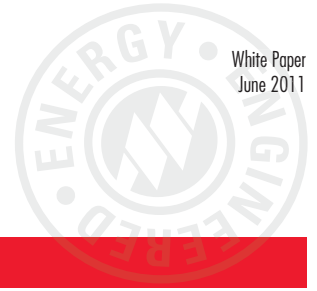


Digital DC Drives vs. Direct Current Constant Potential Controls and Other Series Wound DC Motor Controls



Jason Wellnitz
Product Engineering
Supervisor

Material Handling

The purpose of this paper is to compare Digital DC Drives (DDC) with Direct Current Constant Potential Controls (DCCP) and other series wound DC motor controls. The use of Digital DC Drives in crane and hoist applications can improve performance, safety and reliability of the crane, while minimizing downtime, maintenance expenses and energy costs. In addition, safety can be improved through failsafe torque proving and load control software ensuring the operator has complete control of the load at all times.

INTRODUCTION

In production crane installations using DC power, the series wound motor is usually used. These motors develop very high starting torque and can rapidly accelerate heavy loads. Speed control over a wide range of speeds is accomplished by varying the voltage across the armature and current through the field. The maximum speed of a series motor varies greatly when the load is varied; the speed while handling a light load can be considerably higher than the speed when handling a rated load.

While lowering an overhauling load the series motor functions as a self-exciting generator, it produces a braking action called dynamic lowering. Optimum speed regulation is achieved with 100% load during raising, but somewhat faster speeds are common during lowering.

DIRECT CURRENT CONSTANT POTENTIAL (DCCP) CONTROL

DCCP was the first variable speed DC control available. DCCP control technology dates back to the late 1800s and the principles behind their simple design have not changed. DCCP controls work by limiting the voltage across the armature by varying the resistance both in series and in shunt motor fields. Typically, the hoist direction will add series resistance and the lower direction will have series and shunt resistance. So, as the load varies so does the torque and speed characteristics of the hoist. As speed selections are changed abrupt speed changes and high in-rush currents can be expected.

Increasing the load leads to decreased speeds and higher torques, while smaller loads lead to higher speed and lower torques. This in turn, has its own issues as the operator's timing and control of the crane changes depending on each load. The operator is therefore required to adjust each load movement because of the varying speed characteristics.

These varying speed characteristics allow the operator to control the torque through plugging. Plugging is the change in direction and deceleration proportional to the deflection of the master switch, and it correlates to the amount of torque applied to the motor. However, there is typically a 200-millisecond delay in speed changes because of electro-mechanical delays, which is slower than newer control technologies.

Also, for every speed point a contactor is required; usually five speed contactors, two main contactors, and one dynamic braking contactor, as depicted in Table 1.0. Because of the high power required to pick up and lower the load, resistors are typically as large as the control cabinets. In addition, separate interconnects are needed for motor overload switches. The lifespan of electro-mechanical contractors is decreased because all contact switches are turned on and off as an operator cycles through speed points to get to the desired operating speed. The contacts are always switched under load with current flowing through the contactor tips. When the current flow is broken this causes arcing and tip burnout.

Crane Board	No. of Contactors	No. of Relays	Typical No. of E/M Components
Hoist	9	4	13
Trolley	9	3	12
Bridge	9	3	12
Total	27	10	37

Table 1.0: Typical DCCP Contactor Requirements

The two-quadrant nature of the DCCP control means that nearly all of the regenerative energy is consumed by the resistor bank and the motor at different speed points. In the event of a broken shaft under load, motor damage can be caused by motor runaway because of the open-loop design of DCCP controls.

DCCP controls are used in crane and hoist applications in both hoist and traverse motions, on quench cars and locomotives where a DC power supply is present. DCCP controls are used in load sharing applications where two or more connected motors work together.

In large steel mills built in the 1950s and 1960s, there can be several hundred cranes with the minority of these retrofitted with newer technology. As DC-to-DC solid state control continues to prove its cost effectiveness and

reliability in steel mills and other industrial applications, DCCP technology will continue to be phased out, which will make it increasingly difficult to procure components.

