THE CONSIDERATIONS TO USE SOFT START AC CONTROLLERS IN NUCLEAR APPLICATION

Dusan Raonic, Saša Maljukan
Atomic Energy of Canada Limited, Mississauga, Ontario, Canada
Email: raonicd@aecl.ca

Abstract

Motors larger than 200 HP shall be fed from 4.16 kV or 2.4 kV fused starters. In CANDU reactors all large pumps motors are supplied directly from the 13.8 kV, 6.3 kV or 4.16 kV AC system. In the MAPLE reactors, the Primary Coolant System pumps are supplied directly from the 2.4 kV AC system.

Starting and stopping a pump may be easy, but the consequences may not always be ones we wanted. It can results in high start current that require large cables and fuses, or hydraulic shocks known as "water hammer" can cause stress and damage to pipes, valves, gaskets and seals. .

If the nuclear plant installs soft starters, the result will be pump protection, which provides start and stop control, preventing both water hammer and expensive high start currents.

1. Introduction

Full voltage starting can be used whenever the driven load can withstand the shock of instantaneously applying full voltage to the motor and where line disturbances can be tolerated. Full voltage starting uses a main contactor to apply the motor stator windings directly across the main system voltage. This type of starting method provides the lowest cost, a basic and simple design of controller, resulting in low maintenance and the highest starting torque.

Reduced voltage starting may be required if full voltage starting creates objectionable line disturbances on the distribution system or where reduction of mechanical stress to process side is required. It must be noted that when the voltage is reduced from nominal, a decrease in inrush current will occur at a rate of 12% for every 10% decrease in voltage. The starting torque will also decrease at a rate of 20% for every 10% decrease in voltage. This phenomenon also occurs in the opposite manner when the voltage is increased. Figure 1 depicts the behavior of the current required by an 1800-RPM induction motor at various speeds. Two facts stand out: First, the starting current is quite high compared to the running current; and second, the starting current remains fairly constant at this high value as the speed of the machine increases and then drops sharply during the last portion of acceleration to full operating speed.

