Cross Keys Swing Bridge

HAZOP/HAZID Report

Prepared for:	Fairfield Control Systems Randall Park Way Retford DN22 7WF
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Executive summary

Abbott Risk Consulting (ARC) Ltd. was contracted by Fairfield Control Systems to conduct a Hazard and Operability (HAZOP)/Hazard Identification (HAZID) Study of the Cross Keys Swing Bridge located on the River Nene.

The workshop was carried out on the 12th May 2025, with representatives from Fairfield Control Systems, Dodd Group, Lincolnshire County Council, Cross Keys Bridge Operator, and ARC in attendance. The workshop was performed on the Safety, Functional, and Software Design Specification provided by Fairfield, supported by the addition of a Design Risk Assessment.

The workshop was recorded using Microsoft (MS) Excel, and the subsequent findings found in Appendix A.

A total of **17** recommendations raised during the workshop and are listed in Section 4.0. All recommendations shall be afforded detailed consideration and formal close-out.

Abbreviations

Abbreviation / Acronym	Definition
A	Ampere
ARC	Abbott Risk Consulting Ltd.
CCTV	Closed Circuit Television
HPU	Hydraulic Power Unit
LED	Light Emitting Diode
PLC	Programmable Logic Controller
PtW	Permit to Work
HAZID	Hazard Identification Study
HAZOP	Hazard and Operability Study
RA	Risk Assessment
SCADA	Surveillance Control and Data Acquisition
SOP	Standard Operating Procedure
SSoW	Safe System of Work
VSD	Variable Speed Drive

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1.0 Introduction

This report documents the complete findings of the workshop Study carried out for Fairfield Control Systems on the proposed control systems upgrade for the Cross Keys Swing Bridge on the River Nene.

1.1 Overview

Over the course of bridge's operational life it has suffered numerous faults due to obsolete or faulty control equipment. An upgrade to the current hydraulically-powered drive motors to utilise electro-mechanical actuators would see a step change in reliability.

Furthermore, the bridge's control system will also be upgraded to a new Allen-Bradley PLC solution to increase system reliability and maximising bridge availability, reducing the amount of down time spent on rectifying system faults.

The totality of the project's scope of work is currently limited to the issuing of necessary design documentation, the build and supply of bridge hardware, and the development of the control system software.

On completion a robust testing, commissioning, and operator/maintainer training regime will be implemented to ensure the system functionality adheres to the agreed Safety, Functional and Software Design Specifications.

A detailed description of the proposed works can be found in the source documentation supplied by Fairfield Control Systems outlined in Appendix B.

1.2 Scope of the Study

The workshop was conducted by exclusion due to the similarity in system function between the nodes. This means that if a hazard was common across multiple nodes, the workshop team came to a consensus that no new hazards would be identified all subsequent line items were struck from HAZID record as no additional consequences would materialise.

The Study considered all the operational steps within Fairfield's scope of the Cross Keys Swing Bridge project.

2.0 Study Methodology

2.1 Procedure

The HAZOP / HAZID was undertaken as a combined study.

The HAZID part considered guidewords relating to external hazards or interfaces and identified any hazards relevant to the upgrade project. For each hazard, the control measures currently foreseen in the design or operation were identified.

The HAZID deviations considered are shown in Table 2-1

Table 2-1 – HAZID Deviations

Deviations		
Temperature	Wind	Power
Visibility	Road Traffic	Communication
Snow and Ice	Vessel Traffic	Access
Water level	Pedestrians	Mechanical
Lightning	Debris	Electrical
Environmental	Fire	

The HAZOP was carried out to consider whether any deviation in operation of the systems and equipment, as currently designed, could cause a hazard to people working in the facility, to the environment, or to the plant, equipment or operation. In addition, and reputational threats to the bridge operators resulting from inability to operate the bridge were considered.

The HAZOP/HAZID is a formal process whereby a design is subject to a systematic review by a multi-disciplinary team. By using guidewords/ deviations and discussing the implications of a variety of credible malfunctions or mal-operations, the review team were able to consider whether:

- Any deviation from normal operation could cause a hazard or operability problem.
- The safeguarding equipment or systems were sufficient to prevent the hazard or mitigate the consequences to an acceptable level.
- The process can be started, operated, maintained and shut-down safely.

As a sequential operating process, the main steps in the process were considered in turn and deviations from the intent of the step were identified. For each deviation the team

considered potential causes and the consequences without considering safeguards. The team then considered safeguards currently foreseen in the design basis and determined if they would be effective and acceptable to the operator.

In instances where the Team were not confident that existing safeguards were sufficient to prevent or mitigate potential consequences, or to address operability concerns, recommendations were recorded. A list of recommendations generated during the review can be found in Section 4.0.

The system under review was divided into smaller sub-systems, or nodes, to make the workshop study more manageable. Functional steps were established to breakdown the node. These nodes and steps were agreed on by the Team during the workshop.

The breakdown of nodes and steps for the workshop are shown below:

- 1 – Normal Opening Sequence
  - 1 – General
  - 2 – Stop Traffic
  - 3 – Raise Jacks
  - 4 – Remove Slip Blocks
  - 5 – Lower Jacks
  - 6 – Slew Open
  - 7 – Bridge open to Vessels
  - 8 – Operate Foot Bolt
- 2 – Normal Closing Sequence
  - 1 – General
  - 2 – Stop Vessels
  - 3 – Remove Foot Bolt
  - 4 – Slew Closed
  - 5 – Raise Jacks
  - 6 – Insert Slip Blocks
  - 7 – Lower Jacks
  - 8 – Bridge open to Traffic
- 3 – Maintenance
  - 1 – General

Deviations shown in Table 2-2 were applied to each step.

The workshop was recorded using MS Excel. The study worksheet was made visible to each member of the Team during the study and the contents agreed by all parties, including all recommendations.

Table 2-2 – HAZOP Deviations

Deviation	Meaning
Not	Step not conducted at all
Partial	Only part of a step completed
Early	Step conducted earlier than expected less time delay or before a previous step
Late	Step conducted later than expected more time delay or after a following step
Instead of	A different action carried out in place of the correct step
Reversed	Operation in reverse direction or reverse of the step intention (accelerate instead of slow down for example)
Other	Any other deviation from the intention

3.0 Workshop Team Members

The workshop team consisted of a multi-disciplinary team of engineers and other key personnel to enhance the identification of potential hazards and operability problems. Representatives from Fairfield Control Systems, Lincolnshire County Council, Dodd Group, Cross Key Operator and ARC were in attendance at Fairfield Control System Offices in Retford.

The team members who participated in the workshops are presented below in Table 3-1.

Table 3-1 – Attendance record

Name	Company	Job Title	12/05/2025
Andy Scotland	ARC	Chairman	Present
Christopher Clarke-Brown	ARC	Scribe	Present

Name	Company	Job Title	12/05/2025
Craig Fleming	Fairfield Control Systems	Project Manager	Present
Tom Silvester	Fairfield Control Systems	Project Engineer	Present
Edward Sinfield	Fairfield Control Systems	Lead Design Engineer	Present
David Connor	Fairfield Control Systems	QHSE Lead	Present
Ian Booth	Lincolnshire County Council	Principal Engineer	Present
Ellis Harding	Lincolnshire County Council	Apprentice Technician	Present
Peter Parfett	Cross Keys Operator	Operations Manager	Present
Chris Watson	Dodd Group	Project Lead	Present

4.0 Recommendations

Where appropriate, recommendations were raised to eliminate/minimise a potential hazard or mitigate an identified consequence of a deviation. These were recorded in the worksheets and their responsibilities assigned to a relevant department. The complete worksheets are shown in Appendix A.

A total of **17** recommend Bridge fire risk assessment to be fully reviewed actions raised during the workshop and are presented in Table 4-1. All recommendations shall be afforded detailed consideration and formal close-out.

Table 4-1 - Recommendations

Recommendations	Responsibility
1. Consider conducting an ergonomic review with bridge operators to ensure adequate location of control equipment.	Fairfield Cross Keys Operator
2. When conducting ergonomic review, excess lighting should be considered when viewing control panels.	Fairfield Cross Keys Operator
3. Ensure any new equipment fitted doesn't obstruct the line of sight.	Fairfield
4. Consider what the maximum water level could be in the event of the bund over-topping and whether the location of the electrical equipment is high enough to prevent damage. Conduct an IP rating review to ensure that	Fairfield Lincolnshire County Council

Recommendations	Responsibility
proposed system design has sufficient water protection if the above scenario was to materialise. Also, consider whether operator protocols are sufficient for new equipment and review IP rating of electrical equipment.	
5. Existing bridge lightning protection system testing required.	Lincolnshire County Council
6. Consider whether existing pump room can be made more watertight and secure, once the diesel generator has been relocated to the west end generator kiosk.	Lincolnshire County Council
7. Consider if maximum shock/vibration levels have be reviewed as part of the design for the mounting arrangements of the new control panels.	Fairfield
8. Consider what the bridges maximum dead weight is to permit safe operation with new control system.	Fairfield
9. Consider effect on loss of frequency control of 160A AC supply on bridge on control system, in particular gate-drive VSDs.	Fairfield
10. Consider the benefit of having a duty/standby actuator configuration. This is a long-term consideration.	Lincolnshire County Council
11. Consider how an individual VSD can be electrically/mechanically isolated in the event of a mechanical failure to prevent damage to the inverter.	Fairfield
12. Clarify the positioning of the ultimate open limit switch is sufficient to stop the bridge before the fully open position is exceeded.	Fairfield
13. Consider that the motor timing out should be a warning, rather than a trip.	Fairfield
14. In the event of a loss of power consider what intervention is available to reset the PLC and resume bridge operations. E.g. is a UPS required for the PLC and SCADA.	Fairfield
15. Review all existing RA's, SSoW, PtWs to reflect the new equipment layout and maintenance requirements.	Lincolnshire County Council
16. Review maintenance requirements for the diesel generator.	Fairfield
17. Fully review the existing bridge fire risk assessment.	Lincolnshire County Council

Appendix A Worksheets

1.0 Node: 1. Normal opening sequence

Step	Guideword (Deviations)	Cause	Consequence	Safeguard	Recommendation/Action	Resp.	Due Date
1. General	1. Temperature	1. High ambient temperature	Structural expansion of bridge leading to jamming.	Structure was modified to provide additional clearance space to allow for the expansion.			
		2. Low ambient temperature	Hydraulic fluid temperature reduces leading to lower performance.	Pre-heaters and re-circ pump installed in the hydraulic system.			
			Freezing temperatures lead to inability to operate access doors, slip blocks stuck in position, road traffic barriers stuck in position.	Precautionary winter maintenance program prior to vessel transit including de-icing.			
	2. Visibility	1. Fog	Extreme heavy fog limits visibility of road traffic barriers.	Traffic management system and second operator uitilsed act to mitigate local traffic requirements.			
			Potential collision of vessel with bridge structure.	All vessels are accompanied by a pilot, foghorn on bridge, and protective fenders installed to protect bridge structure on the base of the bridge			
			Road traffic breaches.	Traffic management protocols.			
		2. Glare from sunlight	Glare on bridge control panels and location of panels leads of difficulty in operating bridge controls.	None identified.	Consider conducting an ergonomic review with bridge operators to ensure adequate location of control equipment.	Fairfield - Lead, Bridge Operator - Stakeholder.	
		3. Excess lighting	Excess lighting in control room obscures view of HMI panels.	Lighting dimmer switch in the control room.	When conducting ergonomic review view of control panels also consider excess lighting.	Fairfield - Lead, Bridge Operator - Stakeholder.	
		4. Line of sight	Line of sight obstructed particularly during manual operation of the bridge, resulting in catastrophic damage to bridge equipment	Operator training/administrative controls (SOPs), CCTV, and additional personnel utilised if required.	Ensure any new equipment fitted doesn't obstruct the line of sight.	Fairfield	
	3. Snow and Ice	1. Weather conditions	Major snowfall can prevent operation of bridge, leading to road and vessel traffic disruption.	Precautionary winter maintenance program prior to vessel transit including snow clearance.			
	4. Water level	1. External flooding	Spring tides/tidal surges combined can result in flooding of carousel/pump room and potential damage to equipment.	Equipment room watertight doors and bilge pump available for excessive water ingress. Also high water protocols are implemented in advance of high tide/tidal surge if required.	Consider what the maximum water level could be in the event of the bund over-topping and whether the location of the electrical equipment is high enough to prevent damage. Conduct an IP rating review to ensure that proposed system design has sufficient water protection if the above scenario was to materialise. Also, consider whether operator protocols are sufficient for new equipment and review IP rating of electrical equipment.	Fairfield/Lincolnshire County Council	
	5. Lightning	1. Storm	Lightning strike could a electrical surge in equipment leading to potential damage.	Surge protection built into new control panels by design.	Existing bridge lightning protection system testing required.	Lincolnshire County Council	
	6. Wind	1. Extreme wind	Potential loss of control of the bridge during opening/closing operations.	Maximum permitted wind speed for operation is 55 knots gusting as indicated by anomometer in control room. Ultimate open/closing range of motion limiters will stop bridge motors.			
	7. Other	1. Uncontrolled access	Public gaining access to the bridge control/plant room leading to potential harm to public, bridge personnel, and equipment.	CCTV, secure gates, keycode activated access door to control room.	Consider whether existing pump room can be made more watertight and secure once the diesel generator has been relocated to the west bank.	Lincolnshire County Council	
		2. Single point failure in PLC system	Failure of power supply to PLC results in loss of automatic operation of the bridge.	Emergency mode can provide manual operation of bridge controls.			
		3. Vibration	Vibration from traffic may cause damage to control equipment if not mounted correctly.	Existing control equipment is shock/vibration mounted.	Consider if maximum shock/vibration levels have be reviewed as part of the design for the mounting arrangements of the new control panels.	Fairfield	
2. Stop Traffic	1. Road Traffic	1. Traffic not responding to lights	Traffic entering bridge when about to be moved.	Traffic barriers are not lowered until bridge is sighted clear by the operator.			
		2. Lights not working	Traffic entering bridge when about to be moved.	Manual traffic control can be implemented if required. Lights have been changed to a modern LED system.			
		3. Traffic doesn't clear the bridge, e.g. delays at junction	Delay to bridge operations	Traffic management system and additional traffic signals on Sutton Bridge approach roads.			
		4. Breakdown/accident on the bridge	Delay to bridge operations, and unable to move/stop bridge if heavy vehicle is stuck on bridge	Bridge operators can move smaller vehicles either off the bridge or into the centre of the bridge.	Consider what the bridges maximum dead weight is to permit safe operation with new control system.	Fairfield	
		5. Emergency vehicle approaching	None identified				
	2. Vessel Traffic	1. No additional causes	None identified				

	3. Pedestrians	1. Pedestrians not responding to signals	None identified			
	4. Debris	1. No additional causes	None identified			
	5. Power	1. Loss of power	Loss of 160A AC supply to bridge, leading to inability to operate bridge.	Back up generator automatically cuts in to deal with a loss of supply on under voltage.	Consider effect on loss of frequency control of 160 AC supply on bridge on control system, in particular gate-drive VSDs.	Fairfield
	6. Communication	1. Marine VHF fault	Loss of communication between bridge control and vessels.	Bridge status lights, handheld VHF (Ch.9), mobile phones.		
	7. Access	1. Unanthorised access to the control room	No additional hazards identified			
	8. Mechanical	1. Failure of bridge deck jacks	Failure of single bridge jack will prevent bridge being lifted.	Spare jack kept on-site, however a repair solution can not be implemented quickly.		
		2. Failure of a slip block actuator	Failure of a single slip block will prevent the bridge from being lifted/slewed.	Spare actuator kept on-site, however a repair solution can not be implemented quickly. Slip blocks can be moved manually. Two slip block actuators available.	Consider the benefit of having a duty/standby actuator configuration. This is a long-term consideration.	Lincolnshire County Council
		3. Failure of HPU	Inability to operate hydraulic equipment on the bridge.	New system has two hydraulic pumps, operating in a duty/standby configuration. Each pump has the capacity to operate the whole hydraulic system.		
	9. Electrical	1. Failure of VSD	Potential inability to rotate carousel	Each drive has four VSDs, two per drive can operate the bridge.	Consider how an individual VSD can be electrically/mechanically isolated in the event of a mechanical failure to prevent damage to the inverter.	Fairfield
	10. Not	1. Barriers don't close on demand	Interlock will prevent further bridge movement.	Back-up generator in the event of failure of electrical supply. Barrier can be lowered manually. This requires an override on the interlock.		
	11. Partial	1. Barrier does not close fully	No new hazards			
	12. Early	1. Removal of slip blocks manually before the bridge is raised on jacks	Mechanical damage to the slip block actuators.	Operator training/administrative controls.		
	13. Late	1. No additional causes				
	14. Instead of	1. No additional causes				
	15. Reversed	1. No additional causes				
	16. Other	1. No additional causes				
3. Raise Jacks	1. Road Traffic	1. No additional causes				
	2. Vessel Traffic	1. No additional causes				
	3. Pedestrians	1. No additional causes				
	4. Debris	1. Debris in jack mechanism	No new hazards			
	5. Power	1. Loss of power	No new hazards			
	6. Communication	1. No additional causes				
	7. Access	1. No additional causes				
	8. Mechanical	1. No additional causes				
	9. Electrical	1. No additional causes				
	10. Not	1. Control failure	No new hazards			
	11. Partial	1. One jack fails to operate	No new hazards			
	12. Early	1. Jacking starting with traffic load	No new hazards			
	13. Late	1. No additional causes				
	14. Instead of	1. No additional causes				
	15. Reversed	1. No additional causes				
	16. Other	1. No additional causes				
4. Remove Slip Blocks	1. Other	1. Failure of control system limit switches	Potential inability to operate bridge correctly.	Limit switches have built in redundancy, and manual override is available.		
5. Lower Jacks	1. Other	1. No additional causes	All "raise jack" deviations and causes were considered, no new hazards identified.			
6. Slew Open	1. Road Traffic	1. No additional causes				
	2. Vessel Traffic	1. No additional causes				

	3. Pedestrians	1. No additional causes					
	4. Debris	1. No additional causes					
	5. Power	1. Loss of power	Inability to slew bridge.	Back-up generator available as alternate power supply.			
	6. Communication	1. No additional causes					
	7. Access	1. No additional causes					
	8. Mechanical	1. No additional causes					
	9. Electrical	1. No additional causes					
	10. Not	1. Drive fails to operate	Inability to slew bridge.	None identified.			
	11. Partial	1. Drive brakes do not fully release	Damage to drive motors, inability to slew bridge.	Motor brakes can be manually disengaged via hand lever.			
	12. Early	1. Accelerate too early	No new hazards	Overspeed would alarm and trip the motor.			
		2. Decelerate too early	No new hazards				
		3. Stop too early	No new hazards				
	13. Late	1. Accelerate too late	No new hazards				
		2. Decelerate too late	Damage to the bridge, by exceeding the fully opening position.	Ultimate open limit switch will stop the VSDs.	Clarify the positioning of the ultimate open limit switch is sufficient to stop the bridge before the fully open position is exceeded.	Fairfield	
		3. Stop too late	No new hazards				
	14. Instead of	1. No additional causes					
	15. Reversed	1. Operation in wrong direction	No new hazards				
	16. Other	1. No additional causes					
7. Bridge open to vessels	1. Road Traffic	1. No additional causes					
	2. Vessel Traffic	1. Loss of control of vessel	No new hazards				
	3. Pedestrians	1. No additional causes					
	4. Debris	1. No additional causes					
	5. Power	1. No additional causes					
	6. Communication	1. No additional causes					
	7. Access	1. No additional causes					
	8. Mechanical	1. No additional causes					
	9. Electrical	1. No additional causes					
	10. Not	1. No additional causes					
	11. Partial	1. No additional causes					
	12. Early	1. Operator error bridge moved early after vessel transit	No new hazards				
	13. Late	1. No additional causes					
	14. Instead of	1. No additional causes					
	15. Reversed	1. No additional causes					
	16. Other	1. No additional causes					
8. Operate Foot Bolt	1. Late	1. Foot bolt not retracted before slewing started	Potential damage due to over-torque of drive motors.	Over-torque trip available within VSDs.			

2.0 Node: 2. Normal closing sequence

Step	Guideword (Deviations)	Cause	Consequence	Safeguard	Recommendation/Action	Resp.	Due Date
1. General	6. Wind	1. Extreme wind	Bridge closes too quickly risking mechanical damage due to excessive tail wind.	New control system has setpoints for different wind speeds. Operator can close bridge manually if required.	-		
			Bridge closes too slowly due to excessive head wind, resulting in drive motor timing out.	Operator can take system into manual control.	Consider that the motor timing out should be a warning, rather than a trip.	Fairfield	
2. Stop Vessels	1. Other	1. No additional causes	All Node 1 Step 7 deviations and causes were considered in reverse, no new hazards identified.				
3. Remove Foot Bolt	1. Other	1. No additional causes	All Node 1 Step 8 deviations and causes were considered in reverse, no new hazards identified.				
4. Slew Closed	5. Power	1. Loss of power	In the event of a loss of power the last position of the bridge may not be available to the control PLC. Operator will have to manually reset the system.	Not identified at present.	In the event of a loss of power consider what intervention is available to reset the PLC and resume bridge operations. E.g. is a UPS required for the PLC and SCADA.	Fairfield	
	6. Communication	1. Fault in drive control communication	No new hazards				
	7. Access	1. Uncontrolled access	No new hazards				
	10. Not	1. Drive fails to operate	No new hazards				
	11. Partial	1. Drive brakes do not fully release	No new hazards				
5. Raise Jacks	13. Late	1. Bridge fails to align correctly to the closed position.	Potential for bridge to exceed the closed position and cause damage to the structure.	Under the new system the ultimate close switch will stop the drive motors. The foot bolt will lock the bridge into position. Emergency stop.			
	15. Reversed	1. Jack runs in reverse	No new hazards				
	16. Other	1. Barriers fail to raise after bridge closed	Road traffic is potentially unable to utilise the bridge.	Barriers can be operated manually.			
6. Insert Slip Blocks	1. Not	1. Bridge not fully raised on jacks	If the bridge is not fully raised on the jacks it is not possible to insert the slip blocks.	Interlock between jack fully raised position and slip block actuators.			
7. Lower Jacks	1. Other	1. No additional causes	All Node 1 Step 5 deviations and causes were considered, no new hazards identified.				
8. Bridge open to Traffic	1. Other	1. No additional causes	All Node 1 Step 2 deviations and causes were considered, no new hazards identified.				

