Monthly Informative Application Guidelines, with respect to *Motors & Drives* to keep you better INFORMED.

APPLICATION GUIDELINE #27

(Typical Starting Methods for AC Induction Motors – Part 1)

Brought to you by your Motor & Drive Specialists……

Full Voltage Starting (FVNR) - Motor is connected directly across the AC line by a magnetic contactor.

Line Resistance and Line Reactance Starting - Resistors or inductors are connected in series with the motor winding and progressively switched out after time intervals until all these elements are short circuited and the motor is directly across the AC line.

Part Winding Starting (PW) - One part of the motor stator winding is used to start the motor rotating at reduced current and torque until the rest of the winding is switched in parallel for the run condition.

Wye-Delta Starting (YDOT, YDCT) - Motor winding is switched by three contactors from a wye connection during starting to a delta connection during running.

Autotransformer Starting (RVAT) - Motor is connected to the reduced voltage taps on an autotransformer during starting then directly across the line for running.

Size 4 FVNR (includes vacuum contactor & solid state overload) w/Circuit Breaker

Solid State Starting (SSS) - Motor is started by electronic phase control of the AC line voltage using inverse parallel SCRs. Voltage increase and motor acceleration are smooth and continuous and can be adjusted.

Typical Starting Methods, Current and Torque Characteristics

Starting Method	% Voltage at Motor Terminal	Motor Starting Current as a % of Full Load Current	Line Current as a % of Locked Rotor Current	Motor Starting Torque as % of Locked Rotor Torque	Starter Allowable Acceleration Time	Starting Current & Torque Adjustment
Full Voltage	100	600-700	100	100	Limited by overload protection	Fixed
Part Winding	100	300-350	50	50	2-3sec.	Fixed
Wye Delta	100	200-230	33	33	45-60 sec limited by motor design	Fixed
Autotrans -former	80 65 50	480-560 390-455 300-350	64 42 25	64 42 25	30 sec (NEMA medium duty)	Adjustable (limited by taps)
Solid State Starter	0-100	0-700	0-100	0-100	1 sec to several minutes	Adjustable

Motors are started on full voltage whenever possible because the across the line starter has the lowest cost of all the starter types, its controls are the simplest and it takes up the smallest physical (wall or floor) space. Installation is also the easiest and the least amount of maintenance is required (contains the least number of parts). With full voltage starting, the motor is connected across the line in one step by closing a single main switch (contactor).

Full voltage starting also has the advantage of producing high torque efficiency. The starting torque per ampere of line current is the highest of all methods of starting except for the autotransformer method that has equivalent torque efficiency.

The heavy starting current and high torque can create various problems with the motor, driven equipment, and power system. Before full voltage starting method is selected, three conditions must be satisfied:

- The motor must be able to withstand the mechanical forces produced by high currrents. The majority of modern AC motors are designed to withstand these forces without damage.
- The driven equipment must be able to withstand the sudden torque transmitted during starting and acceleration. Some loads cannot be started abruptly because of damage to equipment or product, or injury to personnel.
- The power system must be capable of supplying the starting current without causing an excessive voltage dip on the lines or the feeder protection (circuit breaker) to trip. All utilities have limits for the amount of current available and may specify the maximum horsepower that can be started at full voltage. Utilities have specified as low as 30 horsepower must be started by a reduced voltage starter.

If the analysis of the application indicates that full voltage starting cannot be used and the starting current must be limited, a reduced voltage starting method must be selected. An important point to remember in the selection of a reduced voltage starting method is that starting torque varies as the square of the applied voltage. If the voltage applied to a motor is reduced 50%, the starting torque will be reduced to 25%. The starting method must be closely examined and selected to give the proper compromise between the required starting torque and the desired limitation of inrush current.

Typical Applications	Starting Condition	Typical Load Torque -- % of Full Load Torque			
		Breakaway	Accelerating	Peak Running	Light Running
Conveyors	Loaded	80-150	150	100	20-30
Conveyors	Unloaded	50	100	100	20-30
Crushers	Loaded	80-150	150	150	20-30
Crushers	Unloaded	50	50	150	10-20
Extruders		80-100	150	100	50-100
Pumps		30-50	100	100	90-100
Fans, Blowers	Open Damper	15-25	60	100	90-100
Compressors	Open Valve	30-50	100	100	10-20
Saws		30-50	75	150	10-20
Grinders		40	50	150	10-20

TYPICAL CUSTOMER PROBLEMS

Mechanical

- Belts breaking, squealing or wearing out frequently
- Gears breaking
- Coupling damage
- Drive train shafts bending or breaking

Motor Problems

- Motor insulation deterioration and premature winding failure
- Mounting or foundation cracking or bolts breaking
- Bearing failure
- Motor shaft bending or breaking
- Energy (excess) consumption

Electrical Problems

- Contactor main contacts pitting and wearing out
- Contactor coil burnout
- Circuit breakers tripping

Inrush Current Related Problems

- Voltage drop causing electromechanical (contactor) coils to drop out or contact chattering, resulting in coil or main contact failure
- Soft supply system may not have available current to start motor
- Power supply brown-outs causing lights dimming or computer glitches
- Circuit breakers tripping or fuses blowing during starting
- High starting current resulting in utility peak demand charges

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Product Problems

- Materials chip, crack, spill or break
- Positioned products are shifted