Drilling drives for availability and redundancy

TOBIAS ERIKSSON – Drilling drives and their control systems are essential for the drilling system to control the drill string and auxiliaries. Drilling drives are also an integral part of the overall electric system that keeps dynamically positioned vessels on location and feeds power to essential consumers on board the vessel, allowing for safe and reliable operations.

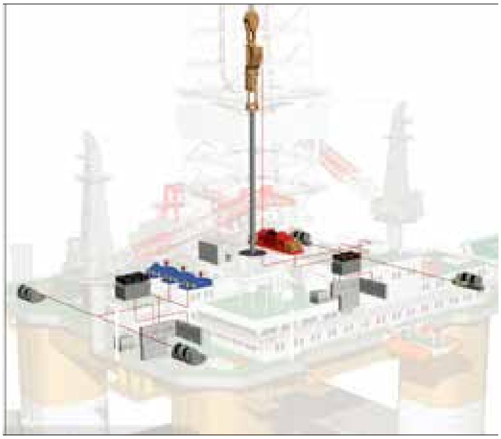
High reliability, serviceability and proper redundancy of essential functions are taken into account during system design and equipment selection. Different approaches are needed to meet stricter requirements for availability in drilling equipment. New and existing functionalities in ABB Drilling Drives System aimed at meeting these demanding requirements are described in this article.

The ABB Drilling Drives System consists of several parts: ABB ACS800 Multi-Drive Lineups, Braking Resistors, Motors, Remote I/O panels and an embedded control system.

The embedded control system, or Drilling Drives Control (DDC), controls, monitors and protects the drive lineup, including supply, DC bus and inverters for the drilling motors. It also serves as an interface for the drilling process and auxiliaries, the drilling control system, the electrical power plant and the power management system.

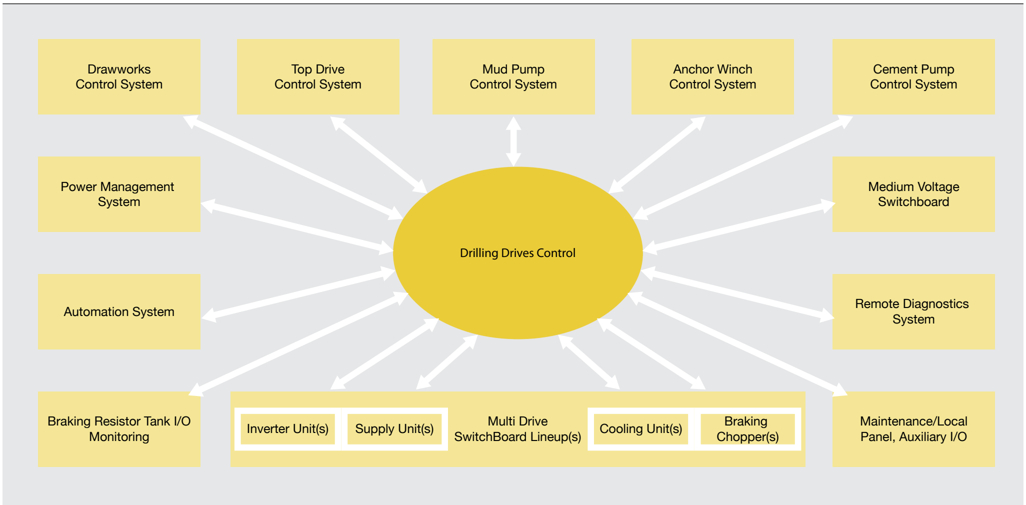
The DDC also controls switching of change-over circuits to run alternate motors, such as changing between anchor winch motors and mudpump motors if fed from the same drive inverter. If equipped with a remote diagnostics system (D4Drilling), the DDC will also be interfaced to the embedded Drilling Drives Control system.

1 Drilling drives system overview showing the electrical connections from transformers, multi-drive switchboards to the drilling equipment drawworks, mudpumps, topdrive and anchor winches



The aim of the Drilling Drives Control is to adhere to standard architecture and tested functionalities to

2 Drilling drives control interfaces overview showing the different interfaces to the embedded control system



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reduce engineering and commissioning and to use established interfaces with third-party suppliers. However, in most cases it will be necessary to adapt specifically to standards to meet process and project specific requirements. To ensure a high level of software quality, it is important that a quality assurance model specifies, tracks and tests such adaptations throughout engineering and commissioning.