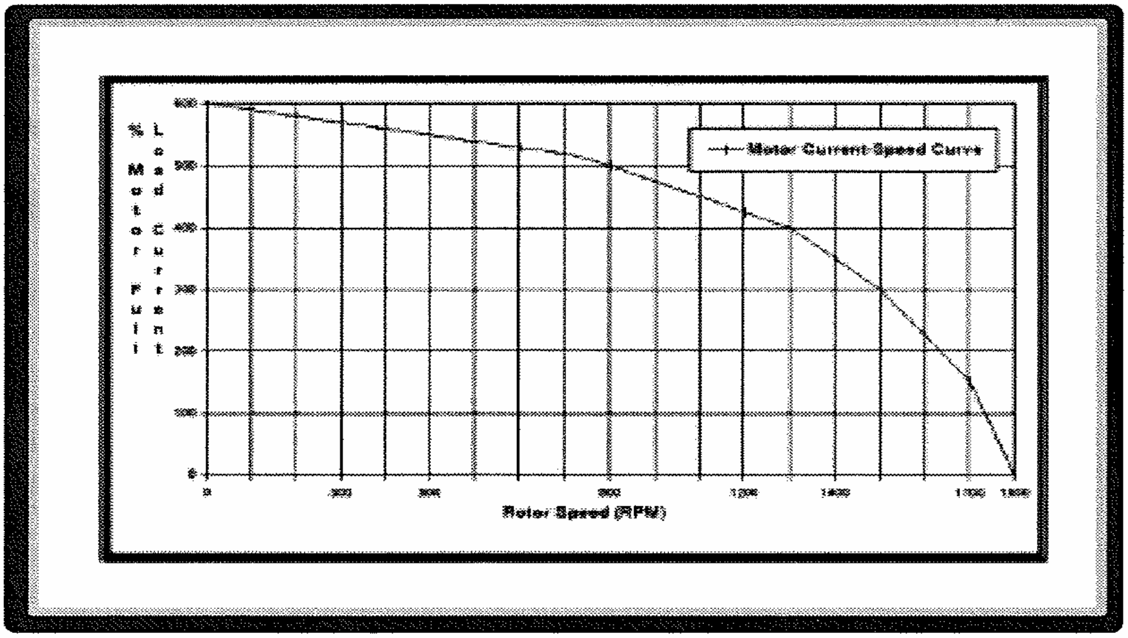


Fig. 1- Motor Current Speed Curve

This means, of course, that the heating effect, to the rotor and the windings, is quite high during acceleration since it is a function of I²t. It also means that a motor may be considered to be in the locked rotor condition during nearly all of the accelerating period.

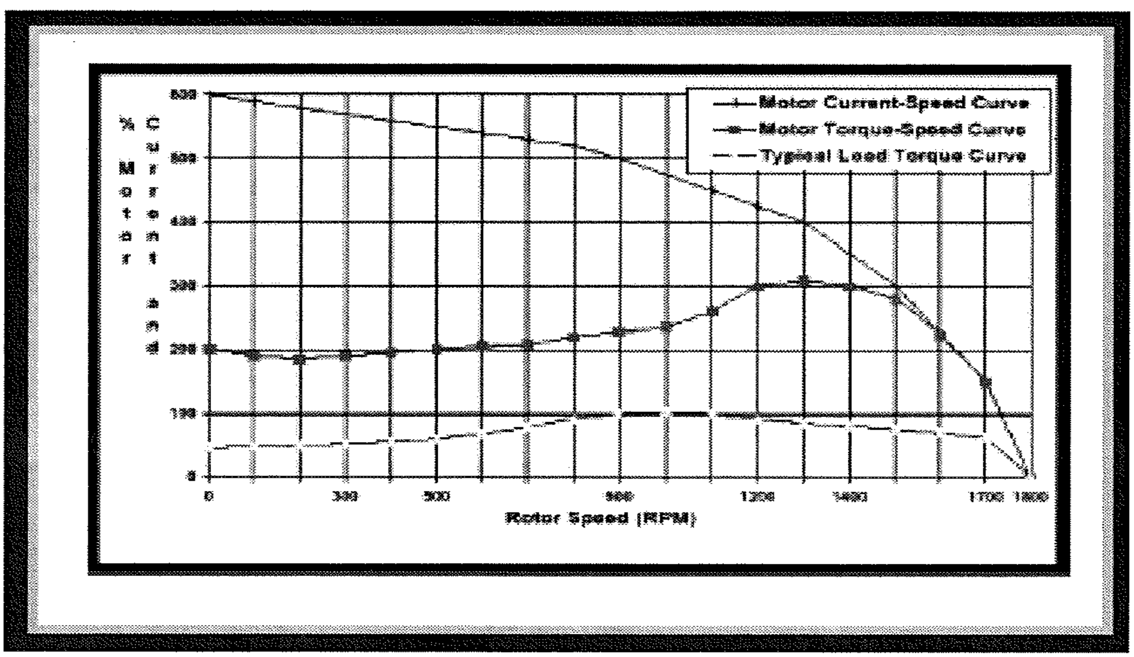


Fig. 2-Torque/Speed Curves

Figure 2 shows a set of torque-speed curves for a typical variable torque load (such as a fan, blower or unloaded centrifugal compressor) and induction motor that could be coupled to a typical induction motor. At this point, it should be mentioned that both the current-speed and torque-speed curves shown are examples of only one particular class of induction machine. As noted previously, the shape of these curves for any individual motor depends mostly on the configuration, material and placement of the rotor bars. Every load and motor combination will exhibit unique torque speed and current speed curves.

The examples shown in Figure 2 is the closest to the typical characteristics of a Class B induction motor. As the horsepower gets higher, the percentage starting torque will be lower and the sag in the torque-speed curve will become more pronounced. The torque of an induction motor is a function of the square of its induced rotor current, and is therefore approximately the square of its line current. If the starting voltage is reduced to 50%, the motor current will drop to 50% of normal full voltage starting current, but the torque will drop to 25% which comes from $(0.5)^2 = 0.25$ or 25%. Were it not for this fact, reduced current starting methods would not create the problems that they do. The inverse is also true. If you increase the voltage the torque will increase in the same proportion. See figure 3 and Table 1.

