



Mobile Drill Rig Control System Retrofit Summary

1. Project Overview and Legacy System Deficiencies

The objective of this retrofit project was to replace the mobile drill rig's existing joystick controls due to two critical hardware and configuration faults. The deficiencies of the legacy system included:

- **Node Identity Instability:** The CANbus node ID for the joysticks was assigned via an externally connected Node ID dongle. This dongle would fault, causing the joystick to jump nodes and rendering the drill inoperable until the node could be reassigned.
- **Mechanical Degradation:** The legacy joysticks lacked necessary robustness, and their internal components suffered wear from off-axis forces applied during machine operation.

To resolve these issues, the decision was made to retrofit the machines with custom PQ Controls M115 CANopen joysticks.

2. Hardware Selection and Data Integration

To ensure a drop-in replacement without altering the master PLC code, the new PQ Controls M115 joysticks were required to match the legacy data structure exactly.

- **Protocol Specification:** The master controller runs standard CANopen, not J1939, meaning no status bits could be included in the data utilizing the J1939 bit-packing format.
- **Data Scaling:** The PLC expects Bytes 0 and 1 to contain a pure, unformatted 16-bit Unsigned Integer (UINT16) to represent the lever's position. The raw integer scale was configured to mimic the legacy hardware:
 - Full Direction 1 (Forward): 100 (Decimal) / 0x0064 (Hex).
 - Neutral (Center): 1028 (Decimal) / 0x0404 (Hex).
 - Full Direction 2 (Reverse): 1950 (Decimal) / 0x079E (Hex).
- **TxPDO1 Payload Structure:**
 - Byte 0: Lower byte of the UINT16 position value (Little Endian).
 - Byte 1: Upper byte of the UINT16 position value (Little Endian).
 - Byte 2: 0x00 (Hardcoded Dummy Byte).

3. Communication Latency Resolution

Following the initial integration, control latency was observed. Under the CANopen standard's "acyclic synchronous" profile, the joystick only transmitted its position when it received a SYNC signal and its physical position changed.

- **The Hazard:** When an operator released the joystick, it snapped to neutral and transmitted its neutral value (1028) exactly once. If bus traffic or a timing offset caused the PLC to miss this single packet, the PLC retained the last known value (full forward), causing the drill to continue driving.
- **The Resolution:** The Object Dictionary EDS files were reconfigured to use cyclic-synchronous TxPDO profiles. The Communication Cycle Period was decreased from 100,000 μ sec (100ms) to 10,000 μ sec (10ms).

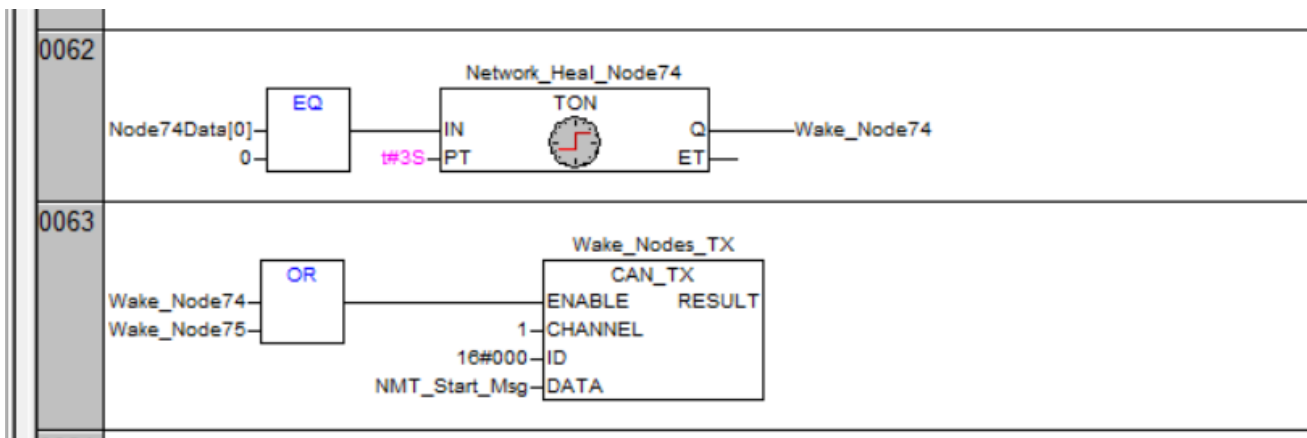
- **Outcome:** The PLC now fires a SYNC heartbeat every 10 milliseconds, forcing the joystick to deliver its exact position continuously. When the joystick springs back to center, the PLC registers the neutral value within 10 milliseconds and halts the drill immediately, rendering the lag imperceptible to the operator.

4. Network Management (NMT) Auto-Healing Architecture

Because the drill operates on multiple power domains, the joysticks experienced boot sequence desynchronization during machine startup. When the rear fuse panel experienced a delayed power-on, the joystick the joystick would either be in Operational state (5) or remain completely silent during the Pre-Operational state (127) resulting in their the state being (0). Because the joystick does not broadcast the 127 heartbeat, the last piece of data the IFM CR1081 master receives from the node on power-up is that single 0x00 Boot-up frame. The CAN_RX block in CoDeSys 2.3 simply holds the last received payload in its buffer. Therefore, Node74Data[0] stays frozen at 0. It sits there silently waiting for the IFM CR1081 master to send the NMT Start command (0x01). Once it receives that wake command, it shifts to Operational and begins transmitting its cyclic 0x05 heartbeat and its joystick position PDOs.

A closed-loop CANopen Network Management (NMT) auto-healing routine was architected to dynamically resolve this:

- **Monitoring Node States:** EQ blocks continuously monitor the raw CAN_RX buffer to check if Node75Data[0] or Node74Data[0] equals 0.
- **Stabilization Delay:** If a state of 0 is detected, the signal feeds into a TON timer instance (Network_Heal_Node75 / Network_Heal_Node74), which waits 3 seconds to allow voltages to stabilize.
- **Global Wake Broadcast:** The timers output to a trigger network where an OR block evaluates the wake requests. This feeds the ENABLE pin of a CAN_TX block to broadcast the global NMT Start command (16#01, 16#00), shifting the nodes to Operational status where they begin transmitting their cyclic 0x05 heartbeats and position PDOs.



5. Fail-Safe Safety Logic Implementation

During testing, a dangerous runaway vulnerability was identified in the legacy code's handling of joystick faults.

- **The Vulnerability:** The original program utilized a NORM_DINT block. If the joystick failed and the variable REAR_JOYSTICK_4_X dropped to 0, the NORM_DINT block processed this as mathematically beyond the full reverse threshold of 100. Because 0 is further from the neutral value of 1018 than 100 is, the block interpreted the sensor failure as a maximum reverse command and clamped the output to YH (REARLIMIT4), pushing full PWM to the reverse drive pump.



- **The Resolution:** A fail-safe window comparator and PWM cut-off were implemented using Function Block Diagram (FBD) logic.
- **Implementation Mechanics:** Less Than or Equal (LE) and Greater Than or Equal (GE) blocks evaluate if FRONT_JOYSTICK_1 drops below 90 or exceeds 1960. If either condition is met, an OR block triggers a Joystick1_Faulted status. A SEL block then evaluates this fault flag; if active, it cuts the PWM output value to 0, safely halting the drive pumps.