3.0 Node: 3. Maintenance

Step	Guideword (Deviations)	Cause	Consequence	Safeguard	Recommendation/Action	Resp.	Due Date
1. General	1. Temperature	1. High temperature equipment	No new hazards				
	2. Visibility	1. Obstructed view from operating position	No new hazards				
		2. Poor lighting	No new hazards				
	13. Access	1. Access to equipment on the bridge for maintenance	Due to equipment being relocated from the top of the bridge to the below the bridge deck, in the carousel room there is potentially more restricted access from maintenance/inspection to be conducted.	Risk assessments, Safe Systems of Work, Permits to Work.	Review all existing RA's, SSoW, PtWs to reflect the new equipment layout and maintenance requirements.	Lincolnshire County Council	
	14. Mechanical	1. Requirement for emergency stop	No new hazards				
	15. Electrical	1. Access to electrical equipment for maintenance	No new hazards				
	14. Environmental	1. Diesel generator is relocated to west bank of river	Potential leakage of diesel fuel into river.	Diesel fuel stored in double bunded tank.	-		
	15. General	1. Diesel generator is relocated to west bank of river	Maintenance of diesel generator is now to be conducted off the bridge.	None identified	Review maintenance requirements for the diesel generator	Fairfield	
	16. Fire	1. Changes to risks from new equipment	Fire risk assessment and fire fighting equipment no longer suitable.	None identified	Bridge fire risk assessment to be fully reviewed.	Lincolnshire County Council	

Appendix B Reference Documents

Title	Revision
Safety Requirement Specification – Cross Keys Swing Bridge Electrical Upgrade (LIN10089-20-14-01)	A02
Functional Design Specification – Cross Keys Swing Bridge Electrical Upgrade (LINC10089-01-01)	A02
Software Design Specification – Cross Keys Swing Bridge Electrical Upgrade (LINC10089-01-02)	A02
Design Risk Assessment (LINC10089-20-12)	A02

Design Risk Assessment

Job Title / Description

S=Severity: CA=Catastrophic, CR=Critical, MA=Marginal, IS=Insignificant
F=Frequency: FR=Frequent, PR=Probable, OC=Occasional, RA=Rare, IM=Improbable,
RL=Risk Level: UA=Unacceptable, UD=Undesirable, AC=Acceptable, NE=Negligible

Risk Levels				
The Frequency of Hazard Occuring	Severity Levels of the Danger Consequences			
	Insignificant (IS)	Marginal (MA)	Critical (CR)	Catastrophic (CA)
Frequent (FR)	Undesirable	Unacceptable	Unacceptable	Unacceptable
Probable (PR)	Acceptable	Undesirable	Unacceptable	Unacceptable
Occasional (OC)	Acceptable	Undesirable	Undesirable	Unacceptable
Rare (RA)	Negligible	Acceptable	Undesirable	Undesirable
Improbable (IM)	Negligible	Negligible	Acceptable	Acceptable
Unrealisable (UN)	Negligible	Negligible	Negligible	Negligible

Risk analysis per zone

Zone	Ref	Risk description	Ref Sub	Source of the risk	Phase / Operating mode / Scenario	Rating without protection measure			Consequence	Protection Measure	Mechanical / Electrical / Documentation	Rating with protection measure			Verification Method	Date	Responsible	Remarks (For SF refer to FDS)
						S	F	RL	Injury Category			S	F	RL				
Water Traffic	1	Vessel colliding with bridge	1	Bridge being too poorly lit to see	All modes of operation	CR	OC	UD	Severe injuries or death for one person	Navigation lights are installed in required locations. Untouched by new systems.	Electrical	CR	IM	AC	SAT		Others	
			2	Reduced visibility due to adverse weather conditions	All modes of operation	CR	OC	UD	Severe injuries or death for one person	Navigation lights are installed in required locations. Untouched by new systems. Fog horn also installed.	Electrical	CR	IM	AC	SAT		Others	
			3	Bridge swinging closed before a vessel has passed through	Closing	CR	OC	UD	Severe injuries or death for one person	Operating procedure method statement. It is an operator decision and action to close the bridge after checking that the vessel is clear. Bridge movements can be stopped at any point by pressing any of the emergency stops. When the emergency stop is pressed, the control system shall quickly ramp down and de-energised equipment in the correct sequence to avoid any structural or mechanical damage to the bridge	Electrical & Documentation	CR	IM	AC	BS EN ISO13849-2 Validation		Fairfields	**SF1 - Emergency Stop**
			4	Bridge swinging too slowly due to increased wind loading	Opening/Closing	CR	OC	UD	Severe injuries or death for one person	The bridge operator can anticipate a potential increase in bridge opening time and open earlier. Wind speed limit on vessel navigation. Pilot hold point at double reds or marker bouy unless bridge is open.	O&M	CR	IM	AC			Others	
			5	Vessel directional lights not set or failed. Vessels travelling towards each other will not be given right of way instruction	Opening/Closing	CR	IM	AC	Severe injuries or death for one person	Vessels in radio contact with control room during bridge opening, Vessel on flood tide always has right of way.	Documentation & Procedures	CR	IM	AC	Training Logs		Others	
			6	Vessel continues through red light	Opening/Closing	CR	IM	AC	Severe injuries or death for one person	Vessels in radio contact with control room during bridge opening Pilots will only proceed if the bridge is open by position 'double reds' Clear line of sight down the river	Documentation & Procedures	CR	IM	AC	Training Logs		Others	
			7	Bridge not opened due to emergency service vehicle requiring access or blockage on bridge roadway.	Opening/Closing	CR	RA	UD	Severe injuries or death for one person	Not quantifiable Pilots will only proceed if the bridge is open by position 'double reds' Operational procedure.	Documentation & Procedures	CR	RA	UD	Training Logs		Others	
			8	Vessel does not follow correct procedure	Opening/Closing	MA	RA	AC	Minor injuries	Pleasure boats can pass under the bridge while closed Experienced pilots only operate large boats that require the bridge to open Vessels in radio contact with the control room during a bridge opening Navigation lights are installed in required locations. Untouched by new systems.	Electrical & Documentation	MA	IM	NE	SAT & Training Logs		Others	
			9	Vessel is unable to receive instructions from the control room	Opening/Closing	MA	RA	AC	Minor injuries	Pleasure boats can pass under the bridge while closed Navigation lights are installed in required locations. Untouched by new systems.	Electrical & Documentation	MA	IM	NE	SAT		Fairfields	
			10	Vessel directional lights not set or failed. With no directional instruction the vessel may stop.	Opening/Closing	CR	IM	AC	Severe injuries or death for one person	Vessels in radio contact with control room during bridge opening Only specific pilots are allowed to navigate through the bridge	Documentation	CR	IM	AC	Training Logs		Others	
			11	Navigational lights & Marine Traffic lights cannot be seen	Opening/Closing	MA	RA	AC	Minor injuries	Routine maintenance checks on all marine lights Experienced pilots only operate large boats that require the bridge to open Vessels in radio contact with the control room during bridge opening Bridge has fog horn.	Electrical & Documentation	MA	IM	NE	SAT & Training Logs		Others	
			12	Bridge side structure lights power failure	Opening/Closing	MA	RA	AC	Minor injuries	Back up generator to power nav lights. Routine maintenance checks on navigation lights Experienced pilots only operate large boats that require the bridge to open Bridge operators shall be at the bridge prior to any vessel arriving to open the bridge for marine traffic. Vessels are in radio contact with the control room during bridge opening, any failure of the bridge to open can be	Electrical & Documentation	MA	IM	NE	SAT & Training Logs		Others	

Design Risk Assessment

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Risk Levels				
The Frequency of Hazard Occuring	Severity Levels of the Danger Consequences			
	Insignificant (IS)	Marginal (MA)	Critical (CR)	Catastrophic (CA)
Frequent (FR)	Undesirable	Unacceptable	Unacceptable	Unacceptable
Probable (PR)	Acceptable	Undesirable	Unacceptable	Unacceptable
Occasional (OC)	Acceptable	Undesirable	Undesirable	Unacceptable
Rare (RA)	Negligible	Acceptable	Undesirable	Undesirable
Improbable (IM)	Negligible	Negligible	Acceptable	Acceptable
Unrealisable (UN)	Negligible	Negligible	Negligible	Negligible

Risk analysis per zone

Zone	Ref	Risk description	Ref Sub	Source of the risk	Phase / Operating mode / Scenario	Rating without protection measure			Consequence: Injury Category	Protection Measure	Mechanical / Electrical / Documentation	Rating with protection measure			Verification Method	Date	Responsible	Remarks (For SF refer to FDS)
						S	F	RL				S	F	RL				
Road Traffic (Vehicle and pedestrian)	2	Vehicle or pedestrian on bridge decks	1	Vehicle or pedestrian stopping or crossing bridge too slowly. Or incapacitated.	All modes of operation	CR	OC	UD	Severe injuries or death for one person	Operational procedure Visibility from control room CCTV view of roadway & Pedestrian Walkway.	Electrical & Documentation	CR	IM	AC	SAT		Others	
			2	Reduced visibility due to adverse weather conditions	All modes of operation	CR	OC	UD	Severe injuries or death for one person	Operational procedure Visibility from control room CCTV view of roadway & Pedestrian Walkway. In heavy weather, fog ect the pilots wont proceed down the river.	Electrical & Documentation	CR	IM	AC	SAT		Others	
			3	Bridge swinging before vehicles or pedestrians are clear of bridge	Opening/Closing	CR	OC	UD	Severe injuries or death for one person	Operator observation and emergency stop. Barrier interlock signal into safety function.	Electrical & Documentation	CR	IM	AC	BS EN ISO13849-2 Validation		Fairfields	**SF2 - Traffic Barriers Interlock**
			4	Vehicle or pedestrian continues through Wig-Wags	Opening/Closing	CR	IM	AC	Severe injuries or death for one person	Operational procedure to ensure bridge clear before lowering barriers Road barriers incorporate safety measures to prevent entrapment under barriers.	Documentation	CR	IM	AC	Training Logs		Others	
			5	Vehicle or pedestrian continues through Wig-Wags and beneath lowering barriers	Opening/Closing	CR	IM	AC	Severe injuries or death for one person	Road barriers to incorporate safety measures to prevent entrapment under barriers. Barriers operate on deadmans switch for lowering. Operators to confirm bridge is clear prior to slewing.	Documentation	CR	IM	AC	Training Logs		Others	
			6	Wigwags fail to illuminate	Opening/Closing	CR	IM	AC	Severe injuries or death for one person	Operating procedure method statement. The operator shall confirm traffic has stopped before lowering barriers? On Monthly maintenance list. Operator has no conifrmation of wigwags in operation.	Documentation	CR	IM	AC	Training Logs		Others	
			7	Barriers fail to lower	Opening/Closing	CR	IM	AC	Severe injuries or death for one person	Barrier lowered limit switch Operating procedure method statement. The operator shall confirm barriers are lowered and that approach and bridge is clear of traffic and pedestrian before opening the bridge. Barriers can be hand raised down	Documentation & Procedures	CR	IM	AC	Training Logs		Others	
		Slips, Trips & Falls	8	Poor lighting	All modes of operation	MA	RA	AC	Minor injuries	Suitable lighting already installed. Was assessed when installed.	Electrical	MA	RA	AC	Inspection		Others	
			9	Poor lighting due to damaged cables through flexible trunking onto bridge structure	Opening/Closing	MA	RA	AC	Minor injuries	Compliant energy chain to be installed.	Electrical	MA	RA	AC	Inspection		Fairfields	
		Delays to road/river traffic	10	Vehicle or pedestrian does not follow correct procedure	Opening/Closing	MA	RA	AC	Minor injuries	Operating procedures	Electrical & Documentation	MA	IM	NE	SAT & Training Logs		Others	
			11	Vehicle or pedestrian is unable to receive instructions from the control room	Opening/Closing	MA	RA	AC	Minor injuries	Operating procedures Operator can issue verbal commands.	Electrical & Documentation	MA	IM	NE	SAT		Others	
		Emergency vehicles cannot cross bridge with delay to response time	13	Bridge opened	Opening/Closing	CR	RA	UD	Injury not quantifiable but needs consideration	Not quantifiable	Documentation	CR	RA	UD			Others	
Environmental	3	Flooding causing damage to equipment and loss of control of the bridge	1	Rainfall causing the water levels to rise	All modes of operation	CR	RA	UD	Severe injuries or death for one person	New equipment to be installed at a higher level than existing equipment. Do not operate drives if flooded System requires inspection before restarting	Mechanical	CR	IM	AC	Inspection		Others	
		Slips, Trips & Falls	2	Steps Uneven surfaces Poor visibility Snow & ice	All modes of operation	MA	PR	UD	Minor injuries	Operating procedures Appropriate PPE Appropriate signage in place. Elements have been risk assessed.	Procedures Documentation	MA	OC	UD	SAT		Others	
		Environmental spillage	3	Gearbox and ring lubrication	All modes of operation	IS	OC	AC	Minor injuries for one person	Ensure gearboxes are suitably sealed/plugged. Drip-trays under gearboxes Use of appropriate lubricants for the environment Spill kits are provided Water-tight bund around slewing ring and drive systems to capture spills.	Mechanical	IS	OC	AC	Inspection		Fairifelds & Others	
		Overspeed of bridge travel, slewing out of control	4	High Winds	All modes of operation	MA	OC	UD	Minor injuries	Drive shall monitor and control drive motion Encoder and Torque limiting for speed control. If out of speed tolerance the drive shall trip and brakes shall be applied.	Mechanical & Electrical	MA	IM	NE	SAT		Fairfields	
Bridge Operation	4	Operator Injury	1	Injuries from crouching and over extending to reach controls	Opening / Closing	MA	RA	AC	Minor injuries	Operator control desk is already ergonomically designed so operators are standing during all modes of operation.	Mechanical	MA	IM	NE	FAT		Fairfields	
		Vehicle or pedestrians approaching bridge while the bridge is slewing. Entrapment between wall and bridge as it slews	2	Vehicle or pedestrian ignoring traffic signals and barriers	Opening / Closing	CR	RA	UD	Severe injuries or death for one person	Barriers in place for vehicle and pedestrian Bridge to maintain creep speed while in the area of the abutment to allow persons time to see hazard approaching, or operator to press e-stop.	Electrical	CA	IM	AC	SAT & BS EN ISO13849-2 Validation		Fairfields	**SF1 - Emergency Stop** **SF2 - Traffic Barriers Interlock**

Design Risk Assessment

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Risk Levels				
The Frequency of Hazard Occuring	Severity Levels of the Danger Consequences			
	Insignificant (IS)	Marginal (MA)	Critical (CR)	Catastrophic (CA)
Frequent (FR)	Undesirable	Unacceptable	Unacceptable	Unacceptable
Probable (PR)	Acceptable	Undesirable	Unacceptable	Unacceptable
Occasional (OC)	Acceptable	Undesirable	Undesirable	Unacceptable
Rare (RA)	Negligible	Acceptable	Undesirable	Undesirable
Improbable (IM)	Negligible	Negligible	Acceptable	Acceptable
Unrealisable (UN)	Negligible	Negligible	Negligible	Negligible

Risk analysis per zone

Zone	Ref	Risk description	Ref Sub	Source of the risk	Phase / Operating mode / Scenario	Rating without protection measure			Consequence	Protection Measure	Mechanical / Electrical / Documentation	Rating with protection measure			Verification Method	Date	Responsible	Remarks (For SF refer to FDS)
						S	F	RL	Injury Category			S	F	RL				
		Road Vehicle or pedestrians approaching bridge while the bridge is slewing Falling from height	3	Vehicle or pedestrian ignoring traffic signals and barriers	Opening / Closing	CA	RA	UD	Severe injures or deaths of many persons	Barriers in place for vehicle and pedestrian. Operator procedure.	Mechanical & Procedural	CA	IM	AC	SAT & BS EN ISO13849-2 Validation		Fairfields	**SF2 - Traffic Barriers Interlock**
		Entrapment, crushing, entanglement	4	Under bridge area Bridge movement Public unauthorised access LCC staff on site	All modes of operation	CA	OC	UA	Severe injures or deaths of many persons	Site is fenced Operator visibility from control room CCTV Competent Staff Lock out tag out system. Signed safe waiting area.	Mechanical & Procedural	CA	UN	NE	Training Logs & BS EN ISO13849-2 Validation		Fairfields & Others	**SF3 - Maintenance Access**
		Damage to Energy Chain	5	Bridge overshooting open position.	Opening	CR	OC	UD	Severe injuries or death for one person	Limit switches for ultimate position Encoder position control Competent Staff & Procedures	Electrical	CR	IM	AC	SAT & BS EN ISO13849-2 Validation		Fairfields & Others	**SF4 - Ultimate Open**
		Structural Damage to Bridge	6	Bridge travelling overspeed to the approach of the abutment. Locking bolt used to emergency stop bridge.	Closing	CR	RA	UD	Severe injuries or death for one person	The speed of the bridge swing is controlled by the control system Bridge Ultimate Closed Bridge Ultimate Open Bridge Overspeed alarms for when at the fast and slow-down speed zones. If Overspeed in the fast zone the speed shall be reduced to slow speed. If Overspeed in the slow-down zone the bridge shall stop	Electrical	CR	IM	AC	SAT & BS EN ISO13849-2 Validation		Fairfields	**SF4 - Ultimate Open** **SF5 - Ultimate Close**
		Structural Damage to Bridge	7	The high torque appplied from the new drive train and brakes upon an emergency stop, may cause damage to the bridge structure.	Emergency stop	CR	RA	UD	Severe injuries or death for one person	With reference to 13850:2015 4.1.1.5 The emergency stop function shall be designed, that after actuation of the emergency stop device, hazardous movements and operations of the machine are stopped in an appropriate manner, without creating additional hazards and without any further intervention. Due to the structural limits that can be safely applied to the bridge structure a category 1 stop shall be applied to the slew drives.	Electrical	CR	IM	AC	SAT & BS EN ISO13849-2 Validation		Fairfields	**SF1 - Emergency Stop**
Abutments	5	Entrapment, crushing, entanglement	1	Movement of jacks with persons present near jacks or slewing of the bridge.	Maintenance	CR	RA	UD	Severe injuries or death for one person	Site is fenced Operator visibility from control room CCTV Emergency Stop on the control desk Only trained competent personnel Use of radio to ensure personel are clear Procedures for site visitors. Bridge rotation in area of the abutment shall be creep speed. Isolation Station/Lock out tag out Audible warning before bridge operation.	Mechanical / Electrical / Documentation	CR	IM	AC	BS EN ISO13849-2 Validation, SAT and Training logs		Fairfields	**SF1 - Emergency Stop** **SF3 - Maintenance Access**

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Unrealisable (UN)	Negligible	Negligible	Negligible	Negligible

Risk analysis per zone

Zone	Ref	Risk description	Ref Sub	Source of the risk	Phase / Operating mode / Scenario	Rating without protection measure			Consequence: Injury Category	Protection Measure	Mechanical / Electrical / Documentation	Rating with protection measure			Verification Method	Date	Responsible	Remarks (For SF refer to FDS)
						S	F	RL				S	F	RL				
		Entrapment, crushing, entanglement	2	Personnel hit by the bridge slip-blocks or by the bridge rotating while standing on the walkways	Opening/Closing	CR	RA	UD	Severe injuries or death for one person	Site is fenced Operator visibility from control room CCTV Emergency Stop on the control desk Only trained competent personnel Use of radio to ensure personel are clear Procedures for site visitors. Bridge rotation in area of the abutment shall be creep speed. Isolation Station/Lock out tag out Audible warning before bridge operation.	Mechanical/Electrical	CR	IM	AC	BS EN ISO13849-2 Validation, SAT and Training logs		Fairfields	**SF1 - Emergency Stop** **SF3 - Maintenance Access**
			3	Restricted headroom on abutment platform when bridge closed	Closed	MA	RA	AC	Minor injuries	Suitably RA'd and Appropriate PPE	Documentation	MA	RA	AC	Training Logs		Others	
		Structural Damage to Bridge	4	Jacks not raised/lowered together causing bridge deck to twist	Raising/Lowering	CR	RA	UD	Severe injuries or death for one person	Coordinated PLC control PLC will stop operation on failure of one or more jacks during movement. Operator training	Electrical	CR	IM	AC	SAT		Fairfields	
			5	Overtravel of a Jack	Raising	CR	RA	UD	Severe injuries or death for one person	Position of each jack is monitored back to the control system via Jack Extended limits.	Electrical	CR	IM	AC	SAT		Fairfields	
			6	Jacks raised before closing the bridge	Closing	CR	RA	UD	Severe injuries or death for one person	Control system monitors the position of the jacks and is part of bridge slewing interlock.	Electrical	CR	IM	AC	SAT		Fairfields	
		Delays to road/river traffic	7	Jacks fail to lower	Raising	MA	OC	UD	Minor injuries	Limit switches for raised, lowered positions prevent bridge opening with jacks raised. Interlocks CCTV	Electrical	MA	RA	AC	SAT		Fairfields	
			8	Jacks fail to raise or lower the bridge	Raising/Lowering	MA	OC	UD	Minor injuries	Limit switches for raised, lowered positions Emergency back up generator can be used in the event of power loss	Electrical/Mechanical	MA	RA	AC	SAT		Fairfields & Others	
			9	Loss of power	Raising/Lowering	MA	RA	AC	Minor injuries	Backup generator being installed on land.	Electrical	MA	IM	NE	SAT		Fairfields & Others	
			10	Jack sensors fail	Raising/Lowering	MA	RA	AC	Minor injuries	Duplicate limit switches for raised, lowered positions	Electrical	MA	IM	NE	SAT		Fairfields	
			11	False Detection of sensors due to vibration	Opening/Closing	MA	RA	AC	Minor injuries	Regular maintenance check of sensors Maintenance recovery procedure to recover bridge Sensor health monitored by control system	Electrical & Documentation	MA	IM	NE	Maintenance Logs & SAT		Fairfields & Others	
Slew drive assembly incl rack	6	Entrapment, crushing, entanglement	1	Entrapment and crushing from moving parts within Slew drive assembly when the bridge is slewing	Opening/Closing	CR	OC	UD	Severe injuries or death for one person	Site is fenced Operator visibility from control room CCTV Emergency Stop on the control desk Only trained competent personnel Use of radio to ensure personel are clear Procedures for site visitors. Bridge rotation in area of the abutment shall be creep speed. Isolation Station/Lock out tag out	Mechanical & Electrical	CR	IM	AC	SAT & BS EN ISO13849-2 Validation		Fairfields	**SF1 - Emergency Stop** **SF3 - Maintenance Access**
		Damage to bridge and energy chain	2	Bridge travelling beyond its extreme position of travel	Opening/Closing	CR	OC	UD	Severe injuries or death for one person	Encoders on each drive Limit switches to initiate ramp down to creep speed on approach. Stop position limit switches Ultimate limit switches	Mechanical & Electrical	CR	IM	AC	SAT & BS EN ISO13849-2 Validation		Fairfields	**SF4 - Ultimate Open** **SF5 - Ultimate Close**
		Bridge out of control Brakes engaged Damage to drive system and structure if braked at full speed	3	Loss of power	Opening/Closing	CR	RA	UD	Severe injuries or death for one person	Separately mounted brakes independent of motors enable torque limited braking on power failure.	Mechanical	CR	IM	AC	SAT		Fairfields	