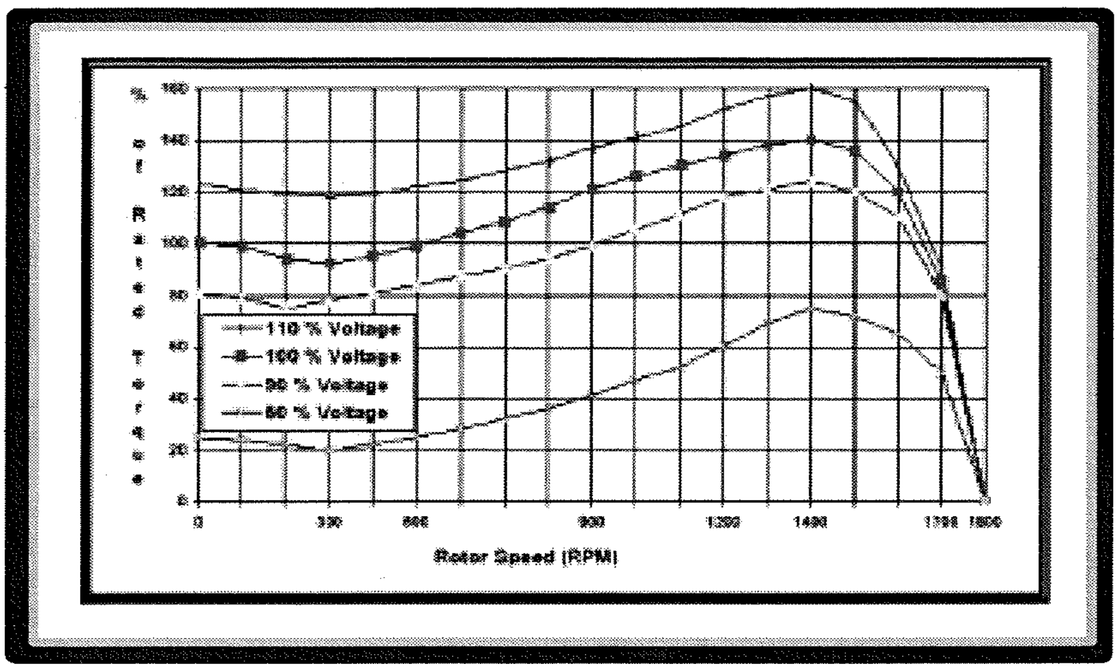


Figure 3- % Voltage/Speed Curves

Full voltage starting of motors can produce initial inrush current, mechanical stress on drive system and create pressure surges or water hammer in pumping application. Starting motor at reduced voltage can help reduce or overcome these problems.
This direct on line start will cause a sudden increase in current drawn from the power system and may result in an excessive drop in voltage unless it is considered in the design of the system.

Table 1-Soft start Consideration

Starting method	Voltage to motor	Motor current	Line current	Starting torque
Full voltage	100%	600%	600%	100%
Auto transformer 80%	80%	80%	64%	64%
Auto transformer 65%	65%	65%	42%	42%
Auto transformer 50%	50%	50%	25%	25%
Way-Delta	100%	33%	33%	33%
Solid state starter	0-100%	0-100%	0-100%	0-100%

The use of phase controlled thyristor AC controllers, as conventional soft starter or smart motor controller, Fig. 4, to produce a reduced voltage for starting, stopping and for light load operation of large induction motors is quite popular [1,2]. It is a cost effective method of starting and stopping a motor as compared to a variable frequency drive (VFD) and is especially attractive in application where continuous speed/torque regulation is not required. Smart Motor Controller (SMC) use the topology of Fig. 4, with a suitable control scheme to reduce motor inrush current during starting, eliminate high torque transient, or reduce the acceleration of the load.

