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

APPLICATION GUIDELINE #29

(Typical Starting Methods for AC Induction Motors - Part 3 of 3)

REDUCED VOLTAGE AUTOTRANSFORMER STARTERS

The reduced voltage autotransformer starter provides a reduced voltage to the motor terminals during starting using taps on a three phase (coil) autotransformer. The autotransformer voltage taps allow adjustment for a range of current and torque requirements. The standard taps are 50%, 65%, and 80% of the full line voltage. Starting torque are therefore 25%, 42% and 64%. While the current to the motor is 50%, 65% and 80% respectively, because of the autotransformer, the line current will be 25%, 42% and 64% of the full voltage rating.
Application - Designed for reduced voltage starting of standard squirrel cage motors, the autotransformer starter provides the highest starting torque per ampere of line current, and is an effective means of motor starting for applications where the inrush current must be reduced with a minimum sacrifice of starting torque. These starters feature closed-circuit transition, an arrangement that maintains a continuous power connection to the motor in the transition from reduced to full voltage. This avoids the high transient switching currents characteristic of starters using open-circuit transition, and provides smoother acceleration.
Construction - Starter components include: Three 3-pole contactors, designated in the schematic as “1S”, “2S”, and “Run”; a 3-phase autotransformer; two adjustable solid state times, designated “TR1”, and “TR2”, one for transition and one for incomplete sequence; and a 3-phase overload relay.
Operation - A start signal (contact closure) closes two contactors (1S and 2S), applying reduced voltage to the motor through the autotransformer. After an adjustable interval, the timer contacts drop out the 1S contactor, breaking the autotransformer connection but leaving part of the windings connected to the motor as a series reactor. The Run contactor then closes applying full voltage to the motor, and then 2S opens. Transition from reduced to full voltage is accomplished without opening the motor circuit. If the Run contactor does not close, damage to the autotransformer will occur. To trip the starter off if the motor does not switch to full voltage, Toshiba autotransformer starters include an incomplete sequence timer. This timer is not standard with most other manufacturers.

Duty Cycle - The transformers used in standard controllers conform to NEMA standards for medium duty and are suitable for general motor starting service. Heavy duty or special autotransformers are available upon special request.

The starting duty cycle rating based on a temperature rise of 85 degrees C, 65% tap with 300% of motor full load current and a power factor of 50% or less is as follows:

Duty Cycle	**To 200 hp**	**200 hp through 3000 hp**
On	15 seconds	30 seconds
Off	3 min. 45 sec.	30 seconds
Repeat	14 times	2 times
Rest	2 hours	1 hour
Repeat	As above	As above

SOLID STATE STARTER

The solid state starter provides a smooth soft start of standard three phase AC induction motors using stepless reduced voltage. The solid state starter uses SCRs (silicon controlled rectifier) to apply voltage motor. Two SCRs are connected back to back per phase, and their firing angle is controlled to increase or decrease the voltage to the motor. This method allows a stepless voltage ramp and therefore there is no transition (no current surge during transition).

Start/Stop Methods - The solid state starter offers various starting and stopping methods. Starting control methods include soft start (voltage control), current control (current limit), and special load (pump) control. Stopping methods include soft stop, DC injection braking, and special load (pump) control.

Voltage Control Method - This method linearly increases the SSS output voltage from an initial voltage to full voltage as shown. The initial voltage and acceleration time are variable. The common setting range of the these starters is 0 to 80% for the initial voltage and 1 to 60 seconds for the acceleration time. This method is used on applications that may require full rated torque or where a gradual increase in torque or speed is desired. This method is generally not effective on high inertia loads (e.g., large fans, band saws, chippers).

Current Control Method (Current Limit) - In this method the SSS output current is basically constant during starting. The maximum output starting current is set, and the output voltage is controlled to limit the current to this value. Current limit of the starters is usually adjustable between 200% and 500%. This method is used where the maximum current drawn from the utility, generator or transformer must be limited, or where the maximum motor output torque must be limited. Also, current limit control is used on high inertia loads where long acceleration time at low starting current levels is required.

Soft Stop - The SSS output voltage linearly decreases from 100% to the initial voltage setting. This function is used when an extended coast to stop time is required. This is applicable on frictional type loads like conveyers, and where torque or speed must be gradually reduced as on pumps where the pressure must be slowly decreased so that the check valve does not slam closed and water hammer does not occur.