OMNIPULSE DDC

The OmniPulse DDC was designed as a drop-in replacement for standard DC Constant Potential contactor and resistor controls for Series Wound Mill Duty 600 and 800 frame motors. Each drive chassis rating has an equivalent NEMA contactor rating and operates on a nominal 250VDC power supply or 400-600VDC optionally.

It offers superior performance and software features specific to the crane and hoist industry, as well as high reliability. In addition, the DDC is the only DC-to-DC drive to offer four-quadrant motor control in the crane and hoist industry. The compact, modular design with universal software requires minimal spares to be kept on-hand and is available from 5 to 500 HP.

The DDC has a compact, modular design using common components for maximum application flexibility. In addition to the rugged steel drive cube, this compact, modular design requires fewer spare parts and offers easy troubleshooting and diagnostics. The universal software in the DDC allows for quick parameter changes to meet changing production needs and facilitates drive replacements.

The DDC's speed regulation from no-load to full load is 5%, and 0.1% with the addition of tachometer feedback. It is designed for four-quadrant motor operation, giving the operator full control at all times, and eliminating the need for directional contactors and resistors in the lowering direction. The DDC also offers additional performance features, such as micro-speed for superior load positioning, enhanced plugging and deceleration capabilities. Thermal management includes operational temperatures of -10°C to +50°C for standard enclosed designs, and systems can be designed for operation up to +60°C without active cooling.

The DDC incorporates Modbus RTU communications via an RS-485 or RS-232 link. This makes the DDC a candidate for automation applications and allows the DDC to interface to advanced diagnostic tools such as IMPULSE Link Basic, and WDS.

OTHER SERIES & RDSI WOUND DC MOTOR CONTROLS

These types of DC Hoist Controls were designed as a hybrid, solid-state and electromechanical control for crane and hoist control applications. They use an open heat sink design with exposed connections.

Direction control is attained by opposing directional contactors and speed control is attained by varying the duty cycle of line-to-line IGBT switching. The use of directional contactors creates an additional failure point and all but eliminates the possibility of accurate, responsive motor control below 10% of base speed.

Other series wound DC motor controls require a different product for hoist versus traverse motions, and also requires specific EFPROMs depending on the application, sizing, motor frame, and other variables. They are only available for 5 to 265 HP at 230 to 300 VDC (360 to 600 VDC optional).

Given the minimal market for DC-to-DC series motor control, there has been little hardware development put into other DC controls over the years, and their designs have relied on antiquated digital circuit technologies. Most notably is the need for individual programming for each drive type and the limited flexibility of each drive model.

OMNIPULSE DDC VS. DCCP

OmniPulse DDC digital crane controls outperform traditional DCCP crane controls in significant operational areas including motor speed and torque control, serviceability, maintenance and energy costs, and safety. The DDC operates in an efficient four-quadrant design at all times, while the DCCP operates only in two quadrants and relies on inefficient resistors to achieve speed control.

DDC drives provide better motor speed and torque control than DCCP electro-mechanical crane controls through the use of digital microprocessor control with flexible software that enables smooth acceleration and deceleration, reducing torque spikes and excess mechanical torque during speed transitions. DCCP Controls use contactor-, relay-, and resistor-based control that results in aggressive transition between speed points and no reduction of mechanical torque. During load positioning DDC controls offer repeatable and accurate speed settings for precise load positioning and the Micro Speed feature offers still finer load positioning accuracy. Because of the use of resistors for speed points for DCCP control, heat can cause alterations over time, which can result in inconsistent load positioning.

The digital technology utilized by the DDC drive provides controlled, repeatable, accurate and variable plugging to stop or reverse crane position. Outdated DCCP technology results in plugging torque inconsistency. The DDC's software provides 5% speed regulation, from no load to full load, while DCCP speed regulation can vary by as much as 80% of base speed depending on direction and load due to load changes and the effect of heat.

Downtime is minimized and serviceability improved with the use of DDC controls versus DCCP electro-mechanical controls. The DDC's control software is capable of supporting various material handling applications for programming flexibility. It is also capable of remote monitoring and parameter modification. This is not possible with DCCP controls. OmniPulse DDC's solid-state design has fewer electromechanical components than DCCP, and DCCP controls have many moveable components that can wear and fail over time requiring extensive maintenance. Maintenance is further simplified for DDC controls because spare part inventories are minimized due to its modular design. The spare parts inventory needed for DCCP

controls is much larger including directional contactors, speed control contactors, contactor tips, interface relays, and power resistors.