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Risk analysis per zone

Zone	Ref	Risk description	Ref Sub	Source of the risk	Phase / Operating mode / Scenario	Rating without protection measure			Consequence	Protection Measure	Mechanical / Electrical / Documentation	Rating with protection measure			Verification Method	Date	Responsible	Remarks (For SF refer to FDS)
						S	F	RL	Injury Category			S	F	RL				
Maintenance	7	Entrapment, crushing, entanglement	1	All items are too heavy for manual handling and will require lifting and/or jacking tools. Risk of dropped loads, trapping and crushing.	Decommissioning	CR	OC	UD	Severe injuries or death for one person	RAMS Ensure all items are equipped with suitable lifting points. Weight and CoG of each item / assembly to be cleared marked on drawings to ensure correct lifting appliances are used. Lifting equipment to conform to LOLER. Wear PPE	Documentation	CR	IM	AC	Training Logs		Fairfields	
			2	Serious injury or death due to falling objects	Maintenance	CR	RA	UD	Severe injuries or death for one person	Items heavier than 20kg must be moved using permanent or mobile lifting equipment	Documentation	CR	IM	AC	Training Logs		Fairfields + Others	
		Health	3	Pigeon droppings present health hazard when working below bridge on mechanical equipment.	Maintenance	CR	RA	UD	Severe injuries or death for one person	Covers / guards to be included to keep droppings off items which require inspection or maintenance. Guards may be jet washed prior to opening. Plastic Anti-pigeon spikes to be considered in areas above slewing equipment.	Documentation & Procedures	CR	RA	UD	Training Logs		Others	
			4	Risk of inhalation of harmful or potentially carcinogenic materials built up over time	Maintenance	CR	RA	UD	Severe injuries or death for one person	Wear PPE (dust mask)	Documentation & Procedures	CR	RA	UD	Training Logs		Others	
		Environmental spillage	5	Gearboxes reservoir may need topping up with oil occasionally and risk of spillage.	Maintenance	MA	OC	UD	Minor injuries	Ensure gearboxes are suitably sealed/plugged. Use of appropriate lubricants for the environment Spill kits to be provided	Documentation	MA	IM	NE	Training Logs		Others	
			6	Risk of contamination working with hydraulic oils	Maintenance	MA	OC	UD	Minor injuries	Wear PPE	Documentation	MA	IM	NE	Training Logs		Others	
		Scratch / laceration	7	Lacerations or minor injuries due to working in confined spaces	Maintenance	MA	OC	UD	Minor injuries	Wear PPE	Documentation	MA	OC	UD	Training Logs		Others	
		Electrical Hazards	8	Electrocution/electric shock working with equipment	Maintenance	CR	RA	UD	Severe injuries or death for one person	SQEP maintenance operators Panels to be isolated if accessed	Documentation	CR	RA	UD	Training Logs		Others	
		Burns	9	High temperature on surface of braking resistors locate din the Main MCC Enclosure	Maintenance	MA	PR	UD	Minor injuries	Braking resistors are located within a ventilated enclosure to protect against contact	Electrical	Ma	IM	NE	Inspection		Fairfields	
		Enclosed space	10	Entrance into turntable	Maintenance	CR	RA	UD	Severe injuries or death for one person	Enclosed space risk assessment Enclosed space rescue plan	Documentation	CR	RA	UD	Training Logs		Others	
		Ladder access	11	Access down to south abutment Access from road-deck to turntable Access down into turntable	Maintenance	CR	RA	UD	Severe injuries or death for one person	Consider BS EN ISO 14122 - Safety of machinery. Permanent means of access to machinery	Documentation	CR	RA	UD	Training Logs		Others	
		Fall	12	Open entrance hole into turntable. Open manhole cover for access onto south abutment.	Maintenance	CR	RA	UD	Severe injuries or death for one person	Guarding in place.	Mechanical	CR	RA	UD	Inspection		Others	
Electrical	8	Electrical hazards	1	Contact with live terminals	All modes	CR	RA	UD	Severe injuries or death for one person	Minimum IP2x Maintenance procedures SQEP engineers	Electrical	CR	IM	AC	Inspection		Fairfields	
			2	Contact with live terminals and arc flash	All modes	CR	RA	UD	Severe injuries or death for one person	Ref MCC design requirements and for arc flash etc	Electrical	CR	IM	AC	Inspection		Fairfields	
			3	Earth fault	All modes	CR	RA	UD	Severe injuries or death for one person	Design to comply with relevant standards at MCC incoming supply	Electrical	CR	IM	AC	Design verification		Fairfields	
			4	Power Failure, emergency stop or fault could cause rapid stop of bridge. Inertia of bridge could cause mechanical or structural failure to the bridge or slewing equipment.	All modes	MA	IM	NE	Minor injuries	Size brakes appropriately and test to ensure maximum torque is within acceptable limits, Independent brakes	Mechanical	MA	IM	NE	SAT		Fairfields	

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Risk analysis per zone

Zone	Ref	Risk description	Ref Sub	Source of the risk	Phase / Operating mode / Scenario	Rating without protection measure			Consequence	Protection Measure	Mechanical / Electrical / Documentation	Rating with protection measure			Verification Method	Date	Responsible	Remarks (For SF refer to FDS)
						S	F	RL	Injury Category			S	F	RL				
Faults	9	Slew drive tripping	1	Vessel colliding with bridge	All modes	MA	OC	UD	Minor injuries	Emergency Status light to warn vessel. Radio comms with vessel Vessel has visual sight of bridge position Pilots wont proceed past 'double red or bouy' unless bridge is open.	Electrical / Documentation	MA	RA	AC	SAT Training logs		Fairfields Others	
		Bridge slew stopped during travel Delay to vessels or road traffic	2	Slew drive fault	All modes	MA	OC	UD	Minor injuries	Emergency Status light to warn vessel. Radio comms with vessel Vessel has visual sight of bridge position Pilots wont proceed past 'double red or bouy' unless bridge is open.	Electrical / Documentation	MA	RA	AC	SAT Training logs		Fairfields Others	
		Cable break	3	Bridge travelling beyond its extreme open position of travel twisting the bridge's flexible cable system thus inhibiting the control system from operating the bridge due to damage to the electrical cables	Opening/Closing	MA	OC	UD	Minor injuries	Bridge posisiton controlled by encoder, with ultimate open position limits to be installed and to be part of the bridge interlocking	Electrical	MA	RA	AC	SAT & BS EN ISO13849-2 Validation		Fairfields	**SF4 - Ultimate Open**
		Bridge slew out of control	4	Loss of mains site power	Opening/Closing	CR	RA	UD	Severe injuries or death for one person	Emergency status light to warn vessel. Back up generator to be installed. UPS to utilised. Radio comms with vessel Vessel has visual sight of bridge position Pilots wont proceed past 'double red or bouy' unless bridge is open.	Electrical / Documentation	CR	RA	UD	SAT Training logs		Fairfields Others	
Installation	10	Drowning	1	Working adjacent to waterway - risk of fall into water / drowning	Installation	CR	OC	UD	Severe injuries or death for one person	Ensure suitable edge protection in place and installers made aware of hazard. Wear PPE	Documentation	CR	OC	UD	Training Logs		All	
		Entrapment, crushing, entanglement, muscular/skeletal injury	2	Items being installed will be too heavy for manual handling and will require craneage. Risk of dropped load, crushing, trapping.	Installation	CR	OC	UD	Severe injuries or death for one person	RAMS Ensure all items are equipped with suitable lifting points. Weight and CoG of each item / assembly to be cleared marked on drawings to ensure correct lifting appliances are used. Lifting equipment to conform to LOLER. Wear PPE	Documentation	CR	OC	UD	Training Logs		All	
			3	Risk of trapping in moving parts during commissioning.	Installation	CR	OC	UD	Severe injuries or death for one person	• Minimal number of personnel to be located in the danger zone.• Radio contact to be maintained between operators and personnel in the danger zone. • Audible warning system for bride movement to be commissioned prior to commissioning activities. Wear PPE	Documentation	CR	OC	UD	Training Logs		All	
		Environmental spillage	4	Gearboxes will be filled with oil on install. Risk of spillage - environmental and health hazard.	Installation	MA	OC	UD	Minor injuries	Spill kits & Bunds	Documentation	MA	OC	UD	Training Logs		All	
		Slips trips and falls	5	Trailing cables, equipment, uneven surfaces.	Installation	MA	OC	UD	Minor injuries	PPE Good housekeeping	Documentation	MA	OC	UD	Training Logs		All	
Decommissioning	11	Environmental spillage	1	Oil within gearboxes presents environmental and health hazard if spilled.	Decommissioning	CR	OC	UD	Severe injuries or death for one person	Spill kits & Bunds	Documentation	CR	OC	UD	Training Logs		All	
		Entrapment, crushing, entanglement, muscular/skeletal injury	2	All items are too heavy for manual handling and will require lifting and/or jacking tools. Risk of dropped loads, trapping and crushing.	Decommissioning	CR	OC	UD	Severe injuries or death for one person	RAMS Ensure all items are equipped with suitable lifting points. Weight and CoG of each item / assembly to be cleared marked on drawings to ensure correct lifting appliances are used. Lifting equipment to conform to LOLER. Wear PPE	Documentation	CR	OC	UD	Training Logs		All	
		Electrical Hazards	3	Risk of electrocution during dismantling and/or decommissioning	Decommissioning	CR	OC	UD	Severe injuries or death for one person	SQEP Safe systems of work Wear PPE	Documentation	CR	OC	UD	Training Logs		All	
		Drowning	4	Serious injury or death due to drowning whilst dismantling	Decommissioning	CR	OC	UD	Severe injuries or death for one person	Wear PPE. No lone working Use of safety boat.	Documentation	CR	OC	UD	Training Logs		All	

LINC10089-01-01

Revision A03

FUNCTIONAL DESIGN SPECIFICATION

Cross Keys Swing Bridge
Electrical Upgrade

Lincolnshire County Council

Classification: Protected

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Precedence

As this specification may have been designed to take account of matters which had not been considered previously, this document once approved, will take precedence over any other specification in the event of a conflict.

Approval

When this document is submitted for approval, you should ensure that you are aware of its review period which unless stated within the contract document is 5 working days. If we either receive your written approval or have not received a written response from you prior to expiry of the review period, then this document will be deemed approved. However, if we receive written comments prior to the expiry of the review period, we will deal with them appropriately.

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1. Document Details

1.1. Project Details

FCS Project Ref:	LINC10089
Project Title:	Cross Keys Swing Bridge Electrical Upgrade
Customer:	Lincolnshire County Council
Document ref:	LINC10089-01-01

1.2. Revision History

Previous issues of this document are to be destroyed or marked superseded

Revision	Job Ref	Date	Description Of Amendment
P01	FES5241	03/12/2024	Initial Draft
P02	FES5241	06/01/2025	Initial Draft
A01	FES5241	09/01/2025	For Approval
A02	FES5241	30/04/2025	Amendments made based on changes to scope
A03	FES5241	22/05/2025	Client comments incorporated (08/05/2025)

Table 1-1 - Revision History

Revision	Author	Date	Checked By	Date
P01	Tom Silvester	03/12/2024	Daniel Rosen	03/12/2024
P02	Ryan Evans	06/01/2025	Tom Silvester	07/01/2025
A01	Ryan Evans	09/01/2025	Tom Silvester	09/01/2025
A02	Tom Silvester	30/04/2025	Daniel Rosen	30/04/2025
A03	Tom Silvester	22/05/2025	Daniel Rosen	22/05/2024

Table 1-2 - Author & Approval

1.3. Standards

The standards identified in the table below were referenced in the production of this document.

Reference	Description	Revision
BS EN ISO 13849:1	Safety of Machinery. Safety-related parts of control systems.	2023
BS EN ISO 12100	Safety of Machinery. General principles for design. Risk assessment and risk reduction	2010
BS EN 60204-1:2006+A1:	BS EN 60204-1:2006+A1:2009 Safety of machinery. Electrical equipment of machines. General requirements.	2009
BS EN ISO 13850	Emergency stop function	2015

Table 1-3: Standards

1.4. Reference Documents

The project documents identified in the table below were referenced in the production of this document.

Reference	Description	Revision
LINC10089-01-02	Software Requirement Specification	A03
LINC10089-01-05	User Requirement Specification	A01
LINC10089-20-12	Design Risk Assessment	A02
LINC10089-20-14	Safety Requirement Specification	A03
LINC10089-02-01	I/O List	A03
LINC10089-02-08	Power Consumption Technical Note	A01
N/A	Electrical Manual (Dodd Group)	N/A
N/A	Operating Manual (Dodd Group)	N/A
N/A	Generator Manual (Dodd Group)	N/A

Table 1-4 - Reference Documents

1.5. Foreword

The purpose of this document is to provide a description of works to be undertaken by Fairfield Control Systems Ltd on behalf of Fairfield Engineering Solutions Ltd for the electrical upgrade of Cross Keys Swing Bridge.

This document will identify the major items of equipment to be supplied and installed and will provide details of the system configuration and control philosophy.

This document has been compiled before the detailed design, and it is feasible that there will be changes to this document due to the ongoing design process. It is intended that this document will be developed throughout the project's design life and used as the reference document for the electrical control system. Any changes will be subject to review and agreement with Lincolnshire County Council.

2. Glossary of Terms and Acronyms

A	-	Amps
BCD	-	Block Cable Diagram
CPU	-	Central Processing Unit
DLRA	-	Design Level Risk Assessment
FAT	-	Factory Acceptance Test
FDS	-	Functional Design Specification
GA	-	General Arrangement
HMI	-	Human Machine Interface
HPU	-	Hydraulic Power Unit
I/O	-	Input/Output
kW	-	Kilowatts
LC	-	Lucent Connector
MCC	-	Motor Control Centre
PC	-	Personal Computer
PLC	-	Programmable Logic Controller
RAMS	-	Risk Assessment Method Statement
SAT	-	Site Acceptance Test
SCADA	-	Supervisory Control and Data Acquisition
SDS	-	Software Design Specification
SE	-	Site Edition
STO	-	Safe Torque Off
UPS	-	Uninterruptible Power Supply
VAC	-	Volts Alternating Current
VDC	-	Volts Direct Current
VSD	-	Variable Speed Drive

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3. Introduction

Cross Keys is a swing bridge that carries the single carriageway A17 over the River Nene. The bridge was built in 1897 and was originally constructed to carry rail traffic over the river. The railway closed in 1965, and the bridge is now used as a road and pedestrian bridge.

The bridge opens in the anticlockwise direction only to allow river traffic to pass and closes in the clockwise direction to return the bridge to road and pedestrian traffic.

To open the bridge to vessels, the bridge operates in the following sequence from the closed position:

- Wig Wags turned on and Barriers Lowered using the Traffic Control System
- Bridge Jacked Up
- Slip Blocks Retracted
- Bridge Jacked Down
- Bridge Rotated Anticlockwise to the Open Position

To close the bridge to vessels, the bridge is operated in the following sequence from the open position:

- Locking Pins Extended
- Bridge Rotated Clockwise to the Closed Position
- Bridge Jacked Up
- Slip Blocks Extended
- Bridge Jacked Down onto Slip Blocks
- All Barriers Raised and Wig Wags turned off using the Traffic Control System
- Locking Pins Retracted

The bridge has been subject to numerous faults due to obsolete faulty control equipment. The bridge's slewing drive motors will be upgraded from the currently hydraulically powered system to the more reliable electro-mechanical actuators. The bridge's jacking hydraulic actuators are due to be refurbished and upgraded as part of the works. Along with this, the control and visualisation systems are to be upgraded to more modern equipment increasing the control system's availability and reducing downtime due to faults.

For the control system, a new Allen-Bradley PLC solution shall be designed and installed. I/O shall be retrieved around the bridge using CompactIO racks located in the Pump House and the Control Room.

The user-control interface is to be controlled either from the levers located in the Control Room or from the SCADA, which will be upgraded to use FactoryTalk View SE.

4. Scope of Works

4.1. Contract Scope

Fairfield Control System Ltd's scope of work under the terms of the controls is currently limited to the following:

4.1.1. Documentation

1. User Requirement Specification (URS)
2. Design Level Risk Assessment (DLRA)
3. High-Level Cyber Security Assessment
4. Safety Design Specification
5. Functional Design Specification (FDS)
6. Software Design Specification (SDS)
7. Hardware Topology
8. I/O Schedule
9. Block Cable Diagram (BCD)
10. Cable Schedule
11. Control Panel General Arrangement (GA) drawings
12. Electrical Schematic Drawings
13. Electrical Installation RFQ
14. FAT Specification
15. Changeover Methodology
16. SAT Specification
17. Site Work-Related RAMS
18. Operations & Maintenance (O&M) Manual

4.1.2. Hardware

1. Design, Build and Supply the following control panels:
    a. Main Control Panel
    b. Control Console
    c. Junction Boxes as required
2. Supply of the following instrumentation:
    a. 2 x Limit Switches for Ultimate Bridge Positions
    b. 4 x Slewing Motor Encoders
    c. 4 x Clutch Proximity Switches
    d. 2 x Bridge Position Encoders
    e. 6 x Emergency Stops
3. Supply of Remote Access Equipment:
    a. Cisco 927 Integrated Services Router
    b. Firewall
    c. Engineering PC

4.1.3. Software

Design and develop the following software:

1. PLC
2. Safety Controller
3. SCADA

4.1.4. Testing

1. Internal Testing
2. Factory Acceptance Testing (FAT)
3. Site Acceptance Testing (SAT)

4.1.5. Commissioning

1. On-Site Commissioning
2. A period of site-based support to be agreed

4.1.6. Training

1. O&M Manual
2. Formal training to be agreed

5. System Overview

Cross Keys Swing Bridge is an operational road and pedestrian bridge that carries the single-carriageway A17 over the River Nene. The bridge is opened anticlockwise to provide passage for vessels.

The bridge is secured by two foot-bolt Locking Pins and is lifted onto Slip Blocks so that in its “supported” position, the bridge cannot move on its centre point.

When the bridge is to be moved open, the bridge is first lifted off its Slip Blocks. The Slip Blocks are then retracted out of the way and the bridge is lowered. Once lowered, the Locking Pins are retracted, and the bridge is swung open anticlockwise via hydraulic motors.

To open the bridge to vessels, the bridge operates in the following sequence from the closed position:

1. Wig Wags Operated (Traffic Control System)
2. Lower Facer Barriers (Traffic Control System)
3. Lower Trailer Barriers (Traffic Control System)
4. Lower East & West Pedestrian Barriers (Traffic Control System)
5. Bridge Jacked Up
6. Slip Blocks Retracted
7. Bridge Jacked Down
8. Bridge Slewed Anticlockwise to the pre-set Open Position

To close the bridge to vessels, the bridge is operated in the following sequence from the open position:

1. Foot Bolt Locking Pins Extended
2. Bridge Slewed Clockwise to the pre-set Closed Position
3. Bridge Jacked Up
4. Slip Blocks Extended
5. Bridge Lowered onto Slip Blocks
6. All Barriers Raised (Traffic Control System)
7. Foot Bolt Locking Pins Removed
8. Wig Wags Turned Off (Traffic Control System)

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5.1. Bridge Layout

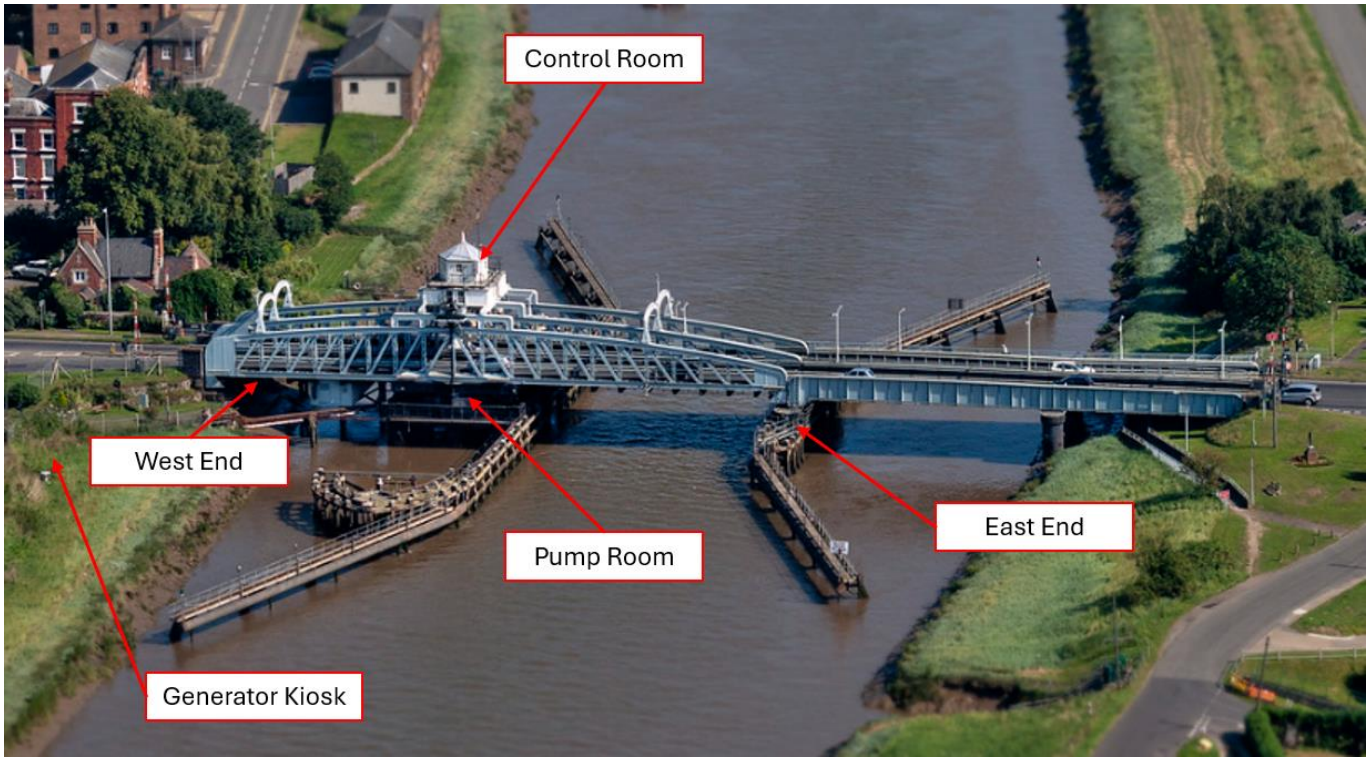


Figure 5-1: Cross Keys Swing Bridge Equipment Locations

The swing bridge has two locations where the upgrade control equipment shall be installed:

Control Room: The operator controls the bridge from here. The Traffic Control Console and Bridge Control Console are located in the Control Room.

Pump Room: The Main Control Panel is to be installed here, which shall house the PLCs and actuator control equipment.

5.2. Interfaces

5.2.1. Control Room

The following equipment from the Control Room shall interface with the control system:

5.2.1.1. Operational Levers

The Operational Levers are to be retained and used to control the bridge. In normal operating conditions, the SCADA controls are used, but the "Manual Control" button on the SCADA can be pressed to allow the levers to be used instead. The control system receives the following digital inputs:

- Jacks Lever - Forward (Lower)
- Jacks Lever - Back (Raise)
- Blocks Lever - Forward (Extend)
- Blocks Lever - Back (Retract)
- Slew Lever - Forward Slow (Close)
- Slew Lever - Forward Fast (Close)
- Slew Lever - Back Slow (Open)
- Slew Lever - Back Fast (Open)

5.2.1.2. Control Console

A Control Console shall be installed in the same position as the existing control panel in the Control Room. This shall contain several pushbuttons to aid recovery of the bridge should a fault occur.

Controls

The following Control Console equipment shall be integrated as fail-safe digital inputs into the Control System:

- Emergency Stop
- Maintenance Access Switch
- Traffic Barrier Override Switch

The following Control Console devices shall be integrated as digital inputs into the Control System:

- Safety Fault Reset Pushbutton
- E-Stop Reset Illuminated Pushbutton
- Maintenance Immobilisation Reset Illuminated Pushbutton
- Ultimate Position Recovery Illuminated Pushbutton
- Ultimate Position Reset Illuminated Pushbutton
- Emergency Control – Enable Key Switch (Fortress)

The following hardwired controls shall be installed on the Control Console and be in use in all modes:

- Lamp Test
- River Traffic Lights On Selector Switch (stay-put)
- River Traffic Lights Selector Switch (stay-put)

The following Emergency control devices shall be integrated as hardwired inputs and will only be enabled once the Emergency Control Enable Key Switch is in the on position:

- Emergency Control – Enable Key Switch (Fortress)
- Emergency Control – Emergency Stop Pushbutton
- Emergency Control – HPU Pump 1/2 Selector Switch (stay-put)
- Emergency Control – Jacking HPU Start Pushbutton
- Emergency Control – Jacking HPU Stop Pushbutton
- Emergency Control – Jacks Direction Selector Switch (spring-return)
- Emergency Control – Slip Blocks Direction Selector Switch (spring-return)
- Emergency Control – Slew Drives 1-4 Healthy Reset illuminate Pushbuttons
- Emergency Control – Slew Drives 1-4 Override Selector Switches
- Emergency Control – Bridge Slew Speed Selector Switch (stay-put)
- Emergency Control – Bridge Slew Direction Selector Switch (spring-return)

The following digital outputs shall illuminate the following pushbuttons:

- E-Stop Reset Illuminated Pushbutton
- Maintenance Immobilisation Illuminated Pushbutton
- Ultimate Position Recovery Illuminated Pushbutton
- Ultimate Position Reset Illuminated Pushbutton

The following hardwired indicators shall be installed on the Control Console and be in use in all modes:

- Wisbech Side Green Lamp
- Wisbech Side Red Lamp
- Sutton Bridge Side Green Lamp
- Sutton Bridge Side Red Lamp

The following shall be hardwired outputs that will and will only be enabled once the Emergency Control Enable Key Switch is in the on position:

- Emergency Control - Enabled Lamp
- Emergency Control - HPU Pump 1 Running Lamp
- Emergency Control - HPU Pump 2 Running Lamp
- Emergency Control - HPU Pump 1 Fault Lamp
- Emergency Control - HPU Pump 2 Fault Lamp
- Emergency Control - Jacks Extended Lamp
- Emergency Control - Jacks Retracted Lamp
- Emergency Control - Slewing Motor 1 Running Lamp
- Emergency Control - Slewing Motor 2 Running Lamp
- Emergency Control - Slewing Motor 3 Running Lamp
- Emergency Control - Slewing Motor 4 Running Lamp
- Emergency Control - Slewing Motor 1 Fault Lamp

- Emergency Control - Slewing Motor 2 Fault Lamp
- Emergency Control - Slewing Motor 3 Fault Lamp
- Emergency Control - Slewing Motor 4 Fault Lamp
- Emergency Control - Slip Blocks Extended Lamp
- Emergency Control - Slip Blocks Retracted Lamp
- Emergency Control - Bridge Open Lamp
- Emergency Control - Bridge Closed Lamp

5.2.2. Bridge Status Lights

The control system controls the following Water Traffic Lights via hardwire outputs:

- Navigation Lights – Red
- Navigation Lights – Amber
- Navigation Lights – Green
- Air Draught Warning Triangle (Channel Closed)

5.2.3. HPU

5.2.3.1. Pumps

The HPU is located in the plant room, comprising two 45kW pumps in a duty-standby configuration. The motors will use soft starters and will provide hydraulic power for the jacks and slip blocks. The control system shall receive the following inputs from the Hydraulic Power Units:

- HPU Pump x Running Full Speed Feedback
- HPU Pump x Soft Start Healthy
- HPU Pump x Motor Protection Healthy
- HPU Pump x Isolator Feedback
- HPU Pump x Thermistor Healthy

The control system shall control the Hydraulic Power Units with the following outputs:

- HPU Pump x Run

5.2.3.2. Oil Recirculation Pump

An oil recirculation system will also be installed, which will consist of a single Direct On Line pump, pump rating 4kW. The control system shall receive the following inputs from the oil recirculation pump:

- Circulation Pump Circuit Protection Healthy
- Circulation Pump Isolator Healthy
- Circulation Pump Running

The control system shall control the Circulation Pump with the following output:

- Circulation Pump Run

5.2.3.3. Instrumentation

The following 24V Digital Input signals will be received from the HPU's.