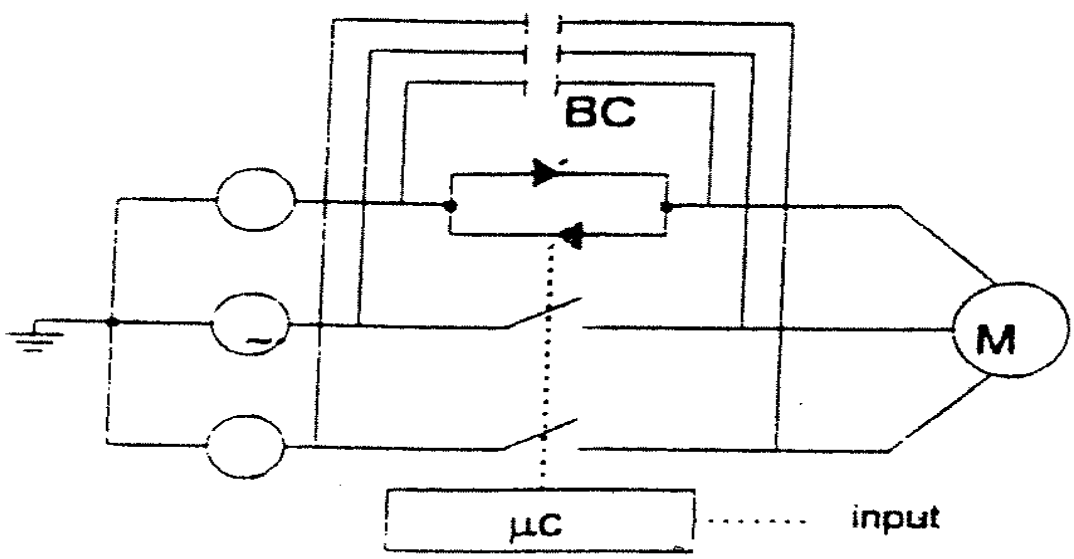


Figure 4- AC controller with bypass contactor (BC)

Braking is done without need of additional equipment and achieves a controlled deceleration of the load [1,3]. Also, the torques generated by conventional soft starters and SMC are shown in Fig. 5a for better understanding of SMC operation. The voltage applied to the motor is typically adjusted by directly controlling either the delay angle α or the hold-off angle γ as shown in Fig. 5b. Hold-off angle γ (also known as notch) control has been shown to achieve a more stable motor operation and is very easy to implement. Therefore it is often the preferred control choice, and is the method used in

