. P. S. Bimbhra, “Electrical machinery”, 7th edition, khanna publishers, New Delhi.
[5] Mukeshkumar Arya , Dr. Sulochana wadhawani “Development of direct torque control model with using svi for three phase induction motor”, International Journal of Engineering Science and Technology (IJEST)-ISSN: 0975-5462-VOL-3 NO. 8 AUG-2011.
[6] Ku. Trupti Deoram Tembhekar, “Improvement And Analysis Of Speed Control Of Three Phase Induction Motor Drive Including Two Methods”, Second International Conference on Emerging Trends in Engineering and Technology, ICETET-2009.
[7] Patel Divyaben Lalitbhai, Prof. C. A. Patel, Mr. B. R. Nanecha, “Simulation of Speed Control of Induction Motor with DTC Scheme”, (IJSRD/Vol. 3/Issue 09/2015/019).
[8] Gund Priyanka, Mahurkar Komal, Waghmare Rohini, Tale Archana, Prof. Kazi K. N, “Protection and Controlling of 3 Phase Induction Motor by Electronic Soft Starter”, (IJSRD/Vol. 7/Issue 04/2019/055).