Drilling Drives Control today

Depending on the project specific configuration, the DDC communicates with several different control systems. Each part of the DDC is embedded into its part of the drive system, and the overall DDC will therefore often comprise several separated subsystems. Such varied control systems calls for highly standardized and consistent functionality, while also providing required process specific adaptabilities.

Some of the functions are identical for each application in terms of drives interfaces, such as start/stop, speed reference, torque limits, etc. Others are application specific. For example, Drawworks may require a torque up logic and handshake together with a mechanical brake. Such functionalities are implemented in the DDC software, not as a completely new customized function, but as additional layers or control blocks that can be enabled depending on the configuration. This ensures consistency in how common functionalities operate within the system through a core library of interfacing functions where blocks are commonly used regardless of application.

In addition, there is a horizontal integration of protection/interlocks/power management functionalities throughout the system.

An example is power distribution. To distribute power effectively, dynamic information from all the running drives and external commands is needed as well as fast response. Reacting quickly to disturbances in the power system is critical to prevent blackouts. Typically, the worst single failure power disturbances will require actions in the order of 200-300 ms.

Reliability is achieved through this common approach to all application software, together with a core library. First, it creates a clear and testable line of responsibility between the external system and the Drilling Drives System. Second, the external system does not require any specific drive monitoring and protection functions as such actions are handled by the DDC. The DDC also has integrated redundancy through design and built-in safety functions.

Safety and availability

The reliability and fault tolerance of the various functions of the Drilling Drives System are critical when operating the drilling equipment, helping minimize downtime due to faults and safety actions to reduce consequences. High reliability and availability can be approached in several ways, and ABB's philosophy is founded on:

- Redundancy in terms of power and control configuration
- Specific functionality carrying out pre-emptive measures
- Design and interacting logic between the different parts of the system
- Monitoring capabilities for the overall system

The following sections present core functionalities related to each of these items.

Safety and reliability are also closely related to the processes used in software development, documentation and testing. Recently launched rules and guidelines for software development from classification societies, such as DNV ISDS and ABS ISQM, will also increase awareness on standardized, defined and tested functions.

Reliability can be improved significantly through robust testing, version control and follow-up. Not only do modules need to be tested during operations, but every conceivable scenario must also be consistently evaluated for all functions.

Configuration and redundancy

Different drilling applications have different redundancy requirements. Mudpumps will typically be redundant in terms of multi-motor configurations distributed on one or several drive line-ups and the mud system will be redundant by system design, which consists of redundant mud-pump configurations. There are fewer requirements for Top Drives, but the focus on safety is higher because of the potentially explosive environment.

The most stringent requirements for redundancy are for the Drawworks, particularly for Active Heave type Drawworks where total loss of operation capabilities directly impact the safety of the installation.

Redundancy must be designed and implemented with care to give a perceived high fault tolerance and availability. On the other hand, a highly complex redundancy design should be avoided. This will make it much more complicated to assess the system behavior in a fault scenario and for operators to perform the correct manual interactions if needed.

Redundancy, of course, means more components will be installed in the system, increasing the likelihood of failure. However, ABB believes it is important to achieve redundancy through simplicity in design and with a minimal increase in complexity. Redundancy should preferably use proven functionalities with necessary and adequate duplication and expansion.

To achieve the necessary level of redundancy, all systems – electrical power, control system architecture, and auxiliary configuration – must be assessed. For both main and auxiliary power supplies, different owners and designers have different approaches. Typical designs get power from segregated subsystems of the main and auxiliary power supply, and may contain back-up assignments for drilling or whinch motors, cross-feed links between drive segments, etc.

Although redundancy appears to be straightforward in designing such systems, it is important to keep in mind that perceived redundancy may be destroyed by increased complexity.

Configurations for software and hardware architecture can easily become even more complex. However, to a certain degree they can be considered independent from power redundancy configurations.

A fundamental challenge is how each component in the control system should behave in a fault scenario where a higher-level control system cannot determine and assign what part should be doing what. For example, if a communication link breaks down between two controllers, how does each controller know whether it should keep running independently or assume the other has taken over?

For drilling applications, multi-motor configurations such as Drawworks, Top Drives and mudpumps have a common shaft. For the control system, this means it is critical that all independent drives are synchronized, regardless of their placement in the power configuration (eg, connected to different drive line-ups or power supplies). From the DDC to the drive, this is done using the ABB Drivebus protocol, a dedicated communication link to the lower-level drive controllers that provides high-speed communication for control and monitoring. While redundancy will still be achieved, this creates some constraints in how the control system should be configured.

