Abstract—This paper shows a comparison simulation results for two controllers using the same name plate of 2750 KW, 6.6 KV, 50 HZ for wound and squirrel cage motors using two methods of controlling, the first method is achieved by a conventional method and the second method is achieved by a frequency inverter respectively.

Keywords—Squirrel cage and slip ring motors, conventional and VSD controllers simulated by MATLAB/SIMULINK.

I. INTRODUCTION

A wound-rotor motor (Slip Ring Motor) is a type of induction motor where the rotor windings are connected through slip rings to external resistances. Adjusting the resistance allows control of the speed/torque characteristic of the motor. Wound-rotor motors can be started with low inrush current, by inserting high resistance into the rotor circuit; as the motor accelerates, the resistance can be decreased. An induction motor is an asynchronous AC motor where power is transferred to the rotor by electromagnetic induction, much like transformer action. Induction motors may be further divided into SCIMs (Squirrel Cage Motors) and WRIMs (Slip Ring Motors). SCIMs (Squirrel Cage Motors) have a heavy winding made up of solid bars, usually aluminum or copper, joined by rings at the ends of the rotor. When one considers only the bars and rings as a whole, they are much like an animal’s rotating exercise cage, hence the name. In a WRIM (Slip Ring Motors), the rotor winding is made of many turns of insulated wire and is connected to slip rings on the motor shaft. An external resistor or other control devices can be connected in the rotor circuit.

Resistors allow control of the motor speed, although significant power is dissipated in the external resistance. A converter can be fed from the rotor circuit and return the slip-frequency power that would otherwise be wasted back into the power system through an inverter or separate motor-generator [1]. Faraday’s electromagnetic experiment, 1821 [2]. Perhaps the first electric motors were simple electrostatic devices created by the Scottish monk Andrew Gordon in the 1740s [3].

The theoretical principle behind production of mechanical force by the interactions of an electric current and a magnetic field, Ampère’s force law, was discovered later by André-Marie Ampère in 1820. The conversion of electrical energy into mechanical energy by electromagnetic means is demonstrated by the British scientist Michael Faraday in 1821. A free-hanging wire was dipped into a pool of mercury, on which a permanent magnet (PM) was placed. When a current was passed through the wire, the wire rotated around the magnet, showing that the current gave rise to a close circular magnetic field around the wire [4]. Jedlik’s “electromagnetic self-rotor”, 1827 (Museum of Applied Arts, Budapest). The historic motor still works perfectly today [5].

In 1827, Hungarian physicist Ányos Jedlik started experimenting with electromagnetic coils. After Jedlik solved the technical problems of the continuous rotation with the invention of commutator, he called his early devices “electromagnetic self-rotors”. Although they were used only for instructional purposes, in 1828 Jedlik demonstrated the first device to contain the three main components of practical DC motors: the stator, rotor and commutator. The device employed no permanent magnets, as the magnetic fields of both the stationary and revolving components were produced solely by the currents flowing through their windings [6-12]. A variable-frequency drive (VFD) (also termed adjustable-frequency drive, variable-speed drive, AC drive, micro drive or inverter drive) is a type of adjustable-speed drive used in electro-mechanical drive systems to control AC motor speed and torque by varying motor input frequency and voltage [13-16]. A variable frequency drive is a device used in a drive system consisting of the following three main sub-systems: AC motor, main drive controller assembly, and drive operator interface [16-17]. The VFD controller is a solid state power electronics conversion system consisting of three distinct sub-systems: a rectifier bridge converter, a direct current (DC) link, and an inverter.

Voltage-source inverter (VSI) drives (see ‘Generic topologies’ sub-section below) are by far the most common type of drives.
Most drives are AC-AC drives in that they convert AC line input to AC inverter output. However, in some applications such as common DC bus or solar applications, drives are configured as DC-AC drives. The most basic rectifier converter for the VSI drive is configured as a three-phase, six-pulse, full-wave diode bridge. In a VSI drive, the DC link consists of a capacitor which smooths out the converter's DC output ripple and provides a stiff input to the inverter. This filtered DC voltage is converted to quasi-sinusoidal AC voltage output using the inverter's active switching elements. VSI drives provide higher power factor and lower harmonic distortion than phase-controlled current-source inverter (CSI) and load-commutated inverter (LCI) drives (see 'Generic topologies' sub-section below). The drive controller can also be configured as a phase converter having single-phase converter input and three-phase inverter output [18].