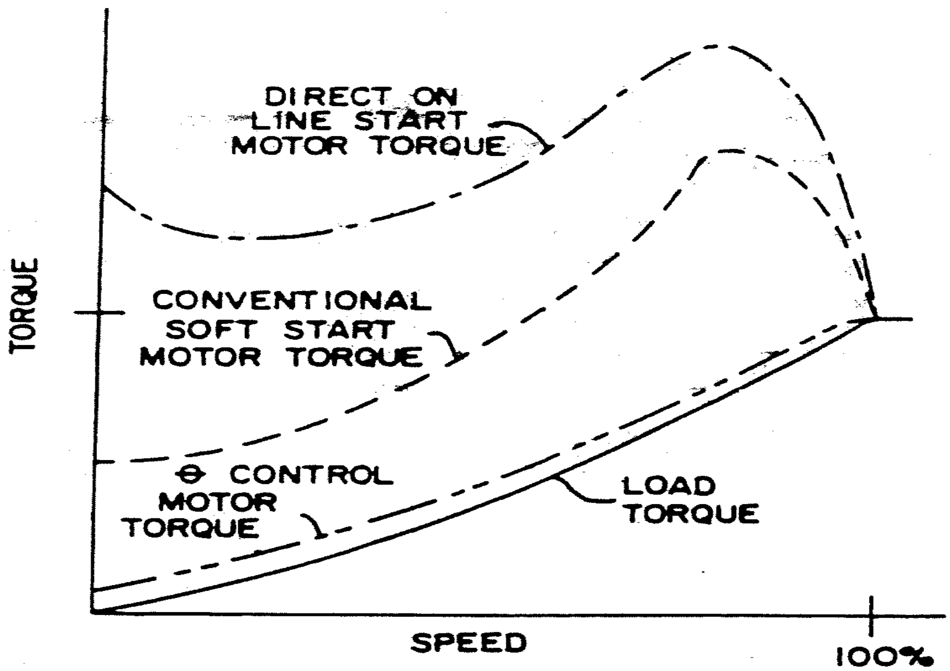
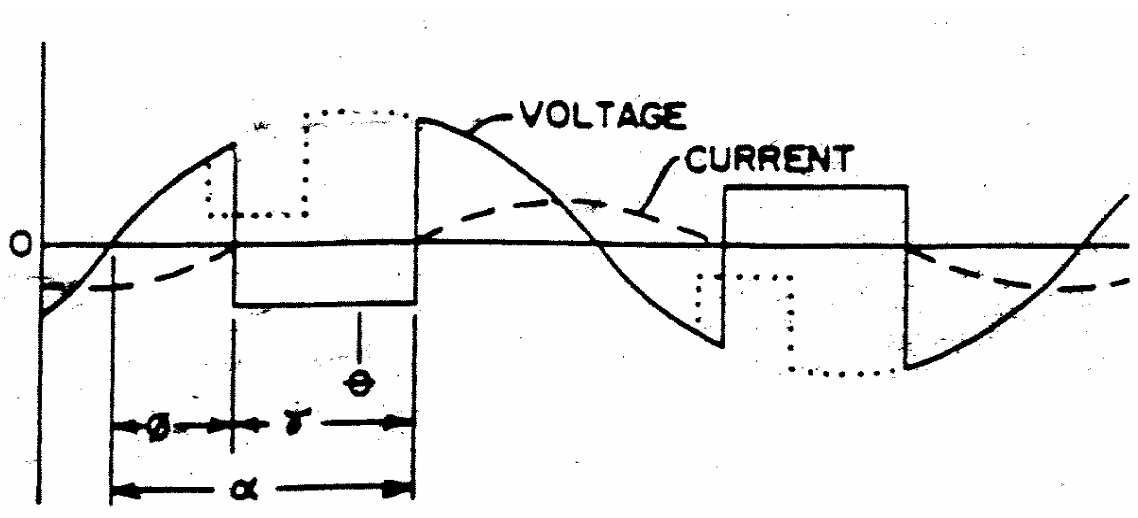


Figure 5- a) torque generated by conventional soft starter and SMC



b)
Figure 5- b) representation of control angle

the SMC, where a control angle θ is calculated according the equation $\theta=\varphi+K\gamma$, where K is a positive number . The control options for SMCs are studied in details in [2,3] and are beyond the scope of this work. The medium voltage solid state starters is used to limit peak starting kVA demand and increase utilization of power system capacity [4].

This is an effective system for starting and stopping a motor smoothly. It can be used for current limitation or torque adjustment. The typical medium voltage motors produce a starting torque of 60 to 80% of full load torque, which allows to select initial value of reduced voltage in order to develop enough starting torque to bring motor up to full speed, Figure 6.

