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BELTCON 4

Electronic Soft Starters

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ELECTRONIC SOFT STARTERS

Electronic soft starters, although a relatively new member to the family of power technology, have proved to be technically sound and versatile in the starting of belt conveyors.

These units offer a variety of options which may be incorporated into the design of the belt conveyor system, to produce reliable and efficient operation.

By careful selection and design of a belt system and starter, the plant engineer can achieve improved productivity and effectively reduce DOWNTIME.

1. *INTRODUCTION*

Why is it, that designers sacrifice efficient, reliable and technically sound systems for the sake of minor additional costs on electronic closed loop controls? I do not believe this is due to a lack of knowledge or technical expertise but possibly due to a lack of research, time and initial capital. Is the man in industry in such a hurry to produce and sell, that he forgets the importance of reliability during design and installation and only remembers this when he is hit by the inevitable blow of DOWNTIME?

The potential saving and selection of any handling system should be based on examining and comparing different modes of bulk transportation available and preparation of cost models based on different tonnages, distances and operating costs, in order to find the most practical solution for each application.

Let us for once, sit back, design and produce a system that will be technically sound and capable of meeting the total belt conveyors needs; (if only in our minds here today)

The Electronic Soft Starter, a recent development in power technology has provided the plant engineer with yet another option in AC induction belt motor starters. By reducing the voltage to an induction motor to approximately 70% at start up, the motor is allowed to begin rotating without drawing excessive current and also effectively reducing mechanical stress and damage to the motor and conveyor belt system due to inrush torque.

Stresses induced in belt conveyors at start up are an important consideration when designing a conveyor system. These stresses are reduced by increasing the start up time of the conveyor and also reducing the torque delivered to the system by using an Electronic Soft Starter. Electronic starters are available in different format and with various options, it is therefore important to install an electronic system which will provide for the belts needs.

2. *APPLICATION EXAMPLES*

LOW REPLACEMENT COSTS

A conveyor belt at a lime plant was carrying limestone of a diameter approximately 4cm. When the belt was started, the sudden jolt on the system due to high inrush torque caused the pieces of rock to jump on the belt and they would take a while to acquire belt speed. The sharp corners tore and cut the belt. To prevent this, the plant engineer installed an electronic soft starter, thus reducing the initial shock created by direct-on-line starting and increasing the life of the belt.

In this particular case, although the angle of incline was acceptable, i.e. below 17%, the belt was still experiencing damage when starting. The electronic soft starter was successful in reducing replacement costs on the belt, and at prices of around R320-00 per metre for belt material alone, this was a substantial saving.

2.2 *PRODUCTION LINE IS KEPT RUNNING CONTINUOUSLY*

A take-up system is required to do two things; to move the accumulation of slack in the belt and also to permit the belt to be stressed to the tension at which the pulley will drive it. If the slack tension is too low, it will slip at start-up and be scraped and torn at the pulley side. If the belt is pulled tighter than is necessary, the high tension might stretch and damage it. By using an electronic soft starter, it is possible for the motor to begin rotating slowly, allowing the tension on the belt to increase at a safe rate. When correct tension is achieved, the starter can be signalled to apply full voltage to the motor.

By doing this, the tension on the belt is always within the required limits, and damage to the belt due to stretching or tearing is minimised, resulting in a continuosly running production line.

2.3 *OVERTIME BUDGET REDUCED*

With long conveyors it is very important to ensure that the correct tension is applied to the belt before starting the system.

On a recent coal conveying system, a gravity take-up was used to introduce a certain amount of tension in the belt. Although the gravity-type of take-up has its advantages. Geoff, the plant engineer, still found that he was experiencing problems due to coal falling off the belt and jamming mechanical rollers. This only occured when the system was being started. After installing and electronic soft starter, the coal remained on the conveyor with no problem. Geoff maintained that a substantial amount of money was saved by the resulting reduction in overtime budget, and maintenance costs.