- Recirculating Pump Filter Blocked
- HPU Pumps Return Filter Blocked
- HPU Pump 1 Filter Blocked
- HPU Pump 2 Filter Blocked
- HPU Pump 1 Ball Valve Closed
- HPU Pump 2 Ball Valve Closed
- Oil - High High Temperature
- Oil - Low Low Level

The following 4-20mA Analogue signals will be received from the HPU's:

- Oil Temperature
- Oil Level
- Pumpset 1 Pressure
- Pumpset 2 Pressure
- Jacking Cylinder Pressure 1
- Jacking Cylinder Pressure 2
- Blocks Cylinder Pressure 1
- Blocks Cylinder Pressure 2

5.2.4. Jacks

At each end of the bridge, there are two Jacks. The position of the Jacks shall be received via four limit switches as 24VDC digital inputs (two for retracted, two for extended). The following IO shall be received from each Jack to the Main MCC RIO rack:

- *x* Jack Retracted 1
- *x* Jack Retracted 2
- *x* Jack Extended 1
- *x* Jack Extended 2

Where x will be South West, South East, North West or North East.

The control system shall actuate the direction of the Jacks to raise and lower via Extend and Retract solenoid valves. Each Jack will have a local solenoid-operated bypass valves to allow flushing of oil through the pipework.

- All Jacks Extend SOV
- All Jacks Retract SOV
- Load Valve – High Pressure SOV
- *x* Jack Bypass SOV

Where x will be South West, South East, North West or North East.

5.2.5. Slip Blocks

There are three Slip Blocks located on each side of the bridge, which are driven via the HPU. The position status of the Slip Blocks shall be received using four existing proximity sensors (two for retracted and two for extended positions). The following IO shall be received from each Slip Block to the Main MCC RIO rack:

- x Block Retracted 1
- *x* Block Retracted 2
- *x* Block Extended 1
- *x* Block Extended 2

Where x will be South West, South, South East, North West, North or North East.

The control system shall actuate the direction of the Slip Blocks to extend and retract via Extend and Retract solenoid valves. Each Slip Block cylinder will have a local solenoid-operated bypass valve to allow flushing of oil through the pipework.

- All Blocks Extend SOV
- All Blocks Retract SOV
- Load Valve – Low Pressure SOV
- Block Cylinder *x* Bypass SOV

5.2.6. Bridge Slewing Motors

The control system shall control the slew of the bridge using four 11kW electro-mechanical motors. The control system shall receive the following 24V DC Digital Input signals from the Bridge Slewing Motors:

- Isolator Feedback
- Thermistor Healthy
- Circuit Protection Healthy
- VSD Fault Status
- Running

The control system shall receive the following 4-20mA Analogue signals from the Bridge Slewing Motors:

- Bridge Slewing Motor *x* Encoder Position

The control system shall control the Bridge Slewing Motors via VSDs with the following outputs:

- Bridge Slewing Motor *x* VSD Run
- Bridge Slewing Motor *x* VSD Forward/Reverse Direction
- Bridge Slewing Motor *x* VSD Speed Setpoint

5.2.7. Load Limitations

Please refer to technical note *LINC10089-02-08* for details of the loading limitations of the system.

5.2.8. Remote Access

A 4G router shall be installed in the Control Room to provide remote access to the control system. This will enable engineers to remotely access the bridge's control system to troubleshoot any issues should they arise. A firewall will be installed between the router and the control network.

6. Operation Requirements

6.1. Design Life

The design life of the electrical equipment shall be 15-20 years, and the design life of the PLC equipment shall be 20 years.

The equipment supplied will have a warranty period of 12 months commencing commissioning.

6.2. Environmental

The following data will be used as the basis for the design, manufacture, testing and delivery:

Temperature -5°C to 30°C

Relative Humidity 90%

6.3. Electrical Data

6.3.1. Main MCC

The Main MCC shall require a 400VAC Three-Phase, Neutral, and Earth supply. The Main MCC shall house power distribution equipment for the control equipment, VSDs for Slewing Motors, and the HPU equipment. It shall also contain circuit protective devices for the VSDs, HPU soft starters, and control equipment, plus miscellaneous circuits such as PSU, heating, and lighting.

6.3.1.1. Feed Circuit

The Main Control Panel shall be fed from the changeover switch located close to the generator. A 160A 3P+N+E feed shall be allocated.

6.3.1.2. Loading Scenarios

The power requirements have been calculated taking into account some diversity. The maximum loading scenario is therefore as follows:

- Slewing Motors 1-4
- HPU Motor 1 or 2 running off load

6.3.2. Control Room Console

The Control Room Console will require a 230VAC Single Phase, Neutral and Earth supply. The Control Room Console shall house circuit protective devices for the 24VDC PSU. Additional circuit protection shall be provided for the 24VDC circuits.

6.3.2.1. Feed Circuit

The Control Room console shall be fed from the Main Control Panel located in the Plant Room.

The Control Room console shall provide a maintained 24VDC power. The maintained 24VDC supply shall be backed by a UPS which will give up to one hour of unsupported supply until the backup generator has started.

7. Safety Requirements

Based on the DRA and the SRS formulated from this, five Safety Functions were identified and designed. A summary is defined below in Table 7-1: Safety Function List. For more information on the below Safety Functions please refer to the SRS document *LINC10089-20-14-01*.

Ref	Name	Type	PL_r Calculation	PL_r
SF1	Emergency Stop	Emergency Stop Function	BS EN 13850*	d
SF2	Traffic Barriers Interlock	Safety-related Stop Function initiated by safeguard	S2 / F2 / P2	e
SF3	Maintenance Access	Safety-related Stop Function initiated by safeguard	S2 / F2 / P2	e
SF4	Ultimate Open	Safety-related Stop Function initiated by safeguard	S2 / F2 / P2	e
SF5	Ultimate Close	Safety-related Stop Function initiated by safeguard	S2 / F2 / P2	e

Table 7-1: Safety Function List

* Note: For Safety Function SF1 the standard BS EN 13850 section 4.1.5 identifies a minimum of PLr c for Emergency Stop functions. Due to the PLr of other Safety Functions in the system all being PLr d or higher, it has been deemed that in this case the Emergency Stop shall also be specified at PLr d.

7.1. SF1 – Emergency Stop

The SF1 Safety Function applies to the following Emergency Stops:

- Main Control Panel
- Control Room Console
- Slew Motor Local Emergency Stop x4
- Bridge Encoder Local Emergency Stop x2

When any of the above Emergency Stops are pressed, the Jack, Slip Blocks and Slew Motors are de-energised, therefore immobilising all bridge movements. The Jacks and Slip Blocks will be stopped immediately (Category 0 Stop) whereas the Slew Motors will use a time-delayed stop after a controlled ramp down (Category 1 Stop).

The Safety Function is reset when the applied Emergency Stop is twist released, and the Emergency Stop Reset illuminated pushbutton is pressed on the Control Console.

Each E-Stop shall have an auxiliary contact installed to alarm which emergency stop has been pressed.

Classification: Protected

7.2. SF2 – Traffic Barrier Interlock

A Traffic Barrier Interlock shall be in place to inhibit the bridge from moving if any of the vehicle or pedestrian barriers are open. A limit switch shall be installed for each of the barriers, and all will be required to be closed to move the bridge. If any of the limit switches are in the open position, the Jacks, Slip Blocks and Slew Motors are stopped, immobilising all bridge movements. The Jacks and Slip Blocks will be stopped immediately (Category 0 Stop), whereas the Slew Motors will use a time-delayed stop after a controlled ramp down (Category 1 Stop).

A barrier override switch shall allow operations in the scenario of a barrier limit switch failure. This is to be implemented as part of the safety function, such that a failure of the override switch will not cause the safety function to be bypassed.

Measures will be required to mitigate the possibility of the switch being left in the override position. E.g. automatically cancelling the override once the barriers are reopened or having to be time-limited/ requiring a positive edge to re-trigger the override.

7.3. SF3 – Maintenance Immobilisation

A trapped Maintenance Immobilisation key shall be installed at the Control Console and used to immobilise the bridge when performing maintenance activities or gaining access to the bridge chamber. When the Maintenance Immobilisation key is released, the Jacks, Slip Blocks and Slew Motors are stopped, immobilising all bridge movements. The Jacks and Slip Blocks will be stopped immediately (Category 0 Stop), whereas the Slew Motors will use a time-delayed stop after a controlled ramp down (Category 1 Stop).

The Maintenance Immobilisation is reset when the Maintenance Immobilisation key is returned to the Control Console and the Maintenance Reset illuminated pushbutton is pressed.

7.4. SF4 - Ultimate Open

To prevent the bridge from going beyond its operational Open position and damaging the energy chain system, a limit switch shall be installed to stop the bridge via the Safety PLC. When the Ultimate Open position is reached, the Slew Motors shall be de-energised, and the bridge swing movements are immobilised. The Slew Motors will use a time delayed stop after a controlled ramp down (Category 1 Stop).

The bridge can be recovered from the Ultimate Open position back to the operational Open position. The bridge is recovered by pressing the Ultimate Position Recovery pushbutton, once illuminated on the Control Console. This will re-energise the slewing motor but shall only be able to operate in the Close direction. The bridge is then slewed back by pressing and holding the Bridge Recovery button on the Control Console.

7.5. SF5 - Ultimate Close

To prevent the bridge from going beyond its operational Close position and damaging the energy chain system, a limit switch shall be installed to stop the bridge via the Safety PLC. When the Ultimate Close position is reached, the Slew Motors shall be de-energised, and the bridge swing movements are immobilised. The Slew Motors will use a time delayed stop after a controlled ramp down (Category 1 Stop).

The bridge can be recovered from the Ultimate Close position back to the operational Close position. The bridge is recovered by pressing the Ultimate Position Recovery pushbutton, once illuminated, on the Control Console. This

will re-energise the slewing motor but shall only be able to operate in the Open direction. The bridge is then slewed back by pressing and holding the Bridge Recovery button on the Control Console.

8. Hardware Specification

8.1. Overview

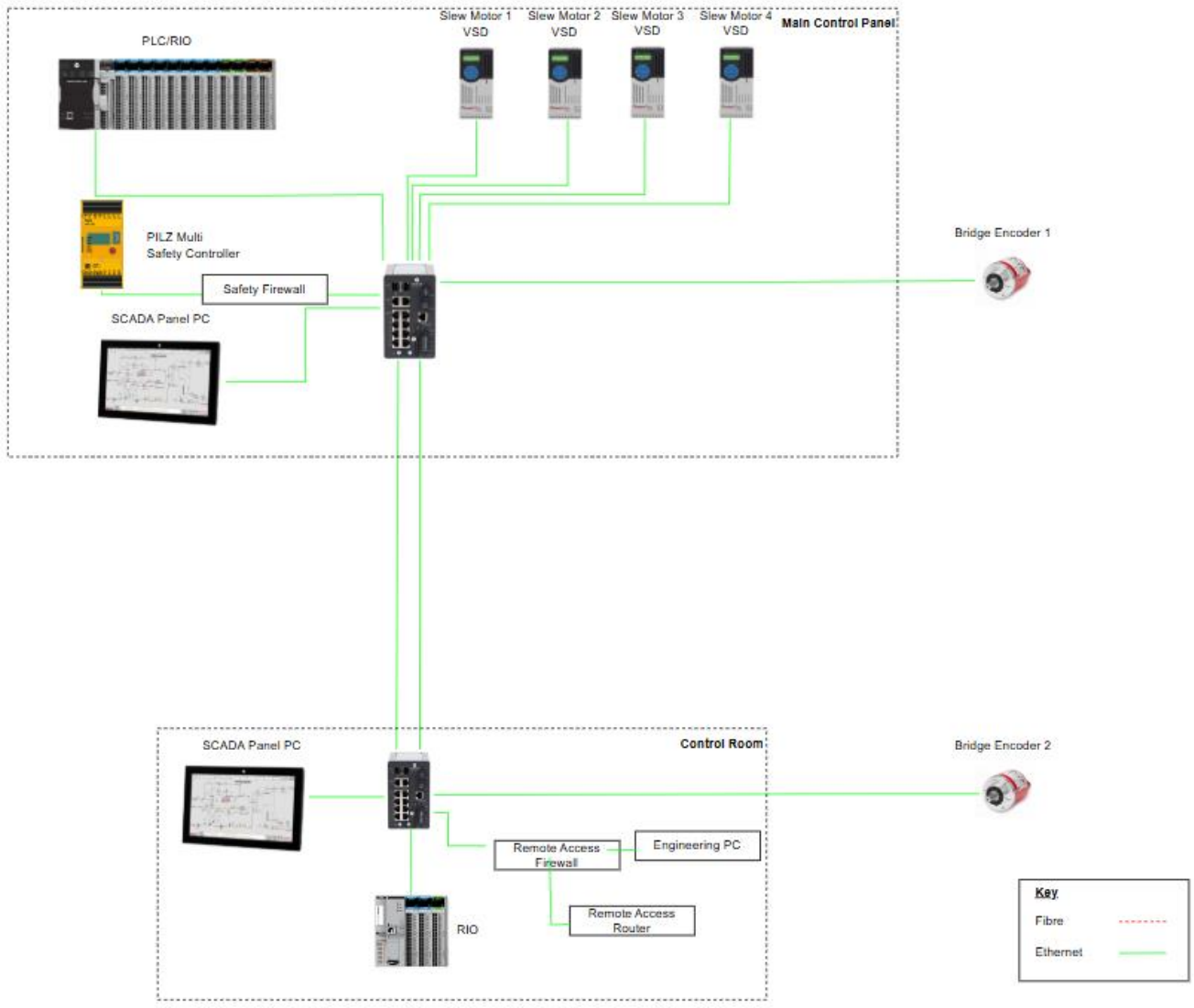


Figure 8-1: Control System Overview

The control system topology shall be implemented with control enclosures installed in the plant and control rooms. Each enclosure shall have a Stratix 5200 managed switch installed to link the control panels over Ethernet.

The control system shall comprise a CompactLogix PLC system that shall handle the bridge control aspects of the control system, and a PILZ Multi Safety Controller shall handle the safety aspects of the control system. The CompactLogix PLC shall utilise the IO located in the Main Control Panel and the Control Room. Panel PCs shall be installed in the Main Control Panel and Control Room Console and are to be used for the SCADA. The SCADA software installed shall be the FactoryTalk View SE package. The SCADA shall be the main means of visualisation of the bridge and provide controls to operate the bridge.

Remote access to the control system shall be provided by a cellular modem for connection, a firewall, a programming terminal and an industrial firewall.

8.2. Enclosure Specification

The following sub-sections shall detail the enclosures to be installed as part of this project.

8.2.1. Main Control Panel

The Main Control Panel shall be installed in the Plant Room. The Main Control Panel shall be a bespoke multi-bay cabinet constructed from mild steel with overall provisional dimensions 3100 x 1400mm x 600mm (width x height x depth) inclusive of a 200mm high plinth, RAL7035 powder coat finish and a protection rating of IP55. Cable entry shall be at the top of the panel.

The Main Control Panel shall provisionally consist of three bays. Multiple cubicles shall be utilised on the "Incomer" bay to enable isolation of the bridge equipment independently. A cubicle shall be assigned for the main incomer for the feed received from the generator. A cubicle shall be assigned for the existing services this shall feed the existing control panel. A cubicle shall be assigned for the bridge power this shall supply the "Bridge Power" bay. A cubicle shall be installed for the bridge control equipment this shall feed the "Bridge Control" bay.

The "Bridge Power" bay shall house the bridge power equipment such as the Slew VSDs and HPU Motor soft starters. The front of the bay shall include a HIM (Human Interface Module) for each Slewing Motor VSDs, a Diris A20 multi-function meter for each HPU Pump motor. Dimensions of the "Bridge Power" bay are to be confirmed.

The "Bridge Control" bay shall house the bridge control equipment such as the PLC equipment and control relays. The bay will include a non-fused isolator with a padlockable handle. The isolator will be door-interlocked and will be defeatable by the use of a tool. This Panel Mount SCADA PC shall be mounted on the Main Control Panel. Dimensions of the "Bridge Power" bay are to be confirmed.

8.2.2. Control Console

A Rittal one-piece desk console shall be installed in the Signal Box. The control console shall be constructed from mild steel with provisional dimensions 1200mm x 955mm x 500mm (width x height x depth) mounted on a 100mm plinth, RAL7035 powder coat finish and a protection rating of IP55. Cable entry shall be at the bottom of the control desk.

The control desk has three doors: One on the console top and the other two at the bottom of the desk. The console top shall have the SCADA touchscreen (see 8.7.1) mounted along with the safety reset, emergency controls and Enable Fortress key. The bottom section of the desk is a double door and shall include a non-fused isolator with a padlockable handle. The isolator will be door-interlocked and will be defeatable by the use of a tool.

A fan, thermostat and lighting will be installed in the control desk.

Existing 230VAC sockets are to be rationalised and removed (by others) to make space for the Control Console.

8.3. 24VDC Power

All 24VDC power shall be provided from 24VDC power supplies that are to be battery-backed via a UPS module.

There shall be both maintained and non-maintained loads. The maintained load shall be circuits critical to the operation and will enable visibility of the status of the bridge and enable core operation should a power loss occur. Non-maintained shall not be backed by the UPS.

8.3.1. 24VDC PSU



Figure 8-2: PULS 24VDC PSU

A PULS 24VDC power supply shall be installed in each of the control panels stated in section 8.2.

The status of each unit shall be hardwired back to local digital input cards and shall be used for the PSU healthy signals.

8.3.2. 24VDC UPS



Figure 8-3: PULS UZK12 UPS

To enable the control system to remain online during the changeover to the generator supply during a power failure, a 24VDC UPS module shall be installed in the control panels stated in section 8.2.

Each UPS module shall keep the control system online for up to 60 minutes to enable time for the system to be changed over to the generator supply. The PULS UB10 UPS units shall be installed and connected to appropriately rated PULS UZK12 battery units.

Three signals from the UPS unit shall be sent to the control system for alarming and status purposes. The following contacts shall be hardwired to digital I/O.

- UPS Ready: Battery charged, and unit healthy
- UPS Buffering: UPS running on battery
- UPS Battery Fault

8.4. Network Switches



Figure 8-4: Allen-Bradley Stratix 5200 Switches

In the Main Control Panel and Control Room Console, an Allen-Bradley Stratix 5200 switch shall be supplied and installed and act as the connection point of the device level ring.

The Stratix 5200 features a number of RJ45 ports that shall be used to connect to control equipment local to the control panel (IO, Encoders etc).

For more information on the network configuration and the network topology please refer to Appendix A.

8.5. PLC Equipment

The following sub-section details the PLC equipment housed in each of the control panels located on the bridge. The PLC control system comprises Allen-Bradley CompactLogix system and a Pilz PNOZmulti Safety Controller that shall handle the safety elements of the control system.

8.5.1. Main Control Panel

The Main MCC shall house a single CompactLogix rack, which shall also house the CPU.

The rack is to contain the following equipment:

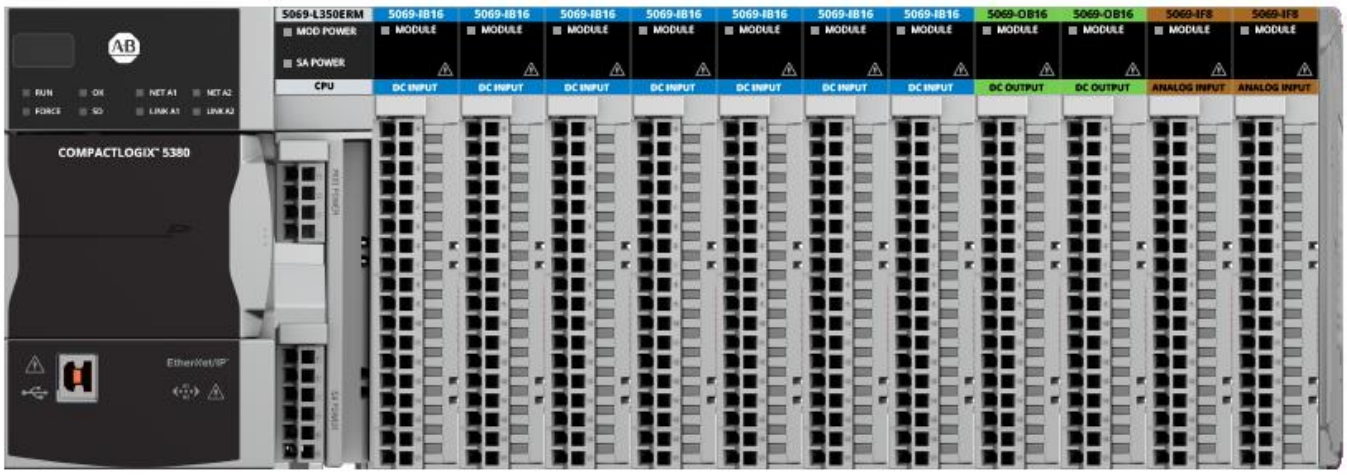


Figure 8-5: Main Control Panel Rack

Slot	Part No.	Description
0	5069-L330ER	CompactLogix 3MB Ethernet Controller CompactLogix
1	5069-IB16	5069 Compact I/O 16 Channel 24VDC Sink Input Module
2	5069-IB16	5069 Compact I/O 16 Channel 24VDC Sink Input Module
3	5069-IB16	5069 Compact I/O 16 Channel 24VDC Sink Input Module
4	5069-IB16	5069 Compact I/O 16 Channel 24VDC Sink Input Module
5	5069-IB16	5069 Compact I/O 16 Channel 24VDC Sink Input Module
6	5069-IB16	5069 Compact I/O 16 Channel 24VDC Sink Input Module
7	5069-IB16	5069 Compact I/O 16 Channel 24VDC Sink Input Module
8	5069-OB16	5069 Compact I/O 16 Channel 24VDC Source Output Module
9	5069-OB16	5069 Compact I/O 16 Channel 24VDC Source Output Module
10	5069-IF8	5069 Compact I/O 8 Channel Voltage/Current Analog Input Module
11	5069-IF8	5069 Compact I/O 8 Channel Voltage/Current Analog Input Module
N/A	5069-ECR	5069 End Cap

Table 8-1: Main Control Panel Rack

Classification: Protected

8.5.2. Control Room

The Control Room Console shall house a CompactLogix rack that shall cater for the IO local to the control room. This shall contain the following equipment:

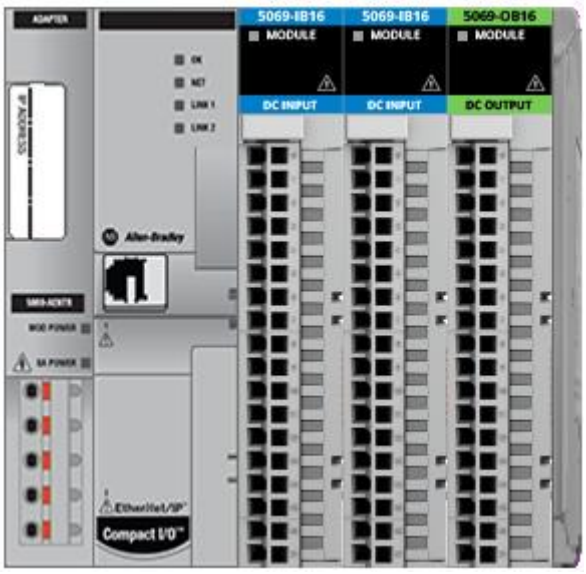


Figure 8-6: Control Room IO Rack

Slot	Part No.	Description
0	5069-AENTR	5069 Compact I/O Ethernet/IP Adapter
1	5069-IB16	5069 Compact I/O 16 Channel 24VDC Sink Input Module
2	5069-IB16	5069 Compact I/O 16 Channel 24VDC Sink Input Module
3	5069-OB16	5069 Compact I/O 16 Channel 24VDC Source Output Module
N/A	5069-ECR	5069 End Cap

Table 8-2: Control Room RIO Rack

Classification: Protected

8.6. Safety Controller

The Pilz Safety Controller shall be installed in the Main Control Panel. This shall be a PILZ PNOZmulti controller. This shall comprise a base unit, an Ethernet/IP module to communicate with the control system and an IO module to cater for the additional IO.