Troubleshooting is simplified for the DDC through built-in diagnostics. Diagnostics include control and motor fault monitoring such as stall prevention, open armature and field detection, which decrease crane repair times. The drive has a built-in fault history, which can be used to track frequency and sequencing of failures for improved crane reliability.

DCCP controls do not have diagnostic capabilities, making troubleshooting more time consuming. On-going maintenance is further reduced for OmniPulse DDC controls because the solid-state design does not use contactor tips, coils, auxiliary contacts, mechanical interlocks, directional contactor or power resistors to operate as do DCCP controls. Brake life is increased with the use of DDC controls because the brakes can be set at much lower speeds than DCCP controls, reducing stress on brake parts while increasing lining life. DDC controls increase the life of brush, commutator and field insulation because the armature current is restricted to a maximum of 200% of the motor rating, and a maximum of 150% of the motor rated field current, while the Counter Electromotive Force (CEMF) is restricted to 110%. There are no restrictions with DCCP controls. Smooth speed acceleration and deceleration is achieved by the OmniPulse DDC, which results in reduced shock loads on the mechanical power train. Deceleration control of the DCCP is dependent on changing resistors.

The OmniPulse DDC control's high-efficiency design regulates motor current and reduces line power demand resulting in energy savings, while DCCP controls utilize resistors that consume additional line power. In specific applications, the DDC can recover power from the load and return it to the DC power supply. The DDC will shut down and set the brake if DC power is lost while lowering a load. Under a similar situation, the DCCP could continue with a controlled lower as the motor is regenerating.

Improving safety is one of the main reasons to use OmniPulse DDC controls instead of DCCP controls. DDC controls utilize continuity check at start to verify control of the load. In hoist applications, the motor armature circuit is checked when the raise/lower command is given, before the brake is released. While DCCP controls are capable of checking for armature continuity they require an additional collector for redundancy. The motor series and field loss detection features of the DDC provide a fault to the drive and set the brake. If the speed input is lost on the DDC, the drive will operate up to the lower speed inputs. On DCCPs a loss of speed input could result in skipped speed points and high current and torque transitions or load drops. Load drops could occur when a speed input is lost because the control cannot deliver the required torque at the lower speed point.

DDC controls are less expensive to install because they require fewer power conductors between external speed control resistors and can maximize catwalk space by decreasing control enclosure sizes by 30-50%. This makes it easier to walk around on the catwalk when several enclosure doors may be open during maintenance.

OMNIPULSE DDC VS. OTHER SERIES WOUND DC MOTOR CONTROLS

OmniPulse DDC digital crane controls outperform other series wound DC motor controls in significant operational areas including ease of monitoring, programming and firmware updates; safe load handling during fault events,;and decreased maintenance and energy costs. The DDC operates in an efficient four-quadrant design at all times, while other series wound DC motor controls are not fully four quadrant designs; they use resistors at low speeds to maintain field voltage and current, reducing design efficiency.

Other series wound DC motor controls use an open heatsink design with exposed connections and components providing minimal protection from high voltage components. They do not offer an integrated display for monitoring or programming, require an external timed overload relay, and mechanically interlocked DC contactors for motor reversal. Although the product can improve performance over typical electromechanical controls, it has less features and functionality than the OmniPulse DDC.

Because the OmniPulse DDC is a closed loop speed regulator and can pass through zero speed without directional contactors, the DDC offers the most consistent traverse plugging performance available. The DDC plugs with individual torque levels for each speed point. Other series wound DC motor controls cannot offer consistent plugging performance because they do not offer torque control for each speed point, only a braking current limit, and must wait for directional contactors to change polarity before current regulation can start.

Other series wound DC motor controls require a different product for hoist versus traverse motions, and also require specific EPROMs dependant on the application, sizing, motor frame, etc. It is available for 5 to 265 HP at 230 to 300 VDC (360-600 VDC optional). The DDC utilizes a single, proven firmware version across all drive sizes on a flash memory chip. Using a single firmware version makes it easier to set up drives in unique applications, reduces training demands, and reduces inventory spares. The utilization of flash technology makes it easy for the customer to upgrade firmware versions, keeping all drives at the same control level if desired, and allows the end user to take advantage of newly developed features at no cost.