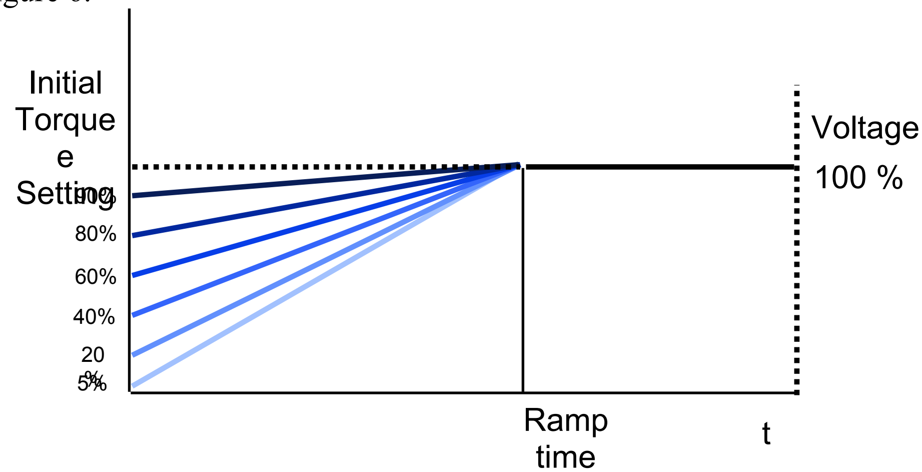


Figure 6- Selected initial torque settings

Control by current limitation sets a maximum current during the starting stage and lowers torque performance. This control is especially suitable for pumps. This type of starter uses devise shunting at the end of starting process and therefore can be used for starting several motors in cascade. Figure 7 shows a typical reduced voltage start. This figure represents a start with rotor locked to show the smooth transition from start to full voltage.

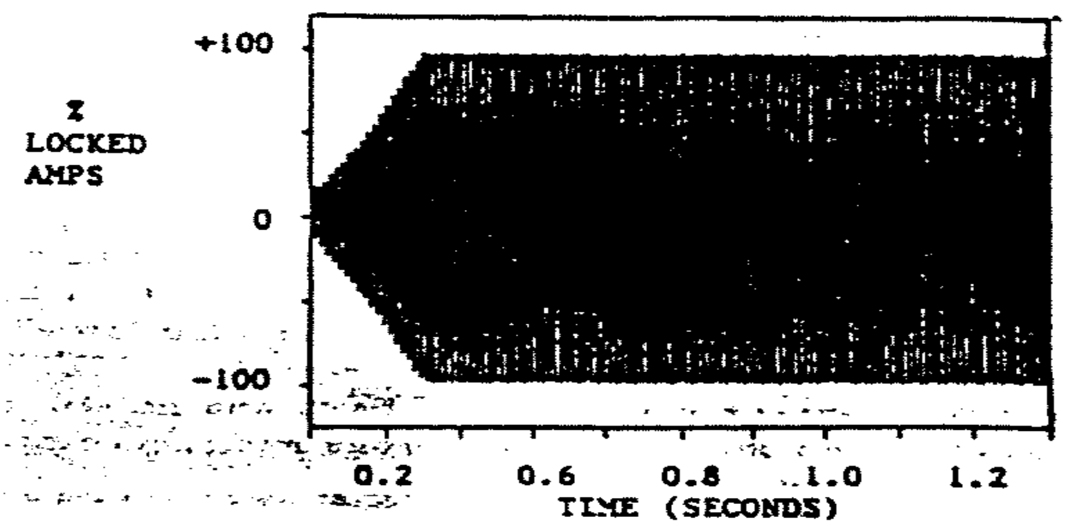
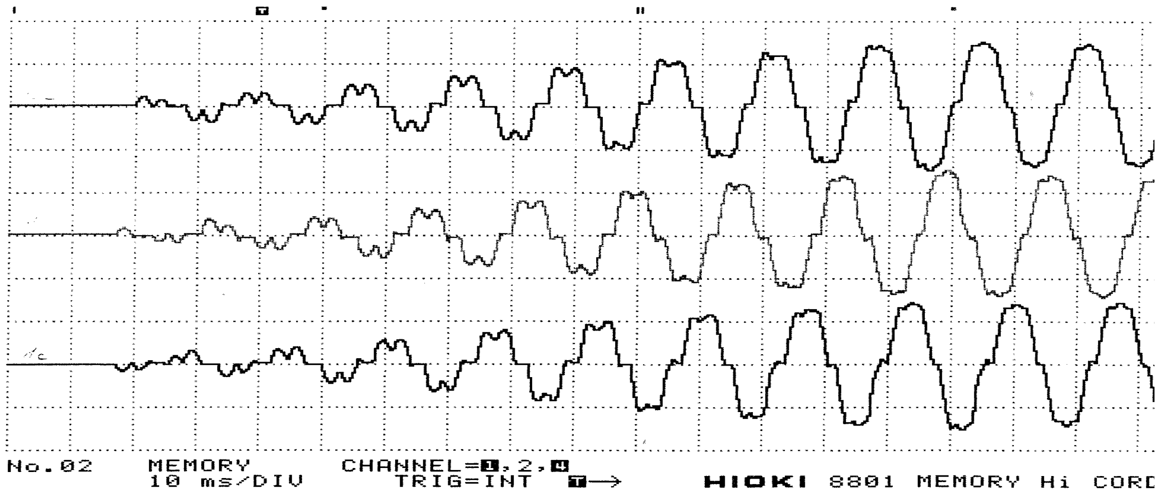