Distributed redundancy

Rather than achieving redundancy through complex software architecture, redundancy is instead achieved by expanding the existing hardware redundancy in separated control cabinets. Two redundant controllers can then be separated by long distances, while still running the same software applications and maintaining synchronized control of the drives. Each controller will connect to its own drives. This is seamlessly implemented into the application software and adds minimally to the complexity of the system (see Figure 3).

If one control cabinet fails, the complete software functionality is intact in another control cabinet because each cabinet has its own link to the drilling control system(s). Even if the overlaying application does not take advantage of dual communication lines, the application is still redundant in two physically separated controllers and still operating during, for example, a UPS control voltage failure.

This controller architecture makes multi-motor applications in different switchboard lineups, such as Drawworks, highly redundant both in terms of power and control design. This is particularly beneficial for Active Heave Drawworks applications with high redundancy requirements.

Multi-motor running configurations

Traditionally, a master-follower approach is often used multi-motor applications where one of the drives controllers (the master) handles all interfaces with DDC controllers and provides the reference to the slave controllers. The slaves simply follow the master's torque output at a given point, providing load sharing. This approach is today typically used in Top Drive applications and can also be applied to Drawworks.

The greatest benefit of such a setup is that all drives run with the same reference values for the torque, with very accurate and adjustable load sharing. However, the master-follower solution has certain weak points in the redundancy that should be mitigated, such as the master-follower link itself and the fundamental issue of what action should be taken if the master fails.

New software logic makes handover from master to slave possible by intelligently looking at the existing feedback and quickly re-assigning the master with minimal interruption of control tasks. This raises the level of redundancy close to the level of a master-master configuration.

In such configurations, each motor is drooped against the other for load sharing. Its input reference from the DDC is identical and perfectly synchronized. There is no link between the drives or logic exchanged between them. As each drive is independent, this setup is very robust.

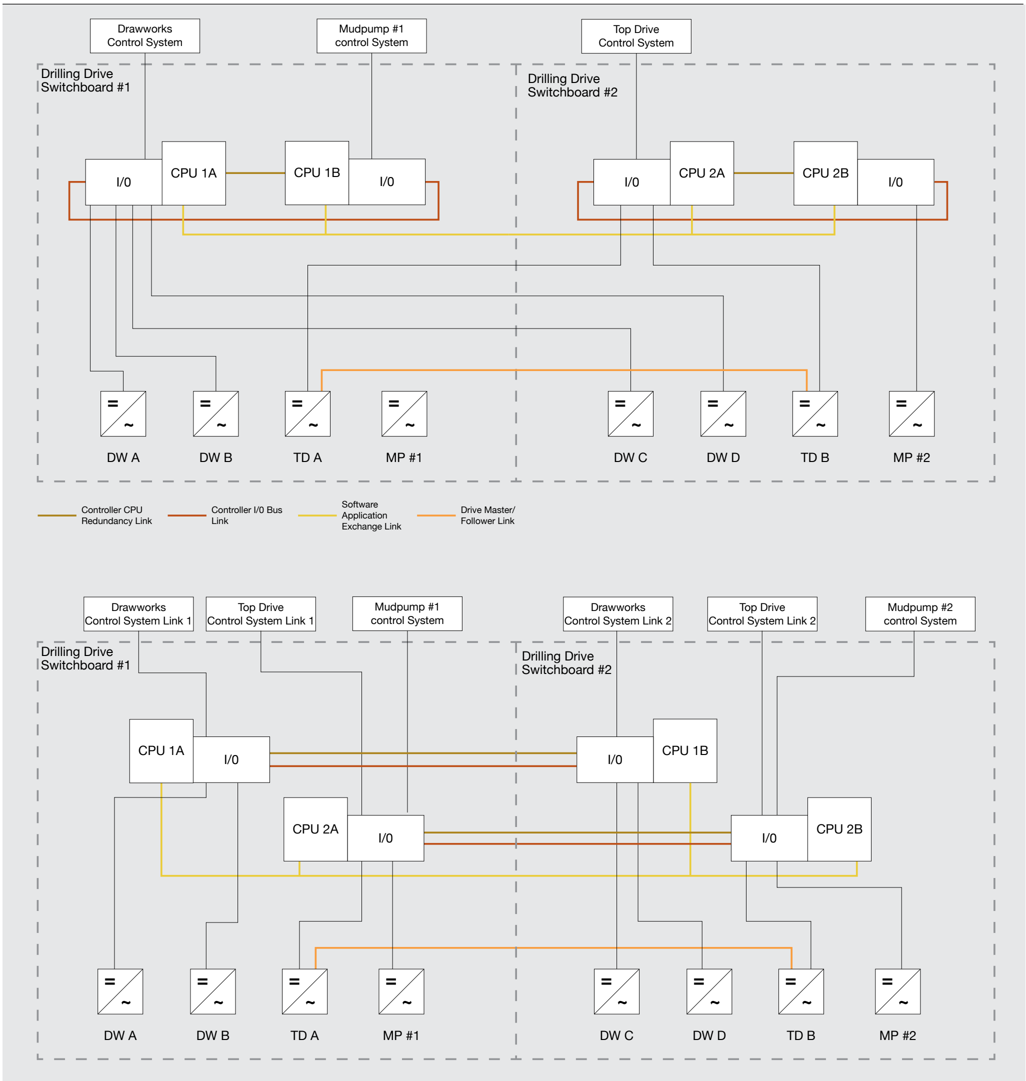
Power distribution and blackout prevention

