Digital Rod Control System

Background
Nuclear power plant control rods are stepped into and out of the reactor by control rod drive mechanisms (CRDMs) located on top of the reactor head. The CRDMs receive their power for movement from the digital rod control system (DRCS), which receives demand signals for automatic rod movement from the plant control system. The system can also receive manual rod movement commands from the control room operators.

Description
The DRCS logic cabinet receives signals from the plant control system and main control room then generates the selection and sequencing signals that control the direction and movement of the CRDMs. A redundant controller provides communications with the plant data network and contains the interlock logic and rod sequence functions.

The controller multiplex and group-select functions select the proper group of CRDMs to move. They prevent rod motion when it is appropriate, such as during periods of excessive reactor power or rod insertion limits.

The rod-sequencer function controls the rod movement speed through individual step commands. The more frequent the commands, the faster the rod movement. The sequencer also controls the step alternation within each rod bank to provide smoother reactivity control. Malfunction detection circuits alert the operator and prevent rod motion in the event the malfunction is severe enough to jeopardize safe system operation.

The rod control power cabinets contain the microprocessor-based control circuits and power electronics that switch and regulate the current to the CRDM coils. The microprocessor system provides detailed status and diagnostics information to the plant data network.

The rod control power cabinets also receive rod motion signals from the rod control logic cabinet. The rod control power cabinets control groups of up to four rods each. The rod banks are split into groups to minimize power transients as each bank of rods is moved. Control circuits within the rod control power cabinets regulate current in the CRDM coils in response to demands from the logic cabinet, to insert or withdraw the control rods. These control circuits monitor CRDM coil currents to provide proper CRDM operation during rod motion. Lift-coil disconnects allow individual rods in a bank to be disabled so that rods out of position can be realigned.

In addition, the rod control power cabinets contain circuitry that detects failures to prevent control rods from dropping due to failure of microprocessor or power circuitry.

The rod control logic cabinet provides a standard interface to the plant data network for interface to the plant control system and operator interface from the main control room.
Benefits
The DRCS offers the following features and benefits:

- Redundant microprocessor system improves reliability.
- Adaptable architecture allows various numbers and groupings of control rods to match control rod configurations.
- Distributed microprocessor architecture enables low-level fault detection and reporting.
- Redundant features and fault detection/recovery features prevent dropping of rods due to single failures in power circuitry or control electronics.
- The rods are held by both the stationary and movable grippers when not in motion (double gripper hold). This eliminates many failure modes that could lead to dropped rods.
- An alternate hold bus (insurance bus) is available to hold the stationary gripper energized in the event of a failure of the normal stationary gripper control circuits. This feature together with double gripper hold eliminates the need for a DC hold cabinet as well.
- The power cabinet monitors and analyzes the current flow to the CRDM coils to confirm that the CRDM latches operate during the rod motion. This confirms that one CRDM gripper latches prior to the other gripper unlatching during rod motion, preventing dropped rods due to sluggish CRDM operation.
- Computer communications between the power cabinets and the logic cabinet support remote diagnostics, maintenance and adjustments to the rod control system.
- There are only five unique printed circuit (PC) cards in the power cabinet card cage. This is a large reduction in spare parts inventory requirements as compared to previous rod control systems.
- All PC cards are “hot swappable,” including the power supply PC card.
- The system provides coil current traces capturing, monitoring and saving for future reference. This allows for the analysis of a misstep or alarm condition without requiring additional steps to capture a current trace.
- The automated CRDM includes features to remove “crud” buildup upon operator demand.
- The system includes a standard interface to the plant data network (Ovation™) system.

Retrofit features
The DRCS is applicable to new plants and retrofits. It will allow:

- Reuse of existing cabinets
- Reuse of existing main control board control and indicators
- Upgrade to soft controls and indicators
- Reuse of existing CRDM cables

The retrofit DRCS is available for:

- Westinghouse solid state rod control system (SSRCS) retrofit
- Combustion Engineering (CE) – control element drive mechanism control system (CEDMCS) retrofit
- CE – control element drive system (CEDS) retrofit

Experience
- The DRCS prototype has been used to test CE- and Westinghouse-type designs.
- The Ovation control logic cabinet is currently installed and operating in Sweden and is being implemented at plants in the United States.