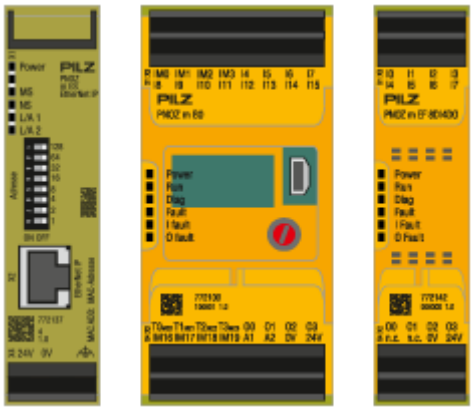


Figure 8-7: Pilz Safety Controller

Slot	Part No.	Description
-1	PNOZ m ES EtherNet/IP	PNOZmulti EtherNet/IP Fieldbus Module
0	PNOZ m B0	PNOZmulti 2 Base Unit
1	PNOZ m EF 8DI4DO	PNOZmulti Expansion Module, 8 Safe Digital Inputs, 4 Safe Semiconductor Outputs

Table 8-3: Pilz Safety Controller

Classification: Protected

8.7. SCADA Equipment

SCADA equipment shall be supplied and installed in the Plant Room and the Control Room. Both SCADA machines shall be identical in terms of operability and screens.

8.7.1. Plant Room and Control Room PCs

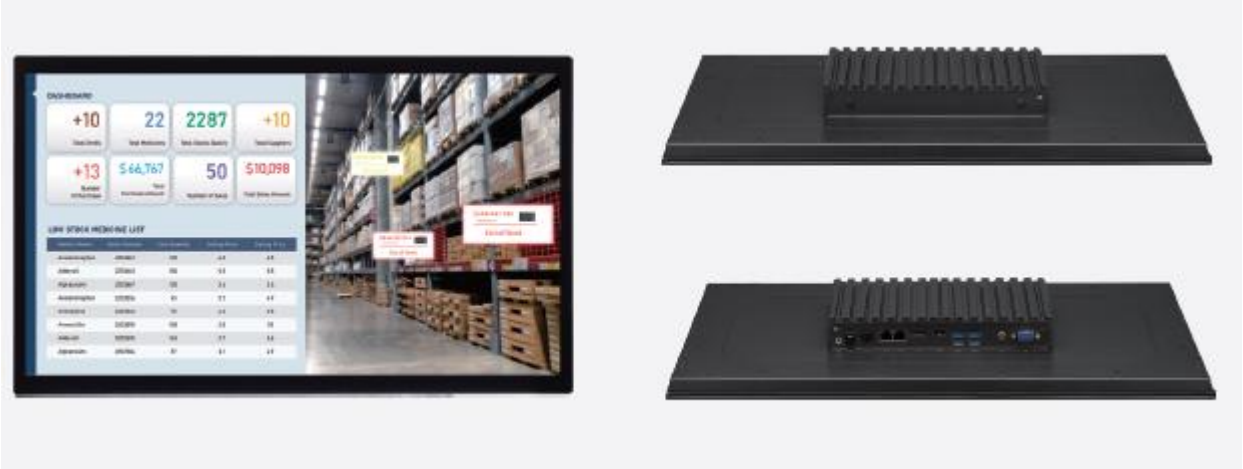


Figure 8-8: SCADA Panel Mount PCs

A 24” Panel PC shall be installed in the Main Control Room Panel located in the Pump Room and the Control Console located in the Control Turret. The Control PCs shall both run identical FactoryTalk View SE applications. From each of the panel PCs, full visualisation of the control system and controls can be accessed. The screens are to be migrated from the existing RSView32 application, so the look, feel and functionality are primarily retained.

Classification: Protected

8.8. Remote Access Equipment

8.8.1. Router

A Cisco C927-4PLTEGB router with a 4G LTE data-enabled SIM card will be installed to provide remote access to the control system via the remote PC. The router shall be installed in the Control Room.

8.8.2. Firewall



Figure 8-9: Siemens SCALANCE SC615 Firewall

Two Siemens SCALANCE SC615 firewalls shall be installed in the Control Console and in the Main Control Panel.

The firewall installed in the Control Console shall provide network protection for the remote access of the control system. The Control Console SCALANCE SC615 shall act as a barrier between the control system and the remote access panel PC and protect against any unauthorised access to the control system.

The firewall installed in the Main Control Panel shall provide network protection for the Pilz PNOZmulti Safety Controller. The Main Control Panel SCALANCE SC615 shall act as a barrier between the control system and the safety controller and protect against any unauthorised access of the safety controller.

8.8.3. Engineering PC

A DIN rail-mounted PC shall be installed in the Control Console to allow remote access to the control system. All the required Rockwell configuration software shall be installed so that the PLC and SCADA code can be accessed and modified if necessary.

Note: The Engineering PC is installed for access to the PLC and SCADA only. The safety controller is protected by Safety Firewall and requires local connection to go online/make modifications.

8.9. Instrumentation

8.9.1. Limit Switches / Proximity Sensors

Existing positional sensors for the Jack and the Blocks are to be retained and reused. Existing limit switches for the position of the bridge shall be replaced with encoders and Ultimate Limit switches.

Description	Sensor	Control Panel
Bridge Open Ultimate Limit Switch	Eaton Moeller LSM-02 Limit Switch	Main Control Panel
Bridge Close Ultimate Limit Switch	Eaton Moeller LSM-02 Limit Switch	Main Control Panel

Table 8-4: Limit Switches / Proximity Sensors

Classification: Protected

8.9.2. Slewing Motor Encoders

Each Slewing Motor will be supplied with an encoder by the motor supplier.

Each Slewing Motor encoder shall be wired directly back to its associated VSD for feedback for the load sharing of the four drives (see section 8.12.4).

8.9.3. Bridge Position Encoders

For the positioning of the bridge, two multi-turn solid shaft encoders shall be installed on the bridge. The details of where the encoders are to be positioned are to be confirmed during detailed design.

When both encoders are healthy, the average of the pair shall be used for the bridge angular position. Should one of the encoders fail, the healthy encoder will then be used and the faulted one disabled for the bridge position.

The shaft size and type are to be confirmed in the detailed design of the project. Each encoder shall be cabled back to a different enclosure to ensure an encoder is available should for example, a fault occur to a network switch. Bridge Encoder 1 is to be cabled back to the Main Control Panel and Bridge Encoder 2 is to be cabled back to the Control Console.

8.10. HPU Pump Motor Starters

The motor starter circuit for the two HPU Pumps shall consist of two contactors and a soft start. As a mitigation against common cause failures of safety functions that require the pumps to stop, the manufacturer of the two contactors shall be different.



Figure 8-10: Allen-Bradley SMC-3 Soft Starter

For the Jacking Pumps, a 45kW Allen-Bradley SMC-3 soft starter shall be installed for each pump. The soft starters shall be switched on via hardwired digital outputs from the control system or when Emergency Operation is enabled, via the HPU Pump start button circuit.

Upstream of each motor are two safety contactors that shall be wired in series. The safety contactors shall be triggered by safe digital outputs via forcibly guided relays from the Pilz Safety Controller. Feedback shall be received from both safety contactors using normally closed auxiliary contacts that are wired back as non-safety digital inputs on the Pilz Safety Controller.

Each of the 45kW hydraulic pumps has a thermistor that shall be wired to a thermistor relay. The contacts of this relay shall be wired back to the PLC system for indication and will be added to the control circuit to stop the pump should the thermistor trip. The thermistor shall be rated to trip at 155°C.

Feedback from the soft starters shall be received as digital inputs. The following digital inputs will be provided.

- HPU Pump *x* Motor Starter Running Full Speed
- HPU Pump *x* Motor Starter Fault

At the Main Control Panel, additional hardwired circuits shall be installed to illuminate the Pump Running and Fault Lamps on the Control Console.

8.11. Circulation Pump DOL

The HPU shall have a circulation pump for the purpose of circulating the hydraulic oil to ensure it stays warm. This shall consist of a single Direct On Line motor of a maximum of 4kW. A contactor will be installed for the purposes of starting the motor when required and to give a “Running” feedback signal to the PLC. The circuit will be protected with a Motor Circuit Breaker. The Circulation Pump DOL shall be controlled by the PLC.

8.12. Slewing Motor VSDs



Figure 8-11: Allen-Bradley PowerFlex 755TS Series VSD

Four off 15kW Heavy Duty PowerFlex 755TS series drives shall be installed in the Main Control Panel for the drives for the 11kW Slewing Motors. The PowerFlex 755TS series comes with an integral brake transistor, embedded dual EtherNet/IP port and embedded IO for integration with the control system. Option cards will be included for encoder feedback, additional IO and Safe Torque Off.

No external EMC filter is required for the drives as each comes with its own integral EMC filter.

The bridge slewing VSDs shall have one common SC line 160A choke installed.

External braking resistors shall be installed for each drive with a duty rating to be determined during detailed design.

A contactor shall be wired between the output of each VSD and its associated motor. The contactor is energised when the motor is enabled for slewing operation using the SCADA or using the override switches when in Emergency Mode.

8.12.1. I/O

The PowerFlex 755TS shall integrate with the control system via both hardwired IO and over comms using the embedded EtherNet/IP. Under normal operation, control signals will be sent to and from the PLC using Ethernet/IP comms.

When the Emergency Operation mode is enabled, this shall bypass the PLC communications and the VSD shall be controlled via the emergency controls on the Control Console, using the following hardwired signals:

- Slewing Motor x Run Forwards
- Slewing Motor x Run Reverse
- Slewing Motor x Slow
- Slewing Motor x Fast

Supplementary information and more detailed status of faults and parameters shall also be sent to the control system via Ethernet/IP comms.

8.12.2. Safe Torque Off

Each PowerFlex drive shall have the 20-750-S3-XT Safe Torque Off (STO) hardwired option module installed. The modules are of performance level PLe and shall meet the required PLe performance levels of some of the Safety Functions stated in section 7.

8.12.3. Thermistor

Each slew motor has a thermistor that shall be wired to thermistor inputs on the corresponding VSD. The thermistors for the Slew motors are rated to warn at 140°C and to trip at 155°C.

8.12.4. Load Sharing

As four slewing motors shall be coupled to the bridge, each motor shall share the mechanical load of slewing the bridge. This shall be realised by utilising the droop feature of the drives. Inherently, induction motors have “slip” where the motor rotor spins at a slower rate that stator’s rotating magnetic fields. This slip produces the motor’s torque, the higher the slip the higher the torque. In a droop configuration the motors slip can be used to prevent one motor from taking a disproportionate amount share of the load. Using droop, the motor’s slip can be controlled by reducing the drive's output frequency in proportion to the load allowing the other motors to take a proportion of the load. The amount of droop can be programmed in the PowerFlex 755TS drives in Hz or % speed.

Load sharing is configured within the logic of the drives and shall operate in both normal operating modes and using the Emergency Controls.

8.12.5. Speed Feedback

For the load sharing of the drives to be accurate and responsive, an encoder shall be wired to each VSD for accurate speed feedback. A 20-750-UFB-1 Universal Feedback module shall be installed in each drive to wire the encoders to the drives.

8.12.6. Auxiliary Power

An auxiliary power module shall be installed to maintain 24VDC power to the drive should there be an incoming supply fault to the drive. This will then ensure visibility of the drive on the control system and SCADA screens should a power fault occur.

8.12.7. Human Interface Module (HIM)

Human Interface Modules for each PowerFlex drive shall be installed on the front of the control panel. From this module, alarms, statuses and parameters of each VSD can be displayed and interrogated. The module can also be used to change drive parameters; however, a passcode shall be required to do so.

8.12.8. Motor Brakes

Each slew motor is equipped with an electromechanical brake. The brake rectifier will be located within the motor terminal box and will receive a 400V 2-phase feed from the Main Control Panel. The slew motor brakes shall be controlled hardwired directly from VSD outputs. These shall all be in parallel, such that if any one VSD is commanded to run, all four slew brakes will be released. This shall operate the same regardless of PLC control or Emergency Operations.

9. Communication Specification

The details of the Communication Network are discussed in the Software Design Specification LINC10089-01-02 A02.

Classification: Protected

10. Control Philosophy

The following section describes the operation and control philosophy of the control system.

A summary of the bridge open sequence is described below:

- Traffic stopped, barriers lowered using the Traffic Control System
- All Barriers Down signal On (from Traffic Control System)
- Operator selects whether to control the sequence using the SCADA levers or using the control levers in the Control Room (SCADA button)
- HPU Pump is started by pressing the Start Pump button on the SCADA
- Jack Lever pushed to the “Jacks Extend” position
- Jacks extend and lift the bridge up
- Slip Blocks Lever moved to the “Blocks Off” position
- Slip Blocks retract to the retracted position
- Jacks Lever moved to the “Jacks Home” position
- Jacks retract and lower the bridge into a free-wheel state
- Bridge Lever pushed to the “Bridge Open” position
- Bridge begins to move at creep speed and then ramps up to full speed
- Once the Bridge Open slowdown position is reached, the bridge will ramp down to slow down speed
- Once the Bride Open position is reached, the bridge will ramp down to a stop

To close the bridge the following sequence is performed:

- Manual Foot Bolt pulled up to extend the Locking Pins
- Bridge Lever pulled to the “Bridge Close” position
- Bridge begins to move at creep speed and then ramps up to full speed
- Once the Bridge Close slowdown position is reached, the bridge will ramp down to slow down speed
- Once the Bridge Closed position is reached, the bridge will ramp down to a stop
- Jacks Lever moved to the “Jacks Extend” position
- Jacks extend and lift the bridge up
- Blocks Lever pushed to the “Blocks On” position
- Slip Blocks extend to the extended position
- Jacks Lever moved to the “Jacks Home” position
- Jacks retract and lower the bridge onto the Slip Blocks
- HPU Pump stopped by pressing the Stop Pump button on the SCADA
- Traffic can be released by pressing and holding the Raise All Barriers button on the Traffic Control System
- Manual Foot Bolt pressed down to retract the Locking Pins

10.1. Control Mode

When operating the bridge in normal conditions, the bridge can be operated in one of three modes:

SCADA Control: When SCADA Control is selected, the bridge is operated by clicking the lever graphics on the Levers screen. The use of the physical control levers shall be inhibited.

Manual Control: When Manual Control is selected, the bridge is operated by pushing and pulling the physical control levers in the Control Room.

Emergency Operation: When the Emergency Operation key is inserted in the Control Console (in the scenario of PLC equipment failure) the control system is in Emergency Operation mode. The bridge is then driven by hardwired controls on the Control Console and will bypass the interlocks stated in the proceeding sub-sections. See section 10.9 for more details.

10.2. HPU Pumps

There are two hydraulic power unit pumps that provide hydraulic pressure to actuate the Jacks and Slip Blocks. The HPU Pumps shall be in a duty/standby configuration with the duty pump running and providing power to actuate the Jacks/Slip Blocks, and the standby pump offline available to take over in the event of a fault

The HPU Pump must be started before the Jacks/Slip Blocks can be operated. The HPU Pump can only run on load when the bridge slewing motors are not operating. They are permitted to remain running offload while slewing the bridge.

The HPU Pumps are available for automatic control when the following interlocks are present:

- Control System not in Emergency Operation
- Safety Functions SF1-SF3
- Isolator in the On position
- Soft Start Healthy
- Thermistor Relay Healthy
- HPU Pump Ball Valve Open
- No Failed to Start Alarm
- No Failed to Achieve Pressure Alarm
- No Pump High Pressure Alarm
- No HiHi HPU Tank Temperature Alarm
- No LoLo HPU Tank Level Alarm

Should any of the above become unhealthy while running, the pump will stop, and the appropriate alarm shall be triggered.

The duty HPU Pump shall be started by pressing the Start Pump button on the SCADA when in SCADA mode. The duty HPU Pump is started automatically when operating either the Jack or Slip Block levers when in Manual Control. The duty is automatically assigned to the pump with the lowest run time.

10.2.1. Priming Sequence

Before jacking, the control sequence shall prime the Jack and Slip Block pipework ready for the span end movements. The sequence is as follows:

- Run the duty HPU Pump
- After a delay, energise the Low Pressure Load Valve
- Energise all Jack and Slip Block cylinder Bypass Valves
- Energise all Jack Retract solenoid valves for a period (duration set using the SCADA)
- Energise all Slip Block Extend solenoid valves for a period (duration set using the SCADA)
- De-energise all Jack and Slip Block cylinder Bypass Valves
- De-energise the Low Pressure Load Valve

After the above sequence, the hydraulics are primed and ready to operate the Jack/Slip Blocks.

10.2.2. Fault Duty Changeover

In usual operating scenarios, the Jacks/Slip Blocks are powered hydraulically by the duty HPU pump running. If a fault occurs to the duty pump during operation, the Jacking/Slip Block action shall stop by de-energising the Retract/Extend valves and the Load Valve. The duty pump shall then stop. After a delay, the control system shall then start the standby pump, and the Jacking/Slip Block action can then be resumed.

10.2.3. Alarms

HPU Pump *x* Failed to Start

Should a command be sent to the pump and the running feedback isn't received, a latching "Failed to Start" alarm shall be triggered. Another attempt can be made once the alarm is reset. Only 10 restarts per hour are permitted for each pump. After this, the pump is inhibited from operation until restarts become available. Once an hour has passed from the first attempt a start shall then become free.

HPU Pump *x* Soft Starter Fault

Should the soft starter have a fault, a latching "Soft Starter Fault" alarm shall be triggered, and the pump shall trip. The pump will be unable to start until the fault is cleared on the soft starter and the alarm is reset using the SCADA.

HPU Pump *x* Isolated

When the isolator is in the off position a latching "Isolated" alarm shall be triggered. The alarm can be cleared once the isolator is returned to the on position and the alarm is reset using the SCADA.

HPU Pump *x* Oil Filter Blocked

Should the oil filter be blocked, a latched "Oil Filter Blocked" alarm shall be triggered. The alarm can be cleared once the filter is unblocked, and the alarm is reset using the SCADA.

HPU Pump *x* Ball Valve Closed

Should the Ball valve be in the closed position, a latched “Ball Valve Closed” alarm shall be triggered. The alarm can be cleared once the ball valve is in the open position and the alarm is cleared using the reset using the SCADA.

HPU Pump *x* Failed to Achieve Pressure

Should the pump fail to achieve pressure within the allotted time while running, a latched “Failed to Achieve Pressure” alarm shall be generated. The alarm can be reset by using the SCADA.

HPU Pump *x* High Pressure

Should the pump pressure go above the High Pressure setpoint, a latched “High Pressure” alarm shall be generated. The alarm can be reset by using the SCADA.

HPU Pump *x* Thermistor Relay

Should the thermistor relay for the pump trip, a latched “Thermistor Relay Tripped” alarm shall be triggered and the pump shall trip. The pump will be unable to start until the temperature has lowered to a healthy level and the thermistor relay has reset and the alarm is reset using the SCADA.

10.3. HPU Circulation Pump

The HPU Circulation Pump shall recirculate oil through the system periodically throughout the day, when the bridge is not in operation. The run time of the HPU Circulation Pump can be changed via setpoint using the SCADA. The HPU Circulation Pump is available for operation when the following interlocks are healthy:

- HPU Circulation Pump Isolator Healthy
- HPU Circulation Circuit Protection Healthy
- No Failed to Start Alarm
- No HiHi HPU Tank Temperature Alarm
- No LoLo HPU Tank Level Alarm
- Bridge is not in operation

10.4. Jacks

The Jacks shall raise and lower the bridge for the open and close cycles. There are two jacks at each end of the bridge. The Jacks are extended to raise the bridge and retracted to lower the bridge. Providing the necessary interlocking is healthy, the Jacks are either operated from the SCADA or the control levers depending on which control mode is applied.

The Jacks are available for control when the following interlocks are present:

- Control System not in Emergency Operation
- Safety Functions SF1-SF3 Healthy
- Duty HPU Pump Running

- No Jack Alarms
- Bridge in the Closed position

10.4.1. Lower

The Jacks are lowered by either clicking the on-screen Jacks lever into the Jacks Home position when in SCADA Control mode, or by pulling the Jacks lever into the Home position when in Manual Control mode.

Once the command is set, a Retract DO signal is sent from the control system to the Jacks Retract valves. The High Pressure Load Valve DO will also be energised to allow hydraulic oil to flow at the correct pressure to the Jacks.

The control system will allow a short period (configurable in SCADA) of time for the Jacks to leave their extended positions. Should a Jack fail to leave its extended position within time, a Failed to Leave Extended alarm shall be triggered, and the Jacks will be stopped.

The Jacks shall continue to retract until the Jacks have reached their home positions. Once each Jack has reached its home position, the Retract DO and High Pressure Load Valve DO signals shall be switched off.

10.4.2. Raise

The Jacks are raised by either clicking the Jacks lever into the on-screen Jacks Extend position when in SCADA Control mode or pushing the Jacks lever into the Extend position when in Manual Control mode.

Once the command is set, an Extend DO signal is sent from the control system to the Jacks Extend valves. The High Pressure Load Valve DO will also be energised to allow hydraulic oil to flow at the correct pressure to the Jacks.

The control system will allow a period (configurable in the SCADA) of time for the Jacks to leave their retracted positions. Should a Jack fail to leave its retracted position within time, a Failed to Leave Retracted alarm shall be triggered, and the Jack actuator will be stopped.

The Jacks shall continue to extend until the Jacks have reached their extended positions. Once each Jack has reached its extended position, the Extend DO and High Pressure Load Valve DO signals shall be switched off.