Figure 7 –a) Reduced voltage start with rotor locked



b)

Figure 7 –b) - Typical motor current waveforms

The variable frequency (speed) drive is effective to use whenever speed must be controlled and adjusted. This starting system can be used on all types of loads, but it is a solution primarily used to control motor speed, starting being a secondary purpose.

2. Application

In CANDU application Heat transport pumps are driven by large totally enclosed, water to air cooled squirrel cage induction motor, supplied directly from 13.8, 10 or 4.16 kV bus. Full voltage starting of motors is used and each motor is equipped with a friction brake. The full voltage starting results in high start current which has to be used for cable, fuse and other equipment design. Also hydraulic shock can cause damage to pipes, valves, gaskets and seals. Pump brakes can be applied when all Heat transport pumps in loop have been tripped and each pump speed has dropped to 100 rpm or less. The existing pumps are vertical centrifugal single suction, double discharge type pumps equipped with motors between 1600 HP and 9000 HP.

Starting the main Primary Coolant System pump caused fluctuations of the Reflector level signals and occasional shutdown of the MAPLE reactor by the Safety Systems. The existing pump is centrifugal type pump equipped with a 450HP motor with open drip proof enclosure. Introduction of a smooth pump start would reduce and perhaps eliminate the level fluctuations and avoid safety system action.

Starting and stopping a pump where the downstream piping may not filled solid may lead to hydraulic shock known as “water hummer” that can cause stress and damage to pipes, valves, gaskets and seals. Using soft start and setting ramp –Figure 6, flow rate is increased slowly allowing lines to fill up and minimize air gaps. Depending upon the process requirements the soft starter can be used to start one or more pumps.

There are several factors to be considered when selecting the starting equipment for any motor driven load in nuclear application:

- The source of power and the effects the motor starting current has on supply line design (larger cable and fuses)
- The starting and breakdown torque characteristics of the motor (motor speed torque characteristic)
- The pumps operate at constant or variable flow
- The motor starting characteristic (torque) that correspond to the motor best suited to the load characteristics at full load and speed
- The requirements for a friction brake, or SMC pump stop feature can be used
- Process consideration: shock, vibration, water hammer, control and maintenance of different starting methods
- The effects the higher current harmonics will have on supply line during the start
- The possibility to use soft start for starting several motors on the same bus.