2.4 *ACTUAL PROBLEMS ELIMINATED BY ELECTRONIC SOFT STARTERS*

A belt on a 20^{o} incline would not run straight. The head pulley had worn so much due to the conveyor slipping when the system was started, that the face was concave instead of convex. The head pulley was replaced and an electronic soft starter was installed, the belt continued to run and no head pulley wear was incurred.

A belt handling grain lasted only five months; others had lasted three years. Investigation showed idler pulleys stuck tight due to grain falling from the conveyor at start and hence blocking the idlers. Belt idlers had to be replaced and electronic soft starters were installed on all conveyors to prevent a possible repeat occurrence.

2.5 GOOD RETURN ON ENERGY COSTS

An obvious advantage of the electronic soft starter, is efficiency. High efficiency results in low power losses, and low power losses results in a better return on payments.

For example, let us examine an 80kW operating direct-on-line;

Motor loss (efficiency 94%) = 4,8kW

Estimated loss in silent chain = 4,05kW drive, countershaft and rope drive

Estimated loss in turning head = 1,8kW shaft at 300m/min belt speed

Total losses up to elevator belt = 10,65kW

Therefore, power delivered to = 69,35kW belt

By installing an electronic soft starter with efficiency of more than 99%, the added power loss of only 0,8kW is negligable, when compared with other drive systems (mechanical) which operate at an efficiency of typically 97%.

By using a bypass contactor together with the electronic unit, the soft starter may be removed from the circuit after the motor has started up thus eliminating any possible losses whatsoever. Mechanical systems however, remain in the circuit continuously, together with their associated losses.

2.6 ENERGY COSTS REDUCED

The installed power generating capacity in India is around 184 billion GWh, with 57% referring to thermal power, 39,5% to hydraulic power and 3,5% to nuclear power. Thus, the thermal power generating capacity in India amounts to around 105 billion GWh. The Fuel Policy Committee has estimated the average consumption of power in the year 1990 to be around 32 billion kWh. The average rule of thumb estimation is around 15,9 km of conveyor belts for every 1 GWh of installed capacity.

A study of Arthur D. Little Company in the U.S.A. reveals that electric motors used to power mechanical devices, are the largest single-catagory consumer of the worlds energy resources. By way of comparison;

1) *Electric motors use one third (1/3) more energy than motor cars (in the U.S.A.).*

2) *In 1976, electric motors consumed 6 million barrels of oil equivalent (1,5 million tons of coal) daily.*

3) *Hundreds of millions of "in service" electric motors could be caused to operate with higher efficiency (e.g. by controlling motor input power in proportion to workload requirement).*

This study, and others, indicates that 66% of all electric power generated in the U.S.A. is consumed by electric motor workload and efficiency. It has been estimated that electric motor control that produced a 10% saving in electric power consumed in U.S.A. industrial applications would save approximately 10 billion kWh annually.

An energy saving feature may be included on the electronic soft starter. This means, when the AC induction motor is operating at light and moderate loads, the reactive power to the motor is decreased so as to reduce energy losses. Although the AC induction motor is highly efficient, it is interesting to note that this high efficiency is only realised above 40% rated load. Therefore, when any induction motor operates at light to moderate loads and receives more power than is needed it wastes a percentage of the applied (excessive) input power in the form of heat.

The energy saving feature is an added advantage on the electronic soft starter and necessary for the reduction of energy consumption costs.

3. *THE ELECTRONIC SOFT STARTER*

Electronic soft starters control the voltage to the load by means of high powered electronic AC switches called thyristors. This system is highly efficient, as minimal losses are produced by the thyristor circuitry.