10.4.3. Alarms

***x* Jack Failed to Leave Home Position**

Should a Jack not leave the retracted position when being commanded to extend, a latched “Failed to Leave Home” alarm shall be triggered and inhibit the movement of the Jacks until the alarm is cleared. Another attempt to extend the Jacks can be made by resetting the alarm using the SCADA.

***x* Jack Failed to Reach Home Position**

Should a Jack not achieve the retracted position when being commanded to retract, a latched “Failed to Reach Home” alarm shall be triggered and inhibit the movement of the Jacks until the alarm is cleared. Another attempt to retract the Jacks can be made by resetting the alarm using the SCADA.

***x* Jack Failed to Leave Extended Position**

Should a Jack not leave the extended position when being commanded to retract, a latched “Failed to Leave Extended” alarm shall be triggered and inhibit the movement of the Jacks until the alarm is cleared. Another attempt to retract the Jacks can be made by resetting the alarm using the SCADA.

***x* Jack Failed to Reach Extended Position**

Should a Jack not achieve the extended position when being commanded to extend, a latched “Failed to Reach Extended” alarm shall be triggered and inhibit the movement of the Jacks until the alarm is cleared. Another attempt to extend the Jacks can be made by resetting the alarm using the SCADA.

***x* Jack Home Limit Fault**

Should there be a discrepancy between Home limit switches for a Jack (One limit switch on, the other limit switch off), a latched “Home Limit Fault” alarm shall be triggered and inhibit the movement of the Jacks until the alarm is cleared. The alarm can be cleared once the Jack limits are out of the illegal state, and the alarm is reset using the SCADA.

***x* Jack Extend Limit Fault**

Should there be a discrepancy between the Extend limit switches for a Jack (One limit switch on, the other limit switch off), a latched “Home Limit Fault” alarm shall be triggered and inhibit the movement of the Jacks until the alarm is cleared. The alarm can be cleared once the Jack limits are out of the illegal state, and the alarm is reset using the SCADA.

10.5. Slip Blocks

The Slip Blocks shall retract and extend while the bridge is raised in conventional operation. There are three Slip Blocks at each end of the bridge actuated by two cylinders. Providing the necessary interlocking is healthy, the Slip Blocks are either operated from the SCADA or the physical control levers depending on which control mode is applied.

The Slip Blocks are available for control when the following are present:

- Safety Functions SF1-SF3
- Bridge in the Closed position
- Bridge Raised
- No Slip Block alarms

10.5.1. Retract

The Slip Blocks are retracted by either clicking the on-screen Blocks Lever into the Blocks Off position when in SCADA Control mode or pulling the Blocks Lever into the Blocks Off position when in Manual Control mode.

Once the command is set, a Retract DO signal is sent from the control system to the Slip Block Retract valves. The Low Pressure Load Valve DO will also be energised to allow hydraulic oil to flow at the correct pressure to the Jacks.

The control system will allow a short period (configurable in SCADA) of time for the Slip Blocks to leave their extended positions. Should a Slip Block fail to leave its extended position within time, a Failed to Leave Extended alarm shall be triggered, and the Slip Block actuator will be stopped.

The Slip Blocks shall continue to retract until the Slip Blocks have reached their home positions. Once each Slip Block has reached its home position, the Retract DO signal and Low Pressure Load Valve DO signal shall be switched off.

10.5.2. Extend

The Slip Blocks are extended by either clicking the on-screen Blocks Lever into the Blocks On position when in SCADA Control mode or pushing the Blocks Lever into the Blocks On position when in Manual Control mode.

Once the command is set, a Extend DO signal is sent from the control system to the Slip Block Retract valves. The Low Pressure Load Valve DO will also be energised to allow hydraulic oil to flow at the correct pressure to the Jacks.

The control system will allow a period (configurable in the SCADA) of time for the Slip Blocks to leave their retracted positions. Should a Slip Block fail to leave its retracted position within time, a Failed to Leave Retracted alarm shall be triggered, and the Slip Block actuator will be stopped.

The Slip Blocks shall continue to extend until the Slip Blocks have reached their extended positions. Once each Slip Block has reached its extended position, the Extend DO signal shall and Low Pressure Load Valve DO signal shall be switched off.

10.5.3. Alarms

***x* Slip Block Failed to Leave Home Position**

Should a Slip Block not leave the retracted position when being commanded to extend, a latched “Failed to Leave Home” alarm shall be triggered and inhibit the movement of the Slip Blocks until the alarm is cleared. Another attempt to extend the Slip Blocks can be made by resetting the alarm using the SCADA.

***x* Slip Block Failed to Reach Home Position**

Should a Slip Block not achieve the retracted position when being commanded to retract, a latched “Failed to Reach Home” alarm shall be triggered and inhibit the movement of the Slip Blocks until the alarm is cleared. Another attempt to retract the Slip Blocks can be made by resetting the alarm using the SCADA.

***x* Slip Block Failed to Leave Extended Position**

Should a Slip Block not leave the extended position when being commanded to retract, a latched “Failed to Leave Extended” alarm shall be triggered and inhibit the movement of the Slip Blocks until the alarm is cleared. Another attempt to retract the Slip Blocks can be made by resetting the alarm using the SCADA.

***x* Slip Block Failed to Reach Extended Position**

Should a Slip Block not achieve the extended position when being commanded to extend, a latched “Failed to Reach Extended” alarm shall be triggered and inhibit the movement of the Slip Blocks until the alarm is cleared. Another attempt to extend the Slip Blocks can be made by resetting the alarm using the SCADA.

***x* Slip Block Home Limit Fault**

Should there be a discrepancy between Home limit switches for a Slip Block (One limit switch on, the other limit switch off), a latched “Home Limit Fault” alarm shall be triggered and inhibit the movement of the Slip Blocks until the alarm is cleared. The alarm can be cleared once the Slip Block Home limit switches are out of the illegal state, and the alarm is reset using the SCADA.

***x* Slip Block Extend Limit Fault**

Should there be a discrepancy between the Extend limit switches for a Slip Block (One limit switch on, the other limit switch off), a latched “Extend Limit Fault” alarm shall be triggered and inhibit the movement of the Slip Blocks until the alarm is cleared. The alarm can be cleared once the Slip Block Extend limits are out of the illegal state, and the alarm is reset using the SCADA.

10.6. Locking Pins

The Locking Pins are operated manually by using the foot pedal in the Control Room. The control system does not control or receive any status feedback from the Locking Pins.

10.7. Slewing

Four Slewing Motors control the bridge swing operating in tandem to slew the bridge. In normal operating conditions, all four motors shall run simultaneously. Should a fault occur to one or more of the motors, the bridge is still capable of swinging with two motors (albeit slower than with running four).

A Slewing Motor is available to run when the following interlocks are present:

- Safety Functions SF1-SF5 Healthy
- Bridge Lowered
- No Jack Alarms
- Slip Blocks Retracted
- No Slip Block Alarms
- Clutch Engaged

10.7.1. Duty Changeover

In normal operating conditions, all four Slewing Motors shall run together simultaneously. Each motor is rated so the bridge can be slewed using just two Slewing Motors. If a Slewing Motor fails while the bridge is being slewed, the following sequence shall happen:

- Fault of affected Slewing Motor triggered
- Slewing Motors ramp down to a stop
- Faulty motor disabled from the control using the SCADA (or override switch when in Emergency Mode)
- Slewing is resumed from the Control Console with the remaining Slewing Motors.
- Once the faulted bridge motor is healthy it shall only return to service once the bridge has been closed.

10.7.2. Bridge Open

The bridge is slewed open by either clicking the on-screen Slew Lever into the Open Bridge position when in SCADA Control mode or pulling the physical Slew Lever into the Open Bridge position when in Manual Control mode.

Once the command is set, a Reverse DO signal is sent from the control system to each Slew Bridge Motor VSD, and the Slew Speed is set to creep speed and sent over Ethernet/IP comms to each Slew Bridge Motor VSD. The bridge position encoders are monitored for the bridge position and an average position is taken from the two encoders when both are healthy. The control system will allow a short period (configurable in SCADA) of time for the bridge to leave the closed position. Should the bridge not leave the closed position within that time, a Failed to Leave Closed alarm shall be triggered.

The bridge shall continue to slew at creep speed until the Close Slowdown has been passed. Once passed, the Slew Bridge Motor speeds shall ramp up the bridge speed to full speed by increasing the Ethernet/IP comms

speed command to each Slew Bridge Motor VSD. The control system will allow a period of time for the bridge to leave the Closed Slowdown position. Should the bridge not leave the Closed Slowdown position in time, a Failed to Leave Closed Slowdown alarm shall be triggered.

The bridge shall continue to slew at full speed until the Open Slowdown position is reached. Once reached, all Slew Bridge Motor speeds shall ramp down to creep speed by decreasing the Ethernet/IP comms speed command to each Slew Bridge Motor VSD. The control system will allow a period for the bridge to reach the Open Slowdown position. Should the bridge not reach the Open Slowdown position in time, a Failed to Reach Open Slowdown position alarm shall be triggered.

When the bridge reaches the Bridge Open position, all Slew Bridge Motor VSDs shall ramp down to a stop. The control system will allow a period of time for the bridge to reach the Open position. Should the bridge not reach the Open position in time, a Failed to Reach Open position alarm shall be triggered, and the Bridge Slew Motors will be stopped.

10.7.3. Bridge Close

The Bridge is slewed closed by either clicking the on-screen Slew Lever into the Close Bridge position when in SCADA Control mode or pushing the Slew Lever into the Close Bridge position when in Manual Control mode.

Once the command is set, a Forward DO signal is sent from the control system to each Slew Bridge Motor VSD, and the Slew Speed is set to creep speed and sent via Ethernet/IP comms to each Slew Bridge Motor VSD. The control system will allow a short period (configurable in SCADA) of time for the bridge to leave the open position. Should the bridge not leave the open position in time, a Failed to Leave Open alarm shall be triggered.

The bridge shall continue to slew at creep speed until the Open Slowdown has been passed. Once passed, all Slew Bridge Motor speeds shall ramp up to full speed by increasing the Ethernet/IP comms speed command to each Slew Bridge Motor VSD. The control system will allow a period of time for the bridge to leave the Open Slowdown position. Should the bridge not leave the Open Slowdown position in time, a Failed to Leave Open Slowdown alarm shall be triggered.

The bridge shall continue to slew at full speed until the Close Slowdown position is reached. Once reached, all Slew Bridge Motor speeds shall ramp down to creep speed by decreasing the Ethernet/IP comms speed command to each Slew Bridge Motor VSD. The control system will allow a period for the bridge to reach the Close Slowdown position. Should the bridge not reach the Close Slowdown position in time, a Failed to Reach Close Slowdown position alarm shall be triggered.

When the bridge reaches the Bridge Closed position, the Slew Bridge Motor VSDs shall ramp down to a stop. The control system will allow a period of time for the bridge to reach the Closed position. Should the bridge not reach the Closed position in time, a Failed to Reach Closed position alarm shall be triggered, and the Bridge Slew Motors will be stopped.

10.7.4. Alarms

Slew Motor *x* Failed to Start

Each Slew Motor shall have a Failed to Start alarm. When a start command is sent to the Slew Motor VSD, the control system shall give a window of time for a running signal to be received back from the drive. If the Slew Motor fails to start in this period, a latched "Failed to Start" alarm shall be triggered, and the Slew Motor shall be inhibited from being started. Another attempt can be made to start the Slew Motor by resetting the alarm using the SCADA.

Slew Motor *x* VSD Fault

Each Slew Motor shall have a VSD Fault alarm. If a fault occurs on the Slew Motor VSD, a latched "VSD Fault" alarm shall be triggered, and the Slew Motor shall be inhibited from being started. Once the VSD fault has been rectified, the alarm can be cleared by resetting the alarm using the SCADA.

Bridge Failed to Leave Closed

A "Failed to Leave Closed" alarm shall be triggered should the bridge not leave the Closed position when commanded to open. The alarm is automatically reset once the bridge is stopped.

Bridge Failed to Leave Closed Slowdown

A "Failed to Leave Closed Slowdown" alarm shall be triggered should the bridge not leave the Closed Slowdown position when commanded to open. The alarm is automatically reset once the bridge is stopped.

Bridge Failed to Reach Open Slowdown

A "Failed to Reach Open Slowdown" alarm shall be triggered should the bridge fail to reach the Open Slowdown position when commanded to open. The alarm is automatically reset once the bridge is stopped.

Bridge Failed to Reach Open

A latched "Failed to Reach Open" alarm shall be triggered should the bridge fail to reach the Open position when commanded to close. This will inhibit the movement of the bridge until the alarm is cleared. Another attempt to open the bridge can be made by resetting the alarm using the SCADA.

Bridge Failed to Leave Open

A "Failed to Leave Open" alarm shall be triggered should the bridge not leave the Open position when commanded to close. The alarm is automatically reset once the bridge is stopped.

Bridge Failed to Leave Open Slowdown

A "Failed to Leave Open Slowdown" alarm shall be triggered should the bridge not leave the Open Slowdown position when commanded to close. The alarm is automatically reset once the bridge is stopped.

Classification: Protected

Bridge Failed to Reach Close Slowdown

A “Failed to Reach Close Slowdown” alarm shall be triggered should the bridge fail to reach the Close Slowdown position when commanded to close. The alarm is automatically reset once the bridge is stopped.

Bridge Failed to Reach Closed

A latched “Failed to Reach Closed” alarm shall be triggered should the bridge fail to reach the Closed position when commanded to close. This will inhibit the movement of the bridge until the alarm is cleared. Another attempt to close the bridge can be made by resetting the alarm using the SCADA.

10.8. Bridge Status Lights and Marine Traffic Control Lights

10.8.1. Bridge Status Lights

The Bridge Status Lights system shall be controlled by the control system and the status of the lights are received and displayed on the SCADA.

10.8.1.1. Red Light

The Red Light is for notifying vessels that the bridge is closing, opening or a fault is present on the bridge.

The Red Light is illuminated when the following interlocks are present:

- Bridge Close Command is on and the Bridge is not at the closed slowdown position

Or:

- Bridge Open Command is on

Or:

- Bridge Not Healthy

10.8.1.2. Amber Light

The Amber Light is for notifying vessels that the bridge is to start of the opening sequence or when the bridge is nearing the close position.

The Amber Light is illuminated when the following interlocks are present:

- All Traffic Barriers Down and the bridge isn’t opening or closing

Or:

- Bridge Close Command is On and is between closed slowdown and closed position

10.8.1.3. Green Light

The Green Light is for notifying vessels that the bridge is open.

The Green Light is illuminated when the following interlocks are present:

- Bridge Open

10.8.1.4. Red Bridge Air Draught Triangle Warning Light

The Red Bridge Air Draught Triangle Warning Light is used to notify the vessel is clear to pass when the lamp is extinguished.

The Red Bridge Air Draught Triangle Warning Light is extinguished when the following interlocks are present:

- Bridge Open

10.8.2. Marine Traffic Control Lights

These lights are used for controlling approaching vessels and are controlled manually from the Control Console. These lights are to be hardwired only with no control from the control system.

10.8.2.1. Red/Red

When the selector switch is in this position both Marine Traffic Control Lights are red, indicating that marine craft are not able to pass through the bridge.

10.8.2.2. Red/Green

When the selector switch is in this position, it indicates to marine traffic at the Wisbech side that the bridge is open, and it is safe for them to pass through. Marine traffic approaching from the South Bridge side of the bridge will be shown a red light indicating that they are not able to pass through the bridge.

10.8.2.3. Green/Red

When the selector switch is in this position, the indication is the reverse of what was indicated in the previous section, allowing marine traffic from the South Bridge side to pass through the open bridge. Marine traffic approaching from the Wisbech side of the bridge will be shown a red light indicating that they are not able to pass through the bridge.

Classification: Protected

10.9. Emergency Control

In the scenario of a failure of some or all of the PLC or SCADA system, the emergency controls can be used on the Control Console. In this mode, all interlocking and safety functions are bypassed, and the bridge is purely driven by the hardwired controls, and it will be up to the operator to follow procedure to ensure safe and correct operations.

NOTE: This mode is to be used in emergency scenarios ONLY. Lincolnshire Council operatives are fully responsible for the safety of others as well as the condition of the bridge when using the Emergency Controls.

Emergency Operations will include the following hardwired controls and indications:

- Emergency Operations Enable key switch (Fortress)
    - This is a trapped key, which must be taken out of a “Normal Operations” key switch on the Control Console and inserted into this key switch.
- Emergency Operation Authorisation key switch (Fortress)
    - This is a trapped key, which must be taken out of a padlocked lockbox in the control room as part of a procedural control and inserted into this key switch.
- “Emergency Stop” red latching pushbutton (common to Normal and Emergency Controls)
- “Emergency Stop Healthy/Reset” white illuminated pushbutton (common to Normal and Emergency Controls)
- “Lamp Test” black pushbutton (common to Normal and Emergency Controls)
- “Emergency Controls In Use” red lamp
- “Slew Drive 1 Healthy/Reset” white illuminated pushbutton
- “Slew Drive 2 Healthy/Reset” white illuminated pushbutton
- “Slew Drive 3 Healthy/Reset” white illuminated pushbutton
- “Slew Drive 4 Healthy/Reset” white illuminated pushbutton
- “Slew Drive 1 Normal/Override” stay-put selector switch
- “Slew Drive 2 Normal/Override” stay-put selector switch
- “Slew Drive 3 Normal/Override” stay-put selector switch
- “Slew Drive 4 Normal/Override” stay-put selector switch
- “HPU Pump 1/2 Select” stay-put selector switch
- “Start HPU Pump” green pushbutton
- “Stop HPU Pump” black pushbutton
- “HPU Pump 1 Running” green lamp
- “HPU Pump 2 Running” green lamp
- “HPU Pump 1 Healthy/Reset” white illuminated pushbutton
- “HPU Pump 2 Healthy/Reset” white illuminated pushbutton
- “Jacks Extend/N/Home” spring-return-to-centre selector switch
- “Blocks Off/N/On” spring-return-to-centre selector switch
- “Bridge Open/N/Close” spring-return-to-centre selector switch
- “Bridge Speed Creep/Slow/Fast” stay-put selector switch
- “River Traffic Lights Off/On” stay-put selector switch
- “River Traffic Lights G,R / R,R / R,G” stay-put selector switch
- “Wisbech Side” red and green lamps
- “S. Bridge Side” red and green lamps

Classification: Protected

- "Air Draught Warning Triangle" red lamp
- Navigation Lights "Red Status Light" selector switch
- Navigation Lights "Amber Status Light" selector switch
- Navigation Lights "Green Status Light" selector switch

10.9.1. Enabling/Disabling

The Emergency Operations are enabled from the Control Console. The emergency control shall only be enabled when the Emergency Operations Enable key and Emergency Operation Authorisation key are inserted in the Control Console.

The Emergency Operations Enable key switch is a trapped key and must be taken out of a "Normal Operations" key switch on the Control Console and inserted into this key switch and turned to the "On" position. The operator will need to obtain authorisation for the Emergency Operation Authorisation key. This is a trapped key which must be taken out of a glass fronted case in the control room as part of a procedural control and inserted into this key switch.

When the Emergency Operations Enable key and Emergency Operation Authorisation key are inserted, all outputs from the PLC Control system are inhibited and the Emergency Control lamp is illuminated. The user is then able to control the bridge manually.

10.9.2. Safety Systems

The only Safety Function in effect when using the emergency controls is the Emergency Stop. All other safety functions are not applicable when in Emergency Control mode.

The Emergency Stop function shall be designed to be usable by both the main PLC system and the Emergency Operations. This shall be achieved as follows:

- All Emergency Stops are series-connected in a dual-channel chain, into the Pilz Safety Controller in the main panel.
    - Note – auxiliary contacts of each Emergency Stop will be wired into PLC standard inputs to allow visibility of which Emergency Stop is pressed in normal operation.
- The Emergency Operations Enable key switch and Emergency Operation Authorisation key switch will be connected to the Pilz Safety Controller.
    - Outputs of the Pilz Safety Controller will energise a set of contactors for each piece of equipment. 2x Jacks HPU pumps safety contactors (instant), 2x Slew Motors Safety Relays for STO (time-delay, triggers the bridge to ramp down to a controlled stop and then trigger STO).
    - Safety Relay will be manually reset via the Emergency Stop Healthy/Reset illuminated pushbutton on the Control Console, with feedback monitoring from NC contacts of all outputs.
- PLd will be achievable due to all equipment being dual channel with high diagnostic coverage.
- With this methodology, any failure of the PLC system does not affect the availability of the Emergency Operations.

10.9.3. Equipment Controls

Each pilot device will be wired back to the main panel as part of an overall multicore cable, with relays for commands being located in the main panel. No control relays for Emergency Operations will be included in the Control Console itself.

The supplies for all controls will be switched through an output contact of the Pilz Safety Controller, such that if not confirmed to be in Emergency Operations, there will be no voltage available to the Emergency Operations controls.

Each “command”, such as Jacks Extend, will have an associated relay, with electrical interlocking between relays of opposite commands, such as between Jacks Extend and Jacks Home. These command relays will then, in parallel with the output relays from the PLC system, go on to activate the relevant output device, whether that is a valve solenoid, or another relay to split commands to several actuators or VSD’s.

For the Jacks Extend and Jacks Home function, if either of these command relays are energised then a third command relay shall also be energised, for the “High Pressure Load Valve”.

For the Slip Blocks Extend and Slip Block Home function, if either of these command relays are energised then a third command relay shall also be energised, for the “Low Pressure Load Valve”.

All the movement functions - Jacks Extend and Home, Slip Blocks Off and On, and Bridge Open and Close, will be hold-to-run functions. Releasing the control will return the selector switch to the centre position and stop the equipment movement.

The slew drive fault signals shall all be hardwired to each other such that if one slew drive faults, all four slew drives are inhibited so as to prevent one motor from being dragged around by the others. If a drive fault cannot be reset, due to a drive or motor fault, the slew motor in question must be removed from control using the corresponding Slew Motor Override switch on the Control Console and the slewing resumed. The faulty motor shall then freewheel with the bridge.

For the Bridge Status Lights, when operating under Emergency Operations, selector switches for red, amber and green lights are present so as to allow these indications to be manually switched on as appropriate to ensure the correct lights are given to marine traffic to indicate the status of the bridge.

10.9.4. HPU Pumps

The HPU Pump selected for operation is chosen by switching the HPU Pump 1/2 selector switch in either the 1 or 2 position. The selected HPU Pump can be started by pressing the HPU Pump Start button on the Control Console. The selected HPU Pump shall be indicated as running by its own Running Lamp being illuminated.

10.9.5. Jack Control

The Jacks are controlled using the Jack spring-return switch on the Control Console. This shall control all four jacks simultaneously. To control the Jacks, the HPU Pumps are required to be started and loaded as per sub-section 10.9.4. When the Jack Direction switch is rotated and held in the left-hand position to the “Retract” position, all Jacks shall retract. When the Jack Direction switch is rotated and held in the right-hand position to the “Extend” position, all Jacks shall extend. All Jacks are confirmed as retracted or extended by the Jack position indicator

lamps on the Control Console. The High Pressure Load valve shall be energised when a Retract or Extend command is given.

10.9.6. Slip Block Control

The Slip Blocks are controlled using the Slip Block spring-return switch on the Control Console. This shall control all six Slip Blocks simultaneously. When the Slip Block Direction switch is rotated and held in the left-hand position to the “Retract” position, all Slip Blocks shall retract. When the Slip Block direction switch is rotated and held in the right-hand position to the “Extend” position, all Slip Blocks shall extend. All Slip Blocks are confirmed as retracted or extended by the Slip Block position indicator lamps on the Control Console. The Low Pressure Load valve shall be energised when a Retract or Extend command is given.

