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International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

AC Induction Motors in High-Performance Applications and Protection System Design

Amit Kumar M

MNIT

ABSTRACT :

The AC variable speed drives have many applied applications in variable torque production and pump motor applications. Induction motors are cheaper than other types of motors. High-performance of induction motors is attributed to advanced drive technologies. Different types of motors, such as brushless direct current motor, have either sinusoidal or trapezoidal waveforms. But induction motors make use of sine waveform for variable frequency drive controls. The basic direct relationship to the frequency makes the frequency control from variable frequency drives feasible for industrial applications of heavy machinery. This applies directly to an ideal selection of motor for an electric vehicle application. Many authors have presented the need for improved design and standards to ensure better speed and torque for the motor at reduced power consumption. The goal of this research extends to the protection system for the induction motor overcurrent and fault conditions.

Keywords: drives, motors, electric vehicles

Introduction :

Operating industrial motors has varying purposes based on the range of the speed required for industrial use. The need for variable speed prime movers is widespread because of the energy savings on fan drives. The use of the basic equation of the motor synchronous speed relating directly to the frequency and inversely to the poles improved performance of these variable-speed drive productivity. The induction motors prospers in scenarios requiring high power output, precise speed controls, and longer operational durations. Unlike DC motors, AC motor do not use commutators which increases the reliability from reduced maintenance requirements. Versatile applications of AC motors in industrial machinery to electric vehicles is notable. Low cost and ruggedness from the AC squirrel cage motors for robotics systems extends to HVAC systems. The current advancements in the permanent magnet motors use the DC power but induction motors are in win-win situation from their cheaper costs.

Electric vehicles with use of permanent magnet synchronous motor, and brushless direct current motor [1] [2] requires high performance drives to derive safer rides. Per [3] [4], improved torque is offered by high-performance drives.

The high performance applications are characterized by following [1]-[19]:

- "Continuous constant torque required below 50% of base speed" – Heavy Industrial Applications, or at low speed traction
- "Continuous constant horsepower required above 150% of base speed" – Heavy Industrial Applications, or at high speed traction
- "High starting loads or overloads – Heavy Industrial Applications, or heavy duty traction"
- "High dynamic performance – Robotics"

The Table 1 shows exact parameters that are required to be changes to attain the desired objective.

Table 1 - Changing Motor Parameters to Meet Performance Objectives [1]-[19]

Objective	*Parameter Change*
Wide Constant-HP Speed Range	Increase peak torque at base speed
Higher Peak Torque	Oversize motor Decrease stator and rotor inductances Decrease stator resistance
Lower Primary Time Constant	Increase stator resistance Decrease inductances

Higher Stator Resistance	Increase stator coil turns Decrease stator wire/slot size
Lower Inductances	Decrease stator coil turns Increase flux densities Change slot shapes
Lower Flux Density	Increase volume of core Increase stator coil turns
Lower Magnetic Noise Level	Decrease slot sizes Decrease flux density Alter shape/volume of material
Higher Efficiency	Decrease stator resistance Decrease rotor resistance Reduce flux density

Charging design for the batteries [13], suitability of chargers [14] [15] clubbed with the selection of appropriate power distribution either overhead or underground [16] increases the energy efficiency of the system. Renewable energy integration of high performance motors operated by battery energy storage system and set of advanced concepts in floating solar photovoltaics becomes a point of future discussion for this work [17] [18].

Electric Vehicle High Performance Motors :

The electric vehicle high-performance induction motors are typically exhibited by a characteristic power (kW) and toque (Nm) curve optimized to ensure a wide range of speeds. This corresponds to item one in the Table 1. The constant torque region is responsible for zero to base speed region (maximum torque). The vehicle can accelerate at low speeds where the torque continues to remain constant with an increase in power. Constant power curve can be visualized for high performance region of operation. The power increases rapidly from zero to base. Power decreases at high speeds. See figure 1 for the speed vs torque characteristics [20].

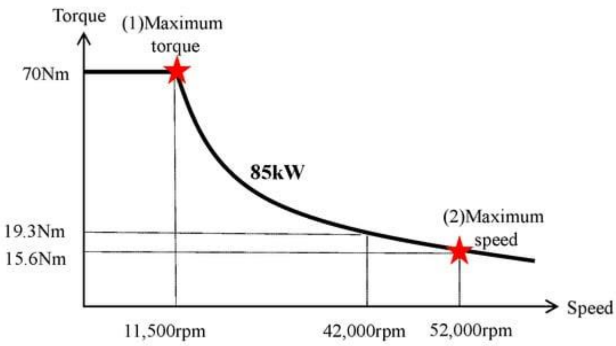

Figure 1. Speed-Torque Curve [20]

Methods

A literature review is the core methodology used for determining high-performance induction motors in the practical world. A systematic database search was performed for the past few years to determine the types of drives used. AC motors are cheaper in design for various applications, but DC motors, because of their high performance, were analyzed. As a designer acceleration is major consideration whereas the deceleration and jerk are variants of the acceleration.