In existing applications, starter can be upgraded with power stack with bypass

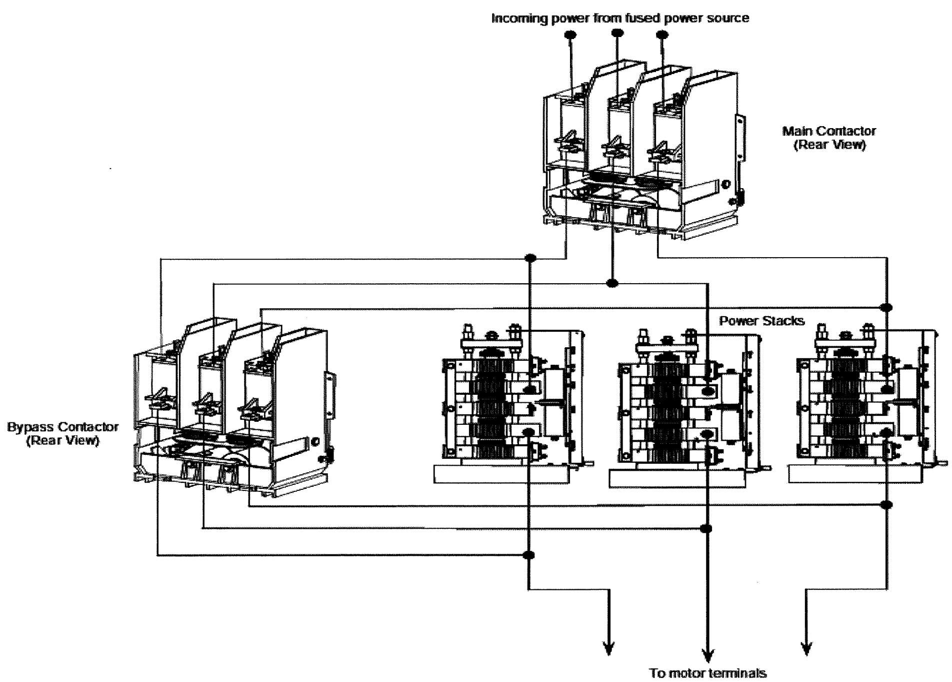


Figure 8 – Main and AC controller with bypass contactor wiring configuration

contactor and in new application starter with AC controller and bypass contactor is preferable solution, Figure 8.

For pump system that provides a variable flow or a constant pressure, the above challenges are most efficiently met by the use of a variable speed drive, Figure 9.

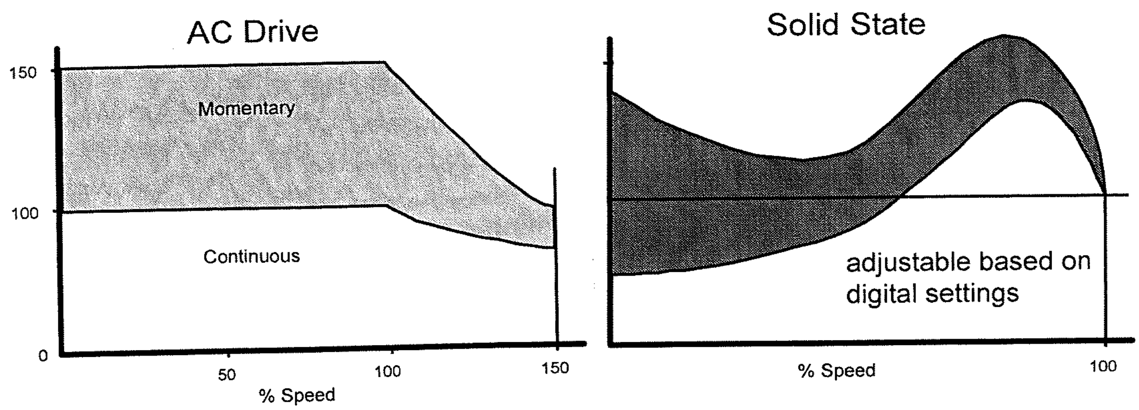


Figure 9- Soft start vs variable speed drive application

3. Conclusion

The initial inrush currents, locked motor current and the resulting torque values produced, are the factors that determine whether the motor can be applied directly across the line, or whether the current has to be reduced to get the required performance to match the load requirements and/or utility line voltage specification. During the starting process, the soft starter progressively increases the motor voltage from zero enabling the pump to accelerate to rated flow minimizing the potential for "water hammer" or current peaks leading to better pump protection and avoiding damage to piping system.

For pumps that operate at full flow, a soft starter offers a cost efficient solution to these problems. Soft starters have a well proven design with documented reliability.

The operating time of the soft starter is small and the generated harmonics, even when higher than IEC and IEEE standards, might be acceptable for the time duration. In case this is not accepted, a harmonic filter needs to be considered.

4. References

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