The DDC must manage the distribution and prioritization of electric power among the individual drives in order to run the most critical loads when power supplies are constrained. The dynamic nature of the drilling equipment's power consumption makes this particularly complex.

Power management can be achieved either by continuously allocating the available power, or by taking specific action if available power is exceeded. Both methods have advantages and disadvantages.
In the power allocation algorithm, there are several constraints and input data also needs to be considered, such as a minimum value for each application and its priority.

Power allocation is further complicated in systems where power availability, load reduction and allocation is shared by several different control systems. Often three or more systems from different vendors

3 Typical control layout (top) and (below) the same layout with distributed redundancy concept



are doing parts of the calculation, requiring special attention to functional integration. A new unified power distribution module now allocates power in most configurations and interfaces. The module itself is the same, regardless of switchboard configurations. This means power limitation actions are more predictable and safer.

The main purpose of power allocation is to avoid overloading the power plant and to prevent blackouts from faults in the plant, particularly a sudden trip of a diesel engine. A classic solution is to monitor the network frequency and to use frequency deviations to initiate power reduction along with hysteresis functions and power ramping to avoid excessive transients and to ensure smooth load changes for the prime movers.

Although frequency-initiated load reduction is robust and may be considered independent from the power management system, it is also a lagging control scheme because the failure has persisted for a while before it is detected. ABB is now implementing Event Based Fast Load Reduction (EBFLR), which works with a direct link to the Medium Voltage switchboard Relion protection relays on the new IEC61850 communication platform using the ultrafast

Goose protocol. Any event (eg, a generator trip) in the plant will trigger a limitation as quickly as possible, effectively limiting the load power before the event has disrupted the plant. This is achieved by using, for example, generator feedback signals and actively monitoring predefined events (eg, a trip). A specific limitation is continuously pre-calculated, ready to be enforced in case of an event. By using control signals in the protection relays, rather than in status signals, the power can actually be reduced even before the generator is disconnected from the switchboard.

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Monitoring

All drilling drive systems are now delivered with hardware prepared for Remote Diagnostics System (RDS) tailored for the Drilling Drives. RDS is a powerful tool for logging and monitoring. It can be used both locally on board a vessel, as well as remotely. The D4Drilling services offer support from ABB experts on shore via the RDS system in case of failures or irregular behavior, minimizing downtime and enabling pre-emptive and periodical checking of the system.

Summary

Operating a drilling system safely, reliably and efficiently depends on the high availability of drilling drives and their control systems. Availability and performance of the control system is achieved through redundancy in design and fault integrity of the software functions and communication.

Physical separation of redundant functions reduces the risk for common failures, and distributed control systems have a higher fault tolerance. Standardized software libraries ensure that proven and tested functions are reused, while project specific software development is kept to a minimum.

For pre-emptive measures, a new unified power distribution module is available. Combined with Event Based Fast Load reduction, this results in a reliable, predictable drilling power management system with improved power allocation and blackout prevention functions.

The use of advanced monitoring and logging of variables and events has been introduced to drilling drives and control systems. They can be connected remotely, providing access to expert support on a nearly continuous basis.

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