10.9.7. Slewing Control

The Slewing Motors are controlled using the Bridge Slew spring-return switch on the Control Console. This shall control all Bridge Motors simultaneously. To control the Slewing Motors, the operator needs to ensure that all Slip Blocks and Jacks are retracted by checking the indicator lamps on the Control Console and check that the foot-operated Locking Pin is released. The operator will need to select the speed of travel using the Bridge Speed Creep/Slow/Fast selector switch. When the Bridge Slew Direction switch is rotated and held in the left-hand position to the “Open” position, all Bridge Slew Motor VSDs shall be commanded to run at the selected slew speed. When the Bridge Slew Direction switch is rotated and held in the right-hand position to the “Close” position, all Bridge Slewing Motor VSDs shall be commanded to run at the selected slew speed in the reverse direction. The bridge is confirmed as Open or Closed by the Bridge position indicator lamps on the Control Console.

10.9.8. Operation Procedure

The procedure to operate the bridge using Emergency Operations is generally as follows:

10.9.8.1. Opening the bridge:

1. Stop road traffic and lower traffic barriers using the existing separate Traffic Control Console.
2. Turn off and remove the Emergency Operations Enable key from the Normal Operations key switch on the Control Console.
3. Insert the Emergency Operations Enable key into the Emergency Operation key switch and turn it On.
4. Obtain authorisation for the Emergency Operations Authorisation key, take it from the lockbox, insert it into the key switch and turn it On.
5. Press the Emergency Stop Healthy/Reset button, which should then illuminate.
6. Press the Start Pumps button to run the selected HPU pump.
7. Turn and hold the Jacks Extend/N/Home selector switch to the Extend position, until the jacks are fully extended.
8. Turn and hold the Blocks Off/N/On selector switch to the Off position, until the blocks are fully retracted.
9. Turn and hold the Jacks Extend/N/Home selector switch to the Home position, until the jacks are fully retracted.
10. Turn and hold the Bridge Open/N/Close selector switch to the Open position, to swing the bridge open. Use the Bridge Speed Creep/Slow/Fast selector switch to control speed during travel.
11. Operate the navigation light controls as required to direct marine traffic.

10.9.8.2. Closing the bridge:

1. Operate the navigation light controls as required to stop marine traffic.
2. Operate the foot-switch to extend the nose pin.
3. Turn and hold the Bridge Open/N/Close selector switch to the Close position, to swing the bridge closed. Use the Bridge Speed Creep/Slow/Fast selector switch to control speed during travel.
4. Turn and hold the Jacks Extend/N/Home selector switch to the Extend position, until the jacks are fully extended.
5. Turn and hold the Blocks Off/N/On selector switch to the On position, until the blocks are fully inserted (confirm using indications on the Control Console, as well as visually)
6. Turn and hold the Jacks Extend/N/Home selector switch to the Home position, until the jacks are fully retracted.
7. Press the Stop Pump button to stop the selected HPU pump.
8. Turn off and remove the Emergency Operations key from the Emergency Operations Enable key switch and return it to the Normal Operations key switch.
9. Open traffic barriers and allow road traffic using the existing separate Traffic Control Console.
10. Operate the foot-switch to retract the nose pin.
11. Turn off and remove the Emergency Operations Authorisation key and return it to the lockbox.

Classification: Protected

11. Visualisation

For operation and an overview of the control system, a SCADA system is provided. One shall be installed on the Control Room console and the other installed on the Main Control Panel. Both applications shall be identical to one another.

Both SCADA machines shall have identical FTView SE Local Station applications installed. All controls and pages shall be accessed on both machines.

11.1. Users

User levels with different user privileges shall be installed on the SCADA system. These are summarised below:

Guest: This is a read-only login and will be the default user group when the SCADA is booted up. In this user group, the user shall only be able to navigate to and from screens. The user shall not be able to operate the bridge or set any setpoints.

Operator: A common user that will enable the operation of the bridge using the Control Levers page and be able to reset any alarms and instrumentation faults on the Reset pages. The user shall not be able to change any of the operational setpoints.

Engineer: With this user group, the user shall have the same privileges as the previous two user groups, plus the facility to change any setpoints. Individual users with separate credentials shall be assigned to this user group.

Administrator: When logged in as a user with Administrator-level privileges, access will be granted to a User Management screen (add users, passwords etc) in addition to any access provided by lower-level logins. This is the highest tier of security. Individual users with separate credentials shall be assigned to this user group.

Auto logout can be enabled to log out a user if the screen is idle for a duration of time.

11.2. Screens

All screens shall have a Bottom Banner and a Status Banner.

11.2.1. Bottom Banner

The Bottom Banner shall provide an alarm summary of any current alarms. Two navigation buttons shall also be part of the alarm banner to navigate to the Alarm Summary page and the Alarm History page.

11.2.2. Status Banner

The Status Banner shall always remain on the right-hand portion of the screen. This shall display the following:

System Status: This displays the generic state of the traffic management system and the bridge. The Barrier Override control button shall be migrated to the FactoryTalk View application.

Navigation Lights: This shall display the status of the navigation lights. The green, amber and red light indicators shall be re-drawn as one column to mimic the actual light system. The commercial/recreational button is available

for the operators to press and timestamp river traffic that passes the bridge. This shall be recorded on a new Boat Log page.

Screen Selection: This shall contain the navigation buttons to the take the operator to the other pages of the SCADA application.

1. **Reset Blocks:** Navigates to Reset Blocks page. Shall change to red if any of the Slip Blocks are in fault.
2. **Reset Jacks**: Navigates to Reset Jacks page. Shall change to red if any of the Jacks are in fault.
3. **Reset Bridge**: Navigates to the Reset Bridge page. Shall change to red if any of the bridge slewing equipment is in fault.
4. **Blocks**: Navigates to the Blocks page. This button shall also change colour depending on the state of the blocks when the traffic barriers are down. Green for if the blocks are on, red for when the blocks are in travel and yellow for when the blocks are off.
5. **Jacks**: Navigates to the Jacks page. This button shall also change colour depending on the state of the jacks when the traffic barriers are down. Green for if the Jacks are home, red for when the jacks are in travel and yellow for when the Jacks are extended.
6. **Bridge:** Navigates to the Bridge page. This button shall also change colour depending on the state of the bridge when the traffic barriers are down. Green for if the bridge is closed, red for when the bridge is in travel and yellow for when the bridge is in the open position.
7. **Override:** Navigates to the Override page.
8. **Intro:** Navigates to the start-up page.
9. **Levers:** Navigates to the Levers page.

11.2.3. Alarm Summary Page

The Alarms Summary page shall display all active alarms on the control system. The Alarm Summary page shall display the date and time the alarm was triggered as well as a description of the alarm. From the Alarm Summary page, the user will be able to acknowledge and reset alarms using the associated push buttons.

11.2.4. Alarm History Page

The Alarm History page shall display all historical alarm entries for when an alarm was triggered, reset and acknowledged. All entries on the page shall display the date and time this occurred. A filter button shall also be available for the user to filter the Alarm History based on the user's requirements. Alarms shall be logged indefinitely.

11.2.5. Control Levers Page

The Control Levers page shall display the status of the Jacks, Blocks and Swing Levers. The user will click on the required lever position when operating the bridge.

SCADA Control, Manual Control and Reset Lever control buttons shall be retained. The SCADA Control button shall place the control system in SCADA control meaning the bridge is controlled exclusively using the two SCADA machines. The Manual Control button, when pressed, shall control the bridge exclusively using the control levers in the Control Room. The Reset Levers button shall reset all Levers back to their neutral positions.

To use the lever on the Control Levers page, the user will require to be logged in with an account in either the *Operator* or *Engineer* user group.

11.2.6. Blocks Page

The Blocks page shall display the position and fault status of the Slip Blocks.

11.2.7. Jacks Page

The Jacks page shall display the position and fault status of the Jacks.

11.2.8. Bridge Page

The Bridge page shall display the position of the bridge as well as status of the Slewing Motors.

11.2.9. Override Page

The Override page shall display the control overrides for the control system. Overrides can only be applied if the user is logged in with the correct login.

11.2.10. Intro Page

The Intro page shall be the first page shown when the SCADA is booted up.

11.2.11. Reset Blocks

The Reset Blocks page shall enable the user to reset any Slip Block integral position limits

11.2.12. Reset Jacks

The Reset Jacks page shall enable the user to reset any Jack integral position limits.

11.2.13. Reset Bridge

The Reset Bridge page shall enable the user to reset any Bridge instrumentation faults.

11.2.14. Setpoints

The Setpoints page shall enable the user to view and change any of the operation setpoints. The user shall require a logon assigned to the *Engineer* user group to change any setpoints.

11.2.15. Boat Log Page

The Boat Log Page shall display the vessels that have been logged as passing through the bridge The vessel type is logged and timestamped by pressing the Commercial/Recreational Boat button that is on the Status Banner.

The stored datalog files can be exported as .csv files

11.2.16. Slewing Motor VSD Page

The Slewing Motor VSD page shall display detailed diagnostics and status of each Slewing Motor VSD.

Appendix A I/O List

Classification: Protected

I/O Card	Slot	Bit	PLC Address	PLC Mnemonic	I/O Type	Description	State=1/ Scale	Comments
5069-IB16	1	DI0			DI	Mains Supply On		
5069-IB16	1	DI1			DI	Surge Barrier Healthy		
5069-IB16	1	DI2			DI	Phase Rotation Healthy		
5069-IB16	1	DI3			DI	24VDC PSU Healthy		
5069-IB16	1	DI4			DI	24VDC UPS Ready		
5069-IB16	1	DI5			DI	24VDC UPS Buffering		
5069-IB16	1	DI6			DI	24VDC UPS Battery Fault		
5069-IB16	1	DI7			DI	SPARE		
5069-IB16	1	DI8			DI	HPU Pump 1 Running Full Speed Feedback		
5069-IB16	1	DI9			DI	HPU Pump 1 Soft Start Healthy		
5069-IB16	1	DI10			DI	HPU Pump 1 Motor Protection Healthy		
5069-IB16	1	DI11			DI	HPU Pump 2 Running Full Speed Feedback		
5069-IB16	1	DI12			DI	HPU Pump 2 Soft Start Healthy		
5069-IB16	1	DI13			DI	HPU Pump 2 Motor Protection Healthy		
5069-IB16	1	DI14			DI	Circulation Pump Circuit Protection Healthy		
5069-IB16	1	DI15			DI	Circulation Pump Running		
5069-IB16	2	DI0			DI	HPU Pump 1 Isolator Feedback		
5069-IB16	2	DI1			DI	HPU Pump 1 Thermistor Healthy		
5069-IB16	2	DI2			DI	HPU Pump 2 Isolator Feedback		
5069-IB16	2	DI3			DI	HPU Pump 2 Thermistor Healthy		
5069-IB16	2	DI4			DI	SPARE		
5069-IB16	2	DI5			DI	HPU Pump 1 Ball Valve Closed		
5069-IB16	2	DI6			DI	HPU Pump 2 Ball Valve Closed		
5069-IB16	2	DI7			DI	Oil - High High Temperature		
5069-IB16	2	DI8			DI	Oil - Low Low Level		
5069-IB16	2	DI9			DI	Recirculating Pump Filter Blocked		
5069-IB16	2	DI10			DI	HPU Tank Filter Blocked		
5069-IB16	2	DI11			DI	HPU Pump 1 Filter Blocked		
5069-IB16	2	DI12			DI	HPU Pump 2 Filter Blocked		
5069-IB16	2	DI13			DI	Circulation Pump Isolator Healthy		
5069-IB16	2	DI14			DI	SPARE		
5069-IB16	2	DI15			DI	SPARE		
5069-IB16	3	DI0			DI	Slew Motor 1 Circuit Protection Healthy		
5069-IB16	3	DI1			DI	Slew Motor 1 VSD Healthy		
5069-IB16	3	DI2			DI	Slew Motor 2 Circuit Protection Healthy		
5069-IB16	3	DI3			DI	Slew Motor 2 VSD Healthy		
5069-IB16	3	DI4			DI	Slew Motor 3 Circuit Protection Healthy		
5069-IB16	3	DI5			DI	Slew Motor 3 VSD Healthy		
5069-IB16	3	DI6			DI	Slew Motor 4 Circuit Protection Healthy		
5069-IB16	3	DI7			DI	Slew Motor 4 VSD Healthy		
5069-IB16	3	DI8			DI	Slew Motor 1 Isolator Healthy		
5069-IB16	3	DI9			DI	Slew Motor 1 Clutch Engaged		
5069-IB16	3	DI10			DI	Slew Motor 2 Isolator Healthy		
5069-IB16	3	DI11			DI	Slew Motor 2 Clutch Engaged		
5069-IB16	3	DI12			DI	Slew Motor 3 Isolator Healthy		
5069-IB16	3	DI13			DI	Slew Motor 3 Clutch Engaged		
5069-IB16	3	DI14			DI	Slew Motor 4 Isolator Healthy		

5069-IB16	3	DI15			DI	Slew Motor 4 Clutch Engaged		
5069-IB16	4	DI0			DI	Main Panel Emergency Stop Healthy		
5069-IB16	4	DI1			DI	Slewing Motor 1 Emergency Stop		
5069-IB16	4	DI2			DI	Slewing Motor 2 Emergency Stop		
5069-IB16	4	DI3			DI	Slewing Motor 3 Emergency Stop		
5069-IB16	4	DI4			DI	Slewing Motor 4 Emergency Stop		
5069-IB16	4	DI5			DI	Bridge Encoder 1 Emergency Stop		
5069-IB16	4	DI6			DI	Bridge Encoder 2 Emergency Stop		
5069-IB16	4	DI7			DI	SPARE		
5069-IB16	4	DI8			DI	SPARE		
5069-IB16	4	DI9			DI	SPARE		
5069-IB16	4	DI10			DI	SPARE		
5069-IB16	4	DI11			DI	SPARE		
5069-IB16	4	DI12			DI	SPARE		
5069-IB16	4	DI13			DI	SPARE		
5069-IB16	4	DI14			DI	SPARE		
5069-IB16	4	DI15			DI	SPARE		
5069-IB16	5	DI0			DI	NE Jack Retracted 7A		
5069-IB16	5	DI1			DI	NE Jack Retracted 7AA		
5069-IB16	5	DI2			DI	NE Jack Extended 3A		
5069-IB16	5	DI3			DI	NE Jack Extended 3AA		
5069-IB16	5	DI4			DI	SE Jack Retracted 7B		
5069-IB16	5	DI5			DI	SE Jack Retracted 7BB		
5069-IB16	5	DI6			DI	SE Jack Extended 3B		
5069-IB16	5	DI7			DI	SE Jack Extended 3BB		
5069-IB16	5	DI8			DI	NW Jack Retracted 7D		
5069-IB16	5	DI9			DI	NW Jack Retracted 7DD		
5069-IB16	5	DI10			DI	NW Jack Extended 3D		
5069-IB16	5	DI11			DI	NW Jack Extended 3DD		
5069-IB16	5	DI12			DI	SW Jack Retracted 7C		
5069-IB16	5	DI13			DI	SW Jack Retracted 7CC		
5069-IB16	5	DI14			DI	SW Jack Extended 3C		
5069-IB16	5	DI15			DI	SW Jack Extended 3CC		
5069-IB16	6	DI0			DI	NE Block Retracted 20A		
5069-IB16	6	DI1			DI	NE Block Retracted 20AA		
5069-IB16	6	DI2			DI	NE Block Extended 5A		
5069-IB16	6	DI3			DI	NE Block Extended 5AA		
5069-IB16	6	DI4			DI	E Block Retracted 20B		
5069-IB16	6	DI5			DI	E Block Retracted 20BB		
5069-IB16	6	DI6			DI	E Block Extended 5B		
5069-IB16	6	DI7			DI	E Block Extended 5BB		
5069-IB16	6	DI8			DI	SE Block Retracted 20C		
5069-IB16	6	DI9			DI	SE Block Retracted 20CC		
5069-IB16	6	DI10			DI	SE Block Extended 5C		
5069-IB16	6	DI11			DI	SE Block Extended 5CC		
5069-IB16	6	DI12			DI	SPARE		
5069-IB16	6	DI13			DI	SPARE		
5069-IB16	6	DI14			DI	SPARE		

5069-IB16	6	DI15			DI	SPARE		
5069-IB16	7	DI0			DI	NW Block Retracted 20F		
5069-IB16	7	DI1			DI	NW Block Retracted 20FF		
5069-IB16	7	DI2			DI	NW Block Extended 5F		
5069-IB16	7	DI3			DI	NW Block Extended 5FF		
5069-IB16	7	DI4			DI	W Block Retracted 20E		
5069-IB16	7	DI5			DI	W Block Retracted 20EE		
5069-IB16	7	DI6			DI	W Block Extended 5E		
5069-IB16	7	DI7			DI	W Block Extended 5EE		
5069-IB16	7	DI8			DI	SW Block Retracted 20D		
5069-IB16	7	DI9			DI	SW Block Retracted 20DD		
5069-IB16	7	DI10			DI	SW Block Extended 5D		
5069-IB16	7	DI11			DI	SW Block Extended 5DD		
5069-IB16	7	DI12			DI	SPARE		
5069-IB16	7	DI13			DI	SPARE		
5069-IB16	7	DI14			DI	SPARE		
5069-IB16	7	DI15			DI	SPARE		
5069-OB16	8	DO0			DO	Control System Healthy		
5069-OB16	8	DO1			DO	HPU Pump 1 Run		
5069-OB16	8	DO2			DO	HPU Pump 2 Run		
5069-OB16	8	DO3			DO	Load Valve - Low Pressure (Slip Blocks)		
5069-OB16	8	DO4			DO	Load Valve - High Pressure (Jacks)		
5069-OB16	8	DO5			DO	Jacks Extend Valve 1		
5069-OB16	8	DO6			DO	Jacks Extend Valve 2		
5069-OB16	8	DO7			DO	Jacks Retract Valve 1		
5069-OB16	8	DO8			DO	Jacks Retract Valve 2		
5069-OB16	8	DO9			DO	Blocks Extend Valve 1		
5069-OB16	8	DO10			DO	Blocks Extend Valve 2		
5069-OB16	8	DO11			DO	Blocks Retract Valve 1		
5069-OB16	8	DO12			DO	Blocks Retract Valve 2		
5069-OB16	8	DO13			DO	Circulation Pump Run		
5069-OB16	8	DO14			DO	Oil Heater		
5069-OB16	8	DO15			DO	SPARE		
5069-OB16	9	DO0			DO	North East Jack Bypass		
5069-OB16	9	DO1			DO	South East Jack Bypass		
5069-OB16	9	DO2			DO	North West Jack Bypass		
5069-OB16	9	DO3			DO	South West Jack Bypass		
5069-OB16	9	DO4			DO	East Block Cylinder 1 Bypass		
5069-OB16	9	DO5			DO	East Block Cylinder 2 Bypass		
5069-OB16	9	DO6			DO	West Block Cylinder 1 Bypass		
5069-OB16	9	DO7			DO	West Block Cylinder 2 Bypass		
5069-OB16	9	DO8			DO	SPARE		
5069-OB16	9	DO9			DO	SPARE		
5069-OB16	9	DO10			DO	SPARE		
5069-OB16	9	DO11			DO	SPARE		
5069-OB16	9	DO12			DO	SPARE		
5069-OB16	9	DO13			DO	SPARE		
5069-OB16	9	DO14			DO	SPARE		
5069-OB16	9	DO15			DO	SPARE		

5069-IF8	10	AI0			AI	Oil Temperature		
5069-IF8	10	AI1			AI	Oil Level		
5069-IF8	10	AI2			AI	Pumpset 1 Pressure		
5069-IF8	10	AI3			AI	Pumpset 2 Pressure		
5069-IF8	10	AI4			AI	Jacks Cylinder Pressure 1		
5069-IF8	10	AI5			AI	Jacks Cylinder Pressure 2		
5069-IF8	10	AI6			AI	Blocks Cylinder Pressure 1		
5069-IF8	10	AI7			AI	Blocks Cylinder Pressure 2		
5094-IF8	11	AI0			AI	SPARE		
5094-IF8	11	AI1			AI	SPARE		
5094-IF8	11	AI2			AI	SPARE		
5094-IF8	11	AI3			AI	SPARE		
5094-IF8	11	AI4			AI	SPARE		
5094-IF8	11	AI5			AI	SPARE		
5094-IF8	11	AI6			AI	SPARE		
5094-IF8	11	AI7			AI	SPARE		

I/O Card	Slot	Bit	PLC Address	PLC Mnemonic	I/O Type	Description	State=1/ Scale	Comments
5094-IB32	2	DI0			DI	Mains Supply On		
5094-IB32	2	DI1			DI	Surge Barrier Healthy		
5094-IB32	2	DI2			DI	24VDC PSU Healthy		
5094-IB32	2	DI3			DI	24VDC UPS Ready		
5094-IB32	2	DI4			DI	24VDC UPS Buffering		
5094-IB32	2	DI5			DI	24VDC UPS Battery Fault		
5094-IB32	2	DI6			DI	SPARE		
5094-IB32	2	DI7			DI	SPARE		
5094-IB32	2	DI8			DI	Jacks Lever Forward (Jack Bridge Up)		
5094-IB32	2	DI9			DI	Jacks Lever Back (Jack Bridge Down)		
5094-IB32	2	DI10			DI	Blocks Lever Forward (Retract Blocks)		
5094-IB32	2	DI11			DI	Blocks Lever Back (Extend Blocks)		
5094-IB32	2	DI12			DI	Slew Lever Forward 1 (Bridge Open/Slow Speed)		
5094-IB32	2	DI13			DI	Slew Lever Forward 2 (Bridge Open/Fast Speed)		
5094-IB32	2	DI14			DI	Slew Lever Back 1 (Bridge Close/Slow Speed)		
5094-IB32	2	DI15			DI	Slew Lever Back 2 (Bridge Close/Fast Speed)		
5094-IB32	2	DI16			DI	Safety Fault Reset Illuminated Pushbutton		
5094-IB32	2	DI17			DI	E-Stop Reset Illuminated Pushbutton		
5094-IB32	2	DI18			DI	Safety Key Reset Illuminated Pushbutton		
5094-IB32	2	DI19			DI	Maintenance Immobilisation Reset Illuminated Pushbutton		
5094-IB32	2	DI20			DI	Ultimate Position Recovery Enable Illuminated Pushbutton		
5094-IB32	2	DI21			DI	Ultimate Position Reset Illuminated Pushbutton		
5094-IB32	2	DI22			DI	Control Console E-Stop Healthy Illuminated Pushbutton		
5094-IB32	2	DI23			DI	Control Console Emergency Stop Healthy		
5094-IB32	2	DI24			DI	SPARE		
5094-IB32	2	DI25			DI	SPARE		
5094-IB32	2	DI26			DI	SPARE		
5094-IB32	2	DI27			DI	SPARE		
5094-IB32	2	DI28			DI	SPARE		
5094-IB32	2	DI29			DI	SPARE		
5094-IB32	2	DI30			DI	SPARE		
5094-IB32	2	DI31			DI	SPARE		
5094-OB32	3	DO0			DO	Control System Healthy Lamp		
5094-OB32	3	DO1			DO	Control Console E-Stop Reset Illuminated Pushbutton		
5094-OB32	3	DO2			DO	Maintenance Immobilisation Illuminated Pushbutton		
5094-OB32	3	DO3			DO	Ultimate Position Recovery Enable Illuminated Pushbutton Lamp		
5094-OB32	3	DO4			DO	Ultimate Position Reset Illuminated Pushbutton Lamp		
5094-OB32	3	DO5			DO	SPARE		
5094-OB32	3	DO6			DO	SPARE		
5094-OB32	3	DO7			DO	Red Status Light		
5094-OB32	3	DO8			DO	Amber Status Light		
5094-OB32	3	DO9			DO	Green Status Light		
5094-OB32	3	DO10			DO	SPARE		
5094-OB32	3	DO11			DO	SPARE		
5094-OB32	3	DO12			DO	SPARE		
5094-OB32	3	DO13			DO	SPARE		
5094-OB32	3	DO14			DO	SPARE		