Speed Regulation

Speed regulation due to load changes due to load changes and other changes such as temperature, humidity, line voltage fluctuation and drift can be required for many applications. It is important that the performance of equipment relate to the user's process. A requirement of 1% speed regulation would mean less than 18 RPM change when operating a 4 pole motor at 60Hz. However, if the user intends to operate that motor at 20Hz that 1% speed regulation would require a speed change of no greater than 6 RPM.

From the user's viewpoint, a change greater than 1 inch per second in the product being produced may not be acceptable. If an 18 RPM change resulted in a product movement change of 3 inches per second, the 1% speed regulation at 60Hz would not meet the requirements. Using % of maximum speed or % of operating speed does not relate directly to the user. It is important to first define the exact user needs. Performance specifications of equipment or the equipment terms can then be tied to user's needs.

Speed regulation and speed deviation can result in confusion. An 18 RPM change could be defined as a (+/-) 9 RPM deviation. From the user viewpoint, a change that would jeopardize the process should establish the limits. However, the user must take the responsibility for defining the exact operating point/s and the maximum acceptable deviation from those points. Both short term (minimum critical time) and long term (maximum critical time) must be defined.

Effects Of Supply Voltage Variation On Characteristics Of Induction Motors.

Voltage	Starting Torque & Max. Running Torque	Synchro-Nous Speed	% Slip	Full Load Speed	Full Load Current	Temp. Rise On Full Load	Start-Ing Current
Function Of Voltage	$\propto V^2$	Constant	$\propto 1/V^2$				$\propto V$
90%	Decreases By	Constant	Increases By	Decreases By	Increases	Increases	Decreases
11o %	Increases By 20 %	Constant	Decreases By17 %	Increases By 10 %	Decreases	Decreases By 4°	Increases
120 %	Increases By 45 %	Constant	Decreases By 30 %	Increases By 15 %	Decreases By 10 %	Decreases	Increases

Effects Of Frequency Variation On Characteristics Of Induction Motors

Frequency	Starting Torque & Max. Running Torque	Synchro-Nous Speed	% Slip	Full Load Speed	Full Load Current	Temp. Rise On Full Load	Start-Ing Current
Function Of Frequency	$\propto 1/F^2$	∞ F		∞ F			$\propto 1/F$
95%	Increases By 11 %	Decreases By 5 %	No Change	Decreases By 5 %	Increases Slightly	Increases Slightly	Increases By 5 %
105 %	Decreases By 10 %	Increases By 5 %	No Change	Increases By 5 %	Decreases Slightly	Decreases Slightly	Decreases Slightly

Points To Be Considered While Designing Protection System

Motor Protection Should Be Simple And Economical. Cost Of Protective System Shall Be Generally Within 5 % Of Motor Cost .The Motor Protective Device Should Not Cause Nuisance Tripping By Causing Operation During Starting & Permissible Over Loads. The Choice Of Motor Protection Scheme Depends Upon The Following :

1. Size Of Motor , Rated Voltage , HP.
2. Type Of Motor- Squirrel Cage Or Wound Rotor.
3. Type Of Starter , Switchgear & Control Gear.
4. Cost Of Motor And Driven Equipment .
5. Importance Of Process, Whether Essential Service Motor Or Not.
6. Type Of Load Starting Current , Permissible Abnormal Condition etc.

Points To Be Considered While Selecting Motor Control System

1. Frequency Of Starting & Stopping.
2. Frequency Of Reversals.
3. Light Or Heavy Duty Starting.
4. Fast Or Slow Acceleration.
5. Smooth Starting Or Stepped Starting.
6. Manual Or Automatic Starting.
7. Quick Stop Or Slow Stop

Control Method

The control method used in any application can affect the choice of equipment and the interface between that equipment. A manual control method can require only a speed potentiometer and a start/stop button. An automatic control method can be a simple remote contact or a complex computer interface which activates many functions. The application may require a motion or system controller to give commands to the drive controller in response to other sensors on the process. Interface to other controllers may be a requirement of the pplication.

Selection of the proper equipment will depend on what the user wants and expects from the process. Lack of familiarity with the selected equipment can result in user dissatisfaction. A clear definition of the expectation of the control method will reduce any surprises during commissioning and operation of the equipment. An answer to the question.. What happens when, will reduce question about performance.

Results :

A control technique is summarized in Table 2. However, better materials improve the magnetic properties of the motors, and so do the power electronics used for controls. For example, frequency controls using VFDs utilize power controllers that operate with controlled and rapid switching.

Type of Control	**Advantages**
Field Oriented Control	Magnetic Field in Manipulated
Direct Torque Control	Improve Dynamic Performance
Model Predictive Control	Enables Optimal Controls

Conclusion :

A literature review successfully gave below conclusive points for this research:

- Speed controls for high performance applications in industry and electric vehicles
- Type of speed controls widely used in the industry were Field Oriented Control, Direct Torque Control, and Model Predictive Control.
- Regions of Speed vs Torque for optimized operation.
- Protection system design considerations aspects for induction motors.

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