By firing pulses onto the gate of the thyristor by means of a control circuit, current is allowed to pass through from the AC supply through to the motor. Two types of thyristor configurations are available on the market;

- *The half controlled stack*
- *The fully controlled stack*

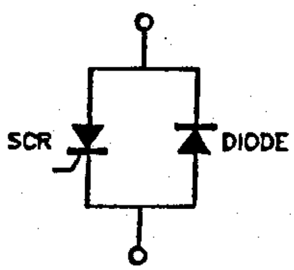

Fig 1(a)

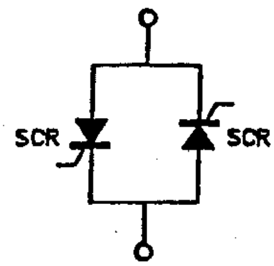

Fig 1(b)

Figure 1(a), the half controlled stack, consists of a thyristor and diode combination. In this case, control is only affected in the positive half cycle of the incoming mains waveform. The output from this stack is an assynchronous type of AC waveform, which induces a DC component into the motor, causing even harmonics and thus creating heat within the motor.

Figure 1(b) shows a fully controlled stack configuration which consists of two thyristors back-to-back. The output waveform is a synchronous type of wave and control is affected in both the positive and negative half cycles of the incoming wave. In this case, no DC component is evident.

Firing of the thyristors is obtained by means of a control circuit. Both half and fully controlled stacks introduce a certain amount of switching transients which may cause heat within the motor with prolonged starting times. The start time must therefore be taken into consideration together with the torque requirements of the motor and belt system.

Clearly, the specification of the starting torque requirements of a machine is an engineering problem and in some cases becomes very involved. In such cases, starting requirements can be ascertained in a similar fashion. In some installations, motors are selected on the full load requirements of the machine, and cases of high inertia loads with low average mechanical work may need to be coupled to a motor selected on starting parameters only, or slip ring (high starting torque) motors used.

There are some calculations that are useful in the determination of approximate starting torque requirements.

1) *The output torque of the motor*

$$T_m = \frac{P \times 60}{2 \times \pi \times N}$$

where : T_m = *Maximum torque*
P = *Rated power*
N = *Rated full speed of the motor (rpm)*

2) *The accelerating torque*

$$T_a = \frac{M \times N \times 9{,}55}{t}$$

where : M = *moment of inertia as seen by the motor including the inertia of the load*

If the load operates at a different speed from the motor, a correction is applied to the load inertia;

$$M = M_{motor} + M_{load} \times \frac{(N_{load})^2}{(N_{motor})^2}$$

Therefore, if the load speed is higher than the motor, the effective inertia is increased.

The starting torque of the motor must exceed the breakaway torque and must also equal or exceed the Work torque during starting plus the load acceleration torque. If the work torque is not known, assume that it is less than or equal to the torque of the machine at full speed under the conditions at which it is started.

Once the starting torque is known, the required starting current can be calculated. The full voltage starting torque of the motor depends on the motor design. For a NEMA A or B, the full voltage starting torque is typically 120% rated torque.

Hence:

$$\frac{T_{fv}}{T_{st}} = \frac{(I_{lr})^2}{(I_{st})^2}$$

Therefore, the starting current;

$$I_{st} = I_{lr} \times \frac{(T_{st})^{1/2}}{(T_{fv})^{1/2}}$$

where; T_{lr} = *Full voltage starting torque*
T_{st} = *Starting torque*
I_{lr} = *Locked rotor current*
I_{st} = *Starting current*

The locked rotor current of a NEMA B motor is approximately six times rated full load current. The locked rotor current is a property of the motor design.

Full voltage starting current is essentially locked rotor current until the motor has reached greater than half speed.

4. CHOOSING A SOFT STARTER

Before choosing an electronic soft starter, it is important that all requirements of the application are considered together with the requirements of the options available with the starter. It is therefore necessary that both the mechanical engineer in charge of the belt conveyor design, and the electrical engineer in charge of the soft start design, meet to discuss the various possibilities of design. The system can then be manufactured to facilitate both the conveyor and starter to attain optimum results and smooth operation.