DC Injection Braking - DC injection braking is optional on some solid state starters. This function is used on applications where the load must be stopped faster than with coast stopping. Applications where this is used include chipper, band saws, and large fans. Factory application assistance is required for DC injection braking.

Pump Load - The TS starter has a special load selection for starting and stopping pumps. When long acceleration or deceleration (i.e. more than 30 seconds) is used on certain pumping applications, an undesirable pressure oscillation can occur. This pressure oscillation is seen when the pump is close or at full speed and the SCRs are still switching, causing torque pulsation from the motor. A special pump circuit is available on many starters to reduce or eliminate this oscillation.

Bypass Control - The SCRs in a solid state starter must be kept within rated temperature or else failure will occur. Most starters include an internal overtemperature detection device. Except for very small units, without proper air ventilation even running at less than 100% load can overheat the SCRs. Fans may be mounted to blow air across the SCR heat sink or cooling fins, but circulating hot air around the starter cabinet will not sufficiently cool the starter. In an environment where a non-ventilated enclosure (e.g., Type 12, 3R, 4, or 4X) is used, a bypass contactor has to be installed. The bypass contactor is connected in parallel with the SCRs, and closes after the SCRs have ramped to full voltage. With Toshiba starters, a bypass contactor is provided as standard on solid state starters supplied in a non-ventilated enclosure, on 48A units and above. On smaller units (32A and below), a bypass contactor is not required due to the small amount of heat produced and rating of the SCRs.

Bypass is also used to extend the life of the SCRs. The bypass contactor protects the SCRs against severe overcurrent conditions, like locked rotor, where the overload protection may not react fast enough. The contactor extends the life of the SCRs on severe duty applications, like centrifuges, chippers and bandsaws, which have long starting times (several minutes), and where long DC injection braking is used.

In Toshiba starters, a full horsepower rated contactor and overload relay is used for the bypass. Manual bypass selection is available by simply adding a relay and a mode selection device (i.e. manual/bypass selector switch). One manufacturer offers an integral bypass on some ratings, which, when activated, parallels a set of bus around the SCRs. This is effective in its intent, but it is not a true contactor which is rated to make and break motor currents. If there is a problem where one of the SCRs can no longer turn on, this integral contact will have to break a high level of current without having an arc chute to disperse the current. This manufacturer states that if there is a solid state starter malfunction, the integral bypass “will deliver a limited number of full voltage starts for emergency conditions.”

The bypass contactor is controlled by either a time delay relay that closes the contactor after a set time period (longer than the acceleration time), or by using a relay on the SSS circuit board to provide a close signal when the SCRs have reached full voltage. Using the timer method allows the possibility of a current surge when the contactor closes and the SCRs are not at full voltage. This is not a problem using voltage control but may be a problem using current control. Many makes of starters do not shut off the SCRs when the bypass contactor closes. If there a problem with the bypass contactor, like a coil failure or disconnected wire, the SCRs will carry all the motor current and may overheat. Also, using the timer method does not allow soft stop. Toshiba starters use the full voltage relay to initiate the bypass signal, even when using current control. Closed transition is standard for all of the selected starting and stopping methods.

<u>Solid State Controller Versus Solid State Starter</u> - Although there are differences between features provided by manufacturers of electromechanical starters, there are big differences between features of solid state soft starts. One important item is the difference between a “Solid State Starter” and “Solid State Controller”. A solid state controller includes the SCR power section and controls board, and that may be all. The solid state starter includes the solid state controller and the addition of overload protection. When selling open chassis style units, many manufacturers sell a solid state controller unless it is specified otherwise. This could mean that the user will have to purchase an overload relay or a complete across the line starter in addition to the solid state controller, resulting in more installation time and material cost, and equipment space. Some solid state starters and all the solid state controllers require other devices or connections not common with electromechanical starters. Many models require 120Vac control power. On these models, the buyer has to figure on the cost of the additional components (e.g., control power transformer, fuses, wiring) and labor, and allow for the additional equipment space. Most models do not include control or pilot devices. Auxiliary contacts for fault trip, run or full voltage indication may not be included or available.