Controller advances have exploited dramatic increases in the voltage and current ratings and switching frequency of solid state power devices over the past six decades. Introduced in 1983, the insulated-gate bipolar transistor (IGBT) has in the past two decades come to dominate VFDs as an inverter switching device [19-20].

II. TECHNICAL FEATURES OF SRM AND SCM

Figure 1 shows that SRM can perform more torque (2.5 rated torque) than SCM (1.6 rated torque) in the start-up near zero speed and gradually the torque drops as the speed reaches the rated speed by using the conventional controlling method.

![FIGURE 1: Torque versus speed SRM and SCM](image)

Figure 2 shows the starting current drops very slowly as the motor accelerates and only begins to fall significantly when the motor has reached at least 80% of the full speed. The induction motor operates due to the torque developed by the interaction of the stator field and the rotor field. Both of these fields are due to currents which have resistive or in phase components and reactive or out of phase components. The starting efficiency can be shown as follow:

![FIGURE 2: Current (LRC)/Torque (LRT) versus rotor speed (full speed)](image)

Figure 3 shows that the slip ring motor has two circuits, the stator and rotor circuits during starting and with adding a resistance on the rotor circuit (Liquid Resistance Starter); we will reduce the current and maintain enough torque to start the rotor. This happens due to less saturation in the magnetic flux core, \( V = IR, I = V/R + X_L \), motor impedance = \( R + X_L \).

![FIGURE 3: Typical Slip Ring Motor](image)
A. Advantages of Slip Ring Motor:
Suited for high inertia loads as it accelerates with excellent starting torque. Low starting current when compared with squirrel cage motor.

B. Disadvantages of Slip Ring Motor:
Maintenance is required for the brushes and slip ring motor periodically, so shutdown is required. As the brushes wears out, it may lead to short circuit and thus a heavy sparking which is causing a big damage. Environmental effect has a huge impact on brushes such as a dry weather which has a huge impact on the brushes and their performance and consequently on the slip ring.

III. SIMULATION RESULTS FOR THE TWO METHODS
The voltage magnitude of the variable frequency supply to the motor is controlled to maintain a constant air gap voltage with frequency so that the machine flux remains constant as shown in the following equation:

\[ \frac{V_1}{V_1 (\text{rated})} = \frac{F_1}{F_1 (\text{rated})} \]

This is known as the “constant Voltz per Hertz” characteristic of a variable speed induction motor drive.

Figure 4 illustrates the VSD’s overload capability with a typical starting load profile of the induction motors. This available torque is more than adequate to provide for typical highest starting torque requirements of the induction motor.

Figure 5 shows torque versus speed for two controllers. The motor which is controlled by the conventional method is producing less torque than the motor which is controlled by the VSD at nearly the beginning of the rotor acceleration by 15%. As the rotor accelerates toward the rated speed the torque produced by VSD controller is higher than the conventional controller by 20%.

Figure 6 shows the starting current versus speed comparison between VSD controller and the conventional controller (liquid resistance starter LRS). Starting currents (input current as seen by the supply) of up to 145% rated current of the motor is not appeared with VSD application. This soft starting capability eliminates power dips associated with high starting currents on the power system without compromising high starting torque requirements.
IV. ADVANTAGES OF USING VSD FOR BIG INDUCTION MOTORS

The followings are the advantages of using the VSD controller over the conventional controller: Low starting Current, smoother starting up, variable speed control, maintain high power factor more than 90% – motor friendly, no brush maintenance, and increased the process availability.

V. CONCLUSIONS

Based on the above illustration and simulation results, the conclusions are: No need for liquid resistance starter. No need for brushes and slip rings. No need for big air-conditioning system due to large amount of heat created by the conventional controller. VSD controller is very reliable system. VSD drive improves the process life cycle and increase the productivity.

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