4.1 THE OPEN LOOP SOFT STARTER

The Open Loop soft starter is a basic low cost unit, available with a half controlled or fully controlled stack. This unit ramps the voltage to the AC motor from approximately 70% of full mains voltage to 100% mains voltage. The initial value of 70% varies from application to application and depends on the design of the motor together with the load requirements. This value is set so that the system can produce the torque to overcome its breakaway requirements. By reducing the voltage to the motor at start up, the current is also effectively reduced and thereby also the torque. This allows the conveyor to start up slowly, reducing stresses and breakages on the belt.

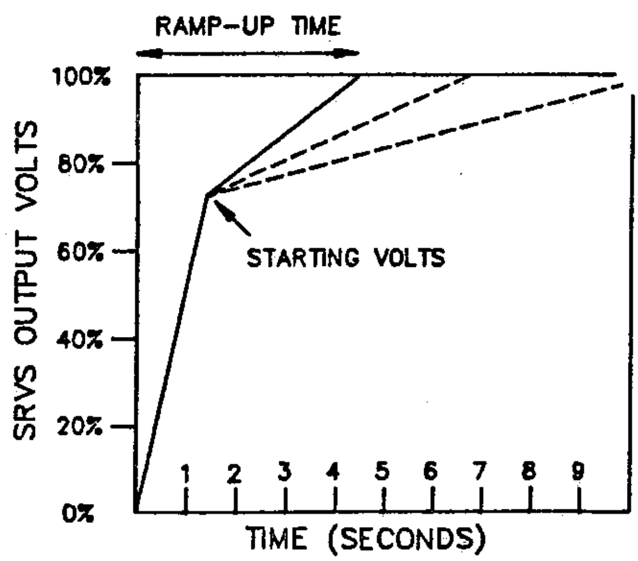

Fig 2 Voltage Ramp Characteristic

This method does not provide any facility for motor protection, neither does it guarantee a constant acceleration time, the acceleration time being dependant on the magnitude of the load applied. Both of the above are important pre-requisites for smooth reliable belt conveyor control.

4.2 THE CLOSED LOOP SOFT STARTERS

The Closed Loop soft starter incorporates a feedback system in the form of either current feedback or speed feedback. Both methods have their advantages and should be considered together with the belt design requirements.

4.2.1 THE CURRENT FEEDBACK METHOD - uses a current transformer to monitor the current to the motor, and this is then fed back into the control circuitry. A two-stage current limit is incorporated so that current can be limited to the motor at start up and then reduced to a lower value (rated full load current of the motor) once the motor has reached full speed. The initial current limit is set to a value which is large enough to allow the motor to develop sufficient torque to overcome the breakaway requirements of the system.

The advantages of the current feedback method are that a stall feature may be included to facilitate motor protection. If the belt conveyor should go into a stall condition, the control circuit will remain in current limit until a stall or cut-out relay is activated. The current feedback method also ensures that the belt conveyor does not overcome any current limitations which are specified by the Electrical Supply Authorities, or by the plant engineer because of soft supply systems.

4.2.2 THE SPEED FEEDBACK METHOD - monitors the speed of the motor at start and full running conditions by feeding back a tacho-generator signal to the control circuit. The control circuit thus fires the thyristors according to the voltage ramp method but at the same time, the speed of the motor is being monitored continuously and is compared with the required speed at any point in time. Should a larger load than normal be applied onto the conveyor, this will, with an open loop starter, vary the start time. By using speed feedback, the control circuit will detect any such retarding torque on the shaft of the motor and still then increase the firing pulses to the thyristors so as to allow an increased supply of voltage through to the motor. This way the motor will accelerate to full speed in a constant time, regardless of the magnitude of the load.

The advantages of this method include the facility for a stall circuit. The motor speed will be monitored for a zero speed (stall condition) and will activate a stall or cut-out relay. Speed feedback also ensures a constant start-up time, which is often necessary with belt conveyors which are designed for specific start times so as to reduce belt oscillations at starting. It is quite possible for the start time on a belt conveyor to vary as they are starting on continuously varying loads.