Other solid-state DC Hoist Controls use a series line inductor to minimize the effect of line voltage variations on speed control. Without the inductor speed variations will be noticeable and audible because of the open-loop nature of the drive. The DDC is not affected by line voltage variations on the



motor control side because it completely closes the speed regulator loop, using motor CEMF and field current feedback to regulate speed. The line inductor is offered as an option for DDC controls in most applications and a line inductor is not typically needed because of the advanced design. Adding components that the control likely will not need adds unnecessary costs. Inductors also generate heat, thereby wasting energy and further increasing ownership costs.

An important feature of the DDC is safe load handling during fault events. An IGBT Failure Mode Analysis of the DDC hoist circuit shows all single point failures result in either a series brake closure or a significantly slow emergency lower. If a diode short circuit occurs and the brake fails to set the DDC will maintain motor torque, limit the hoisting speed, and set an output alarm to allow for safe lowering within the safety guidelines of AIST Technical Report 6. Optional equipment can be added to guarantee a series brake sets if the customer so requires. This is in contrast to other technologies that require the addition of extra contactors to isolate the armature and brake to prevent uncontrolled lowering in the event of IGBT failure. The OmniPulse DDC has the same number of diode paths and would be subject to the same open brake diode failure mode without the closed loop feedback. The DDC provides many protection features over other series wound DC motor controls including built-in motor overload protection, motor ground protection, under/over voltage, motor continuity check, and a fail-safe pre-charge circuit.

Other series wound DC motor controls provide overhauling load protection, which limits over loaded crane speeds. This protects against brake slip and failure. OmniPulse DDC has current limits and decelerates the drive to a stop speed that is safe, which minimizes brake slip for any load and speed combinations.

The OmniPulse DDC operates in a full four-quadrant operation which allows regenerative energy to be consumed by other DC components on the grid. Four-quadrant operation improves crane speed and torque control and allows for significant long term energy savings. Because unconsumed regenerative energy increases the DC bus, Regenerative Power Modules (RPM units) are used to regulate DC bus voltage in a similar fashion to dynamic braking used in AC variable speed drives. The RPM units can be configured in a common bus or non-common bus format which affords several design flexibility advantages. Common bus RPM units can

be sized for multiple cranes, lowering the overall package cost. Non-common bus RPM units are the lowest cost for single motion crane packages. Other series wound DC motor controls are not fully four quadrant designs; they use resistors at low speeds to maintain field voltage and current, reducing design efficiency. They also cannot cross zero speed without changing directional contactors under load and enabling the DB circuit. This causes contactor arcing or DB drift through zero speed. The OmniPulse DDC employs a chassis drive design similar to most AC drive technologies available. High current applications (greater than 400A) use parallel drive chassis, all with common components. This has proven to be a successful design philosophy to reduce inventory count, simplify troubleshooting, and minimize downtime. Other series wound DC motor controls utilize a panel and heatsink mount control design. This means control troubleshooting is taken down to the component level; troubleshooting to the component level in the field requires a higher level of training and is more time consuming than the DDC when time is money in production facilities.

Every electrical component's life expectancy is directly tied to the temperatures they are subjected to, typically for every 10°C temperature rise a component's lifespan is cut in half. The OmniPulse DDC provides two thermal monitors, heatsink and ambient temperature, with corresponding parameters for alarm and fault annunciation. The DDC's ambient temperature fault is set to 75°C and its heatsink temperature fault is set to 90°C by default and both are adjustable. Other series wound DC motor controls state very clearly in their manuals that the heatsink temperature should not exceed 75°C and do not include an ambient temperature monitor.

CONCLUSION

The OmniPulse DDC offers the best technologies to bring DC-DC cranes into the 21st Century. The use of Digital DC Drives in crane and hoist applications can improve performance, safety and reliability of the crane, while minimizing downtime, maintenance expenses and energy costs. In addition safety can be improved through failsafe torque proving and load control software ensuring the operator has complete control of the load at all times. Magnetek's OmniPulse DDC has been successfully applied on hundreds of new and existing cranes and hoists (traverse motion) across North and South America, Europe and Australia.