4.3 FURTHER OPTIONS AVAILABLE

4.3.1 ENERGY SAVING - if the belt conveyor is running under reduced load conditions, the firing angle of the thyristors is reduced so as to minimise the reactive current drawn by the motor. This in turn reduces energy costs. Should a full load be applied once more, the control circuit will detect this (by either current or speed feedback) and will once again supply full voltage to the motor.

4.3.2 PARALLEL OPERATION OF AC MOTORS - up to four motors may be started from the same soft starter simultaneously, provided that they are mechanically connected to the same belt system. Each motor should be individually protected and the starter must be sized according to the total power requirements.

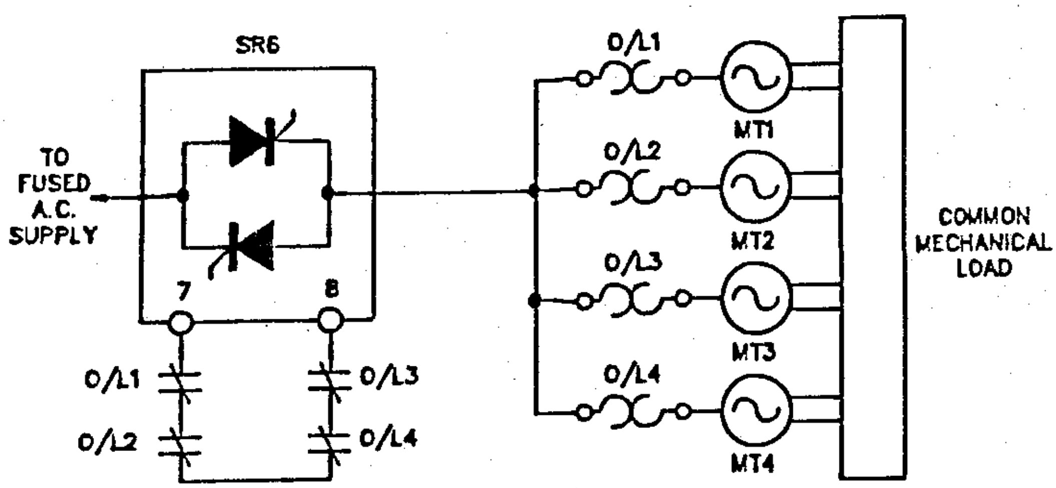

Fig 3

4.3.3 CONSECTIVE STARTING - it is possible to start more than one AC motor consecutively, by using the same starter. Once the first motor has reached full speed, the starter is removed from the circuit by energising a bypass contactor and supplying the motor direct-on-line. The starter is then available to be used to start a second motor, and so on.

4.3.4 BYPASS - it is possible to bypass an electronic soft starter once the motor has reached full speed. This way the motor is supplied direct-on-line, leaving the starter out of the circuit and allowing the unit to be used to start a second system.

4.3.5 SOFT STOP - a soft stop is often necessary to increase the stop time of a belt conveyor. This is possible by reversing the voltage ramp process on the control card. This requires a second control circuit but the same thyristor stack can be made use of.

CONCLUSION

The life of a belt depends upon many factors, but it is important to consider as many of these factors as possible so as to reduce the ever-recurring problem of DOWNTIME.

Factors reducing belt life that suggest the need for an electronic soft starter are stated below :

1. *Start time too fast for effective conveying of lumps; belt becomes cut and abraded;*

2. *Material spilled at start up accumulates around idlers; rolls refuse to turn; maintenance shut down.*

3. *Excessive take-up tension; belt stretches and splices pull out; maintenance shutdown required and replacement costs incurred.*

4. *Frequent starting under full load; belt stretches and splices pull out; maintenance shutdown required and possible costs necessary.*

5. *High energy costs regardless of low load transportation; no damage to conveyor but definite continuous costs are incurred.*

As can be seen, to advance in technology it is extremely important that communication is affected between the belt conveyor designer, the plant engineer and the soft start manufacturer. This way, optimum results, improved designs and finally, less downtime and more golf time for you, the Plant Engineer.

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