5094-OB32	3	DO15			DO	SPARE		
5094-OB32	3	DO16			DO	SPARE		
5094-OB32	3	DO17			DO	SPARE		
5094-OB32	3	DO18			DO	SPARE		
5094-OB32	3	DO19			DO	SPARE		
5094-OB32	3	DO20			DO	SPARE		
5094-OB32	3	DO21			DO	SPARE		
5094-OB32	3	DO22			DO	SPARE		
5094-OB32	3	DO23			DO	SPARE		
5094-OB32	3	DO24			DO	SPARE		
5094-OB32	3	DO25			DO	SPARE		
5094-OB32	3	DO26			DO	SPARE		
5094-OB32	3	DO27			DO	SPARE		
5094-OB32	3	DO28			DO	SPARE		
5094-OB32	3	DO29			DO	SPARE		
5094-OB32	3	DO30			DO	SPARE		
5094-OB32	3	DO31			DO	SPARE		

Component	Slot	Terminal	PLC Address	PLC Mnemonic	Terminal Config	Description	State=1/ Scale	Comments
PNOZ m ES EtherNet/IP	-1	N/A			N/A	Ethernet IP Comms		
PNOZ m B0	0	A1			N/A	24VDC Power Supply		
PNOZ m B0	0	A2			N/A	0VDC Power Supply		
PNOZ m B0	0	I4			Input	Ultimate Open 1		
PNOZ m B0	0	I5			Input	Ultimate Open 2		
PNOZ m B0	0	I6			Input	Ultimate Close 1		
PNOZ m B0	0	I7			Input	Ultimate Close 2		
PNOZ m B0	0	I8			Input	Barriers Down 1		
PNOZ m B0	0	I9			Input	Barriers Down 2		
PNOZ m B0	0	I10			Input	Access Interlock Key 1		
PNOZ m B0	0	I11			Input	Access Interlock Key 2		
PNOZ m B0	0	I12			Input	Emergency Stop 1		
PNOZ m B0	0	I13			Input	Emergency Stop 2		
PNOZ m B0	0	I14			Input	Emergency Mode Fortress Key 1		
PNOZ m B0	0	I15			Input	Emergency Mode Fortress Key 2		
PNOZ m B0	0	IM0			Config I/O - Input	Traffic Barrier Override 1		
PNOZ m B0	0	IM1			Config I/O - Input	Traffic Barrier Override 2		
PNOZ m B0	0	IM2			Config I/O - Input	E-Stop Reset Illuminated Pushbutton		
PNOZ m B0	0	IM3			Config I/O - Standard Output	E-Stop Reset Illuminated Pushbutton		
PNOZ m B0	0	IM16			Config I/O - Input	Safety Fault Illuminated Pushbutton		
PNOZ m B0	0	IM17			Config I/O - Standard Output	Safety Fault Illuminated Pushbutton		
PNOZ m B0	0	IM18			Config I/O	SPARE		
PNOZ m B0	0	IM19			Config I/O	SPARE		
PNOZ m B0	0	T0M20			Test Pulse	Test Pulse 1		
PNOZ m B0	0	T1M21			Test Pulse	Test Pulse 2		
PNOZ m B0	0	T2M22			Test Pulse	Test Pulse 3		
PNOZ m B0	0	T3M23			Test Pulse	Test Pulse 4		
PNOZ m B0	0	0V			N/A	0VDC Output Supply		
PNOZ m B0	0	24			N/A	24VDC Output Supply		
PNOZ m B0	0	O0			Output	HPU Motor Relays		
PNOZ m B0	0	O1			Output	Slew Motor Relays		
PNOZ m B0	0	O2			Output	Slew Clockwise Relays		
PNOZ m B0	0	O3			Output	Slew Anti-Clockwise Relays		
PNOZ m EF 8DI4DO	1	0V			N/A	0VDC Output Supply		
PNOZ m EF 8DI4DO	1	24			N/A	24VDC Output Supply		
PNOZ m EF 8DI4DO	1	I0			Input	Slew Motor Relays 1&2 Feedback		
PNOZ m EF 8DI4DO	1	I1			Input	HPU Motor Relays 1&2 Feedback		
PNOZ m EF 8DI4DO	1	I2			Input	Slew Clockwise Relays Feedback		
PNOZ m EF 8DI4DO	1	I3			Input	Slew Anti-Clockwise Relays Feedback		
PNOZ m EF 8DI4DO	1	I4			Input	Control Desk Auto Interlock Key 1		
PNOZ m EF 8DI4DO	1	I5			Input	Control Desk Auto Interlock Key 2		
PNOZ m EF 8DI4DO	1	I6			Input	Emergency Mode Relay Feedback		
PNOZ m EF 8DI4DO	1	I7			Input	Auto Mode Relay Feedback		
PNOZ m EF 8DI4DO	1	O0			Output	Emergency Mode Relay		
PNOZ m EF 8DI4DO	1	O1			Output	Auto Mode Relay		
PNOZ m EF 8DI4DO	1	O2			Output	SPARE		
PNOZ m EF 8DI4DO	1	O3			Output	SPARE		

Appendix B Preliminary Cable Block Diagram

Classification: Protected

Main Panel

Plant Room

27c (1.5) SWA
27c (1.5) SWA
5pr (0.75) SWA
10pr (0.75) SWA

HPU Junction Box

4c (35) SWA
3c (1.5) SWA
3c (1.5) SWA
Local Isolator

4c (35) SWA
3c (1.5) SWA
3c (1.5) SWA
Local Isolator

4c (2.5) SWA
3c (1.5) SWA
Local Isolator

3c (1.5) SWA
Local Isolator

INST-OEM ×20
SOL-OEM
SOL-OEM

2pr (0.75) SWA

2pr (0.75) SWA

4c (35) SWA
2pr (0.75) SWA
3c (1.5) SWA
M
HPU Pump 1
45kW Motor
Motor Heater

4c (35) SWA
2pr (0.75) SWA
3c (1.5) SWA
M
HPU Pump 2
45kW Motor
Motor Heater

4c (2.5) SWA
M
Circulation Pump
<=4kW

3c (1.5) SWA
Oil Heater
2kW

Pump 1 Ball Valve
Pump 2 Ball Valve
Pumps Return Filter Blocked
Pump 1 Filter Blocked
Pump 2 Filter Blocked
Recirculating Pump Filter Blocked
Oil Temp High High
Oil Level Low Low
Oil Temp
Oil Level
Pumpset 1 Pressure
Pumpset 2 Pressure
Jacking Cylinders Pressure 1
Jacking Cylinders Pressure 2
Blocks Cylinders Pressure 1
Blocks Cylinders Pressure 2
Load Valve Low Pressure (Slip Blocks)
Load Valve High Pressure (Jacks)

HPU

Key

- Power 400V/230V AC
- Digital Control 24V DC
- Analogue Control 4-20 mA
- Ethernet/IP

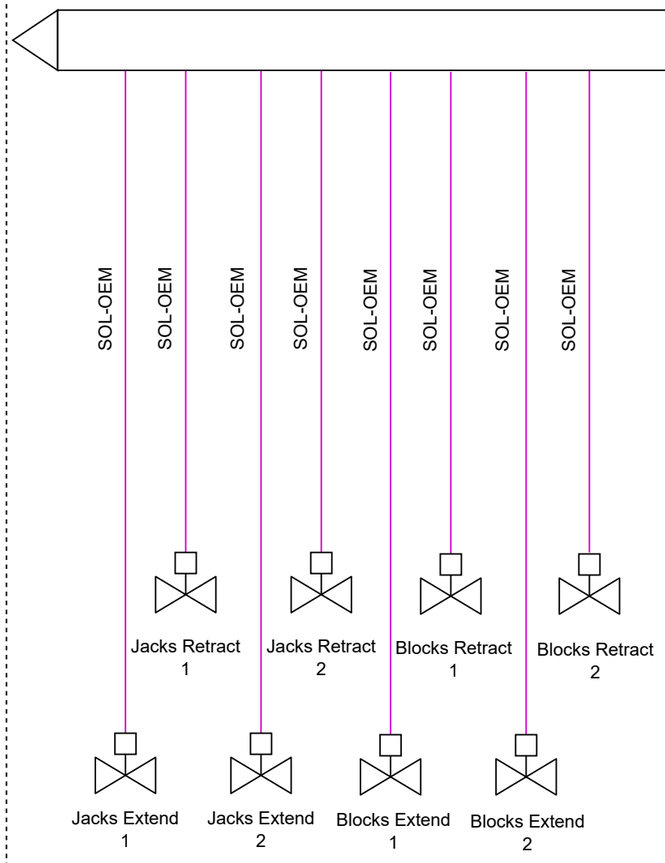
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Rev	Page Revision Description	Drawn	Ck'd	Date
A01	For Approval	RE	TS	08/01/2025
A02	Cable Types Added	TS	TS	04/02/2025
A03	Slip Block Sensors and Load Valve Added	RE	TS	30/04/2025

Document Description: Cross Keys Swing Bridge Block Cable Diagram HPU

Document Number	Job Number	Page
LINC10089-18-01	FES5241	01
Document Classification	Document Rev	
Commercial in Confidence	A03	

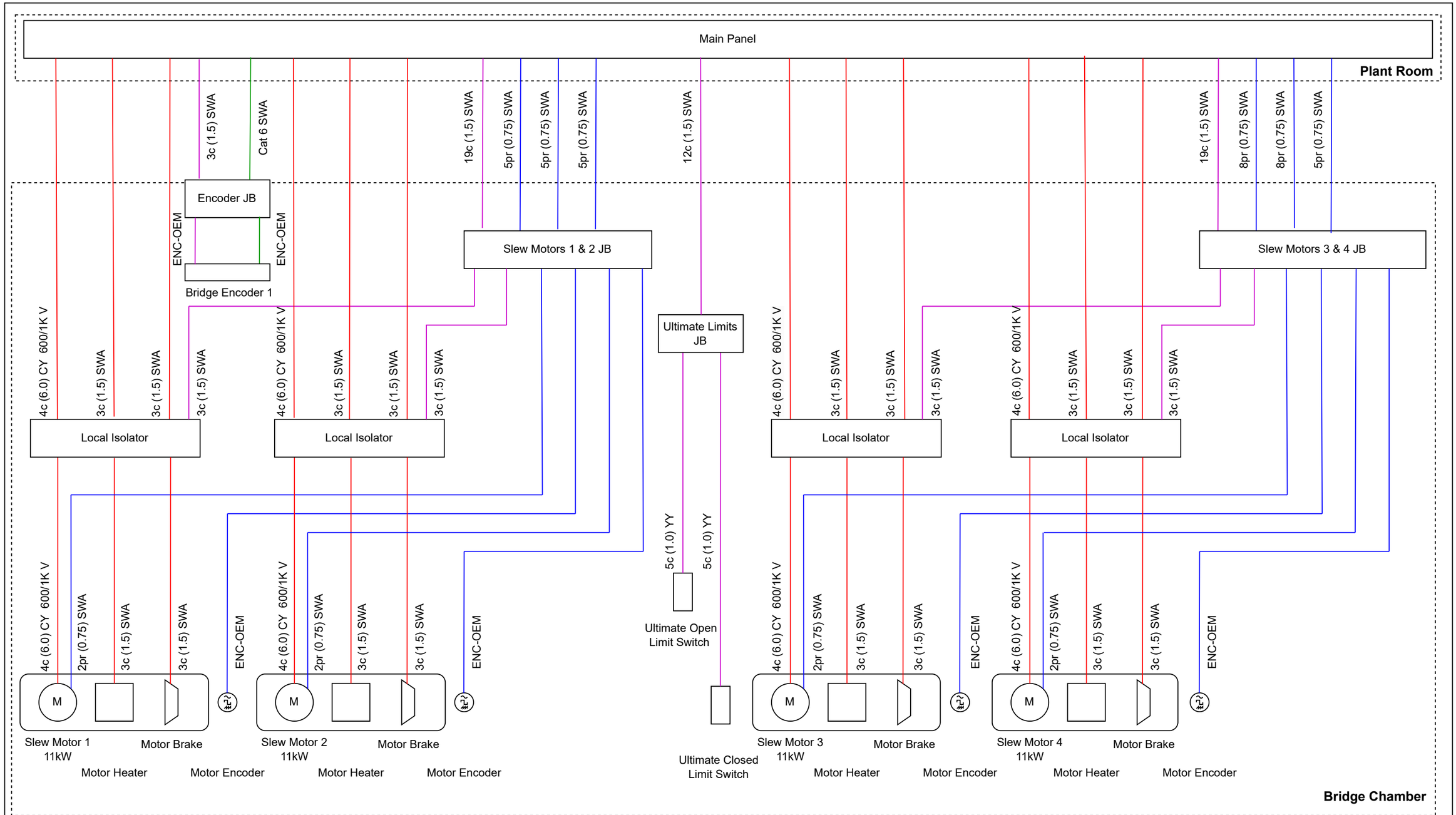


Key

- Power 400V/230V AC
- Digital Control 24V DC
- Analogue Control 4-20 mA
- Ethernet/IP

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Rev	Page Revision Description	Drawn	Ck'd	Date	Document Description	Document Number	Job Number	Page
A03	New Page For Slip Block Solenoids Added	RE	TS	30/04/2025	Cross Keys Swing Bridge Block Cable Diagram HPU	LINC10089-18-01	FES5241	02
						Document Classification	Document Rev	
						Commercial in Confidence	A03	



Key

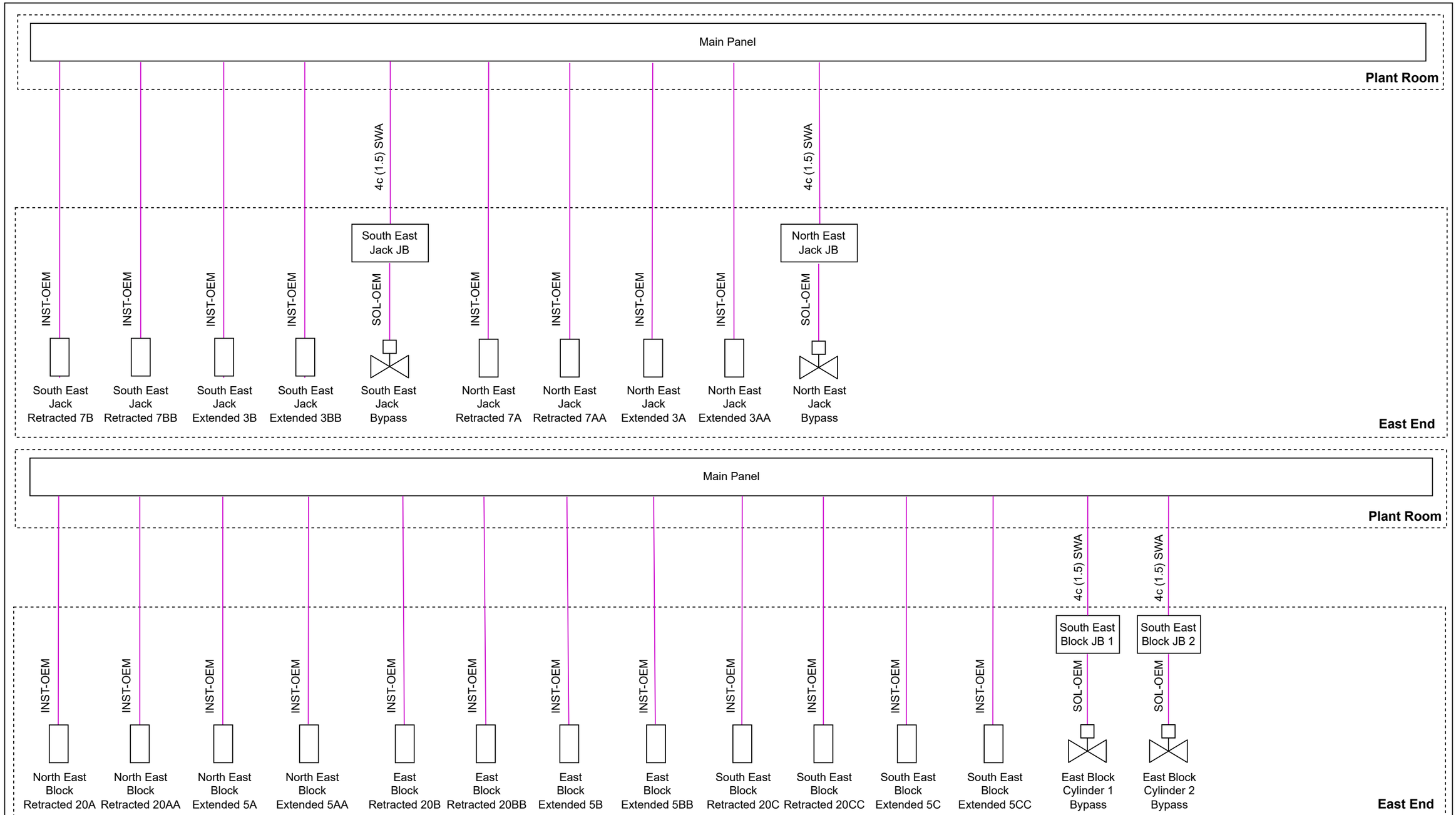
- Power 400V/230V AC
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- Analogue Control 4-20 mA
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Rev	Page Revision Description	Drawn	Ck'd	Date
A01	For Approval	RE	TS	08/01/2025
A02	Cable Types Added	TS	TS	04/02/2025
A03	Minor Detail Changes	RE	TS	30/04/2025

Document Description	Document Number	Job Number	Page
Cross Keys Swing Bridge Block Cable Diagram Slew	LINC10089-18-01	FES5241	03
	Document Classification	Document Rev	
	Commercial in Confidence	A03	



Key

- Power 400V/230V AC
- Digital Control 24V DC
- Analogue Control 4-20 mA
- Ethernet/IP

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Rev	Page Revision Description	Drawn	Ck'd	Date
A01	For Approval	RE	TS	08/01/2025
A02	Cable Types Added	TS	TS	04/02/2025
A03	Slip Block Sensors Added	RE	TS	30/04/2025

Document Description	Document Number	Job Number	Page
Cross Keys Swing Bridge Block Cable Diagram East End	LINC10089-18-01	FES5241	04
	Document Classification	Document Rev	
	Commercial in Confidence	A03	

Main Panel

Plant Room

4c (1.5) SWA

South West Jack JB

4c (1.5) SWA

North West Jack JB

INST-OEM — South West Jack Retracted 7C

INST-OEM — South West Jack Retracted 7CC

INST-OEM — South West Jack Extended 3C

INST-OEM — South West Jack Extended 3CC

SOL-OEM — South West Jack Bypass

INST-OEM — North West Jack Retracted 7D

INST-OEM — North West Jack Retracted 7DD

INST-OEM — North West Jack Extended 3D

INST-OEM — North West Jack Extended 3DD

SOL-OEM — North West Jack Bypass

West End

Main Panel

Plant Room

4c (1.5) SWA

South West Block JB 1

4c (1.5) SWA

South West Block JB 2

INST-OEM — North West Block Retracted 20F

INST-OEM — North West Block Retracted 20FF

INST-OEM — North West Block Extended 5F

INST-OEM — North West Block Extended 5FF

INST-OEM — West Block Retracted 20E

INST-OEM — West Block Retracted 20EE

INST-OEM — West Block Extended 5E

INST-OEM — West Block Extended 5EE

INST-OEM — South West Block Retracted 20D

INST-OEM — South West Block Retracted 20DD

INST-OEM — South West Block Extended 5D

INST-OEM — South West Block Extended 5DD

SOL-OEM — West Block Cylinder 1 Bypass

SOL-OEM — West Block Cylinder 2 Bypass

West End

Key

- Power 400V/230V AC
- Digital Control 24V DC
- Analogue Control 4-20 mA
- Ethernet/IP

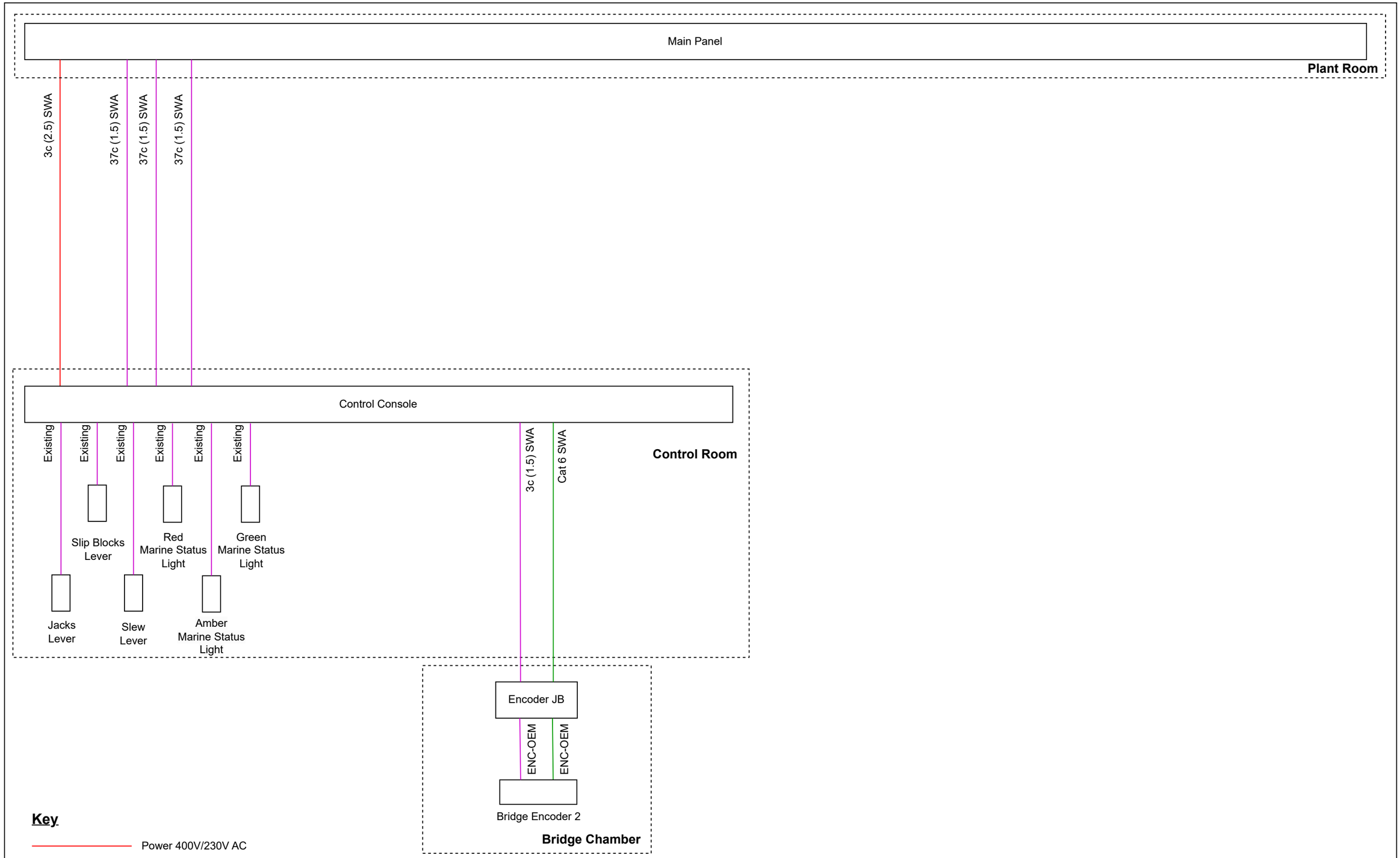
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Rev	Page Revision Description	Drawn	Ck'd	Date
A01	For Approval	RE	TS	08/01/2025
A02	Cable Types Added	TS	TS	04/02/2025
A03	Slip Block Sensors Added	RE	TS	30/04/2025

Document Description: Cross Keys Swing Bridge Block Cable Diagram West End

Document Number	Job Number	Page
LINC10089-18-01	FES5241	05
Document Classification	Document Rev	
Commercial in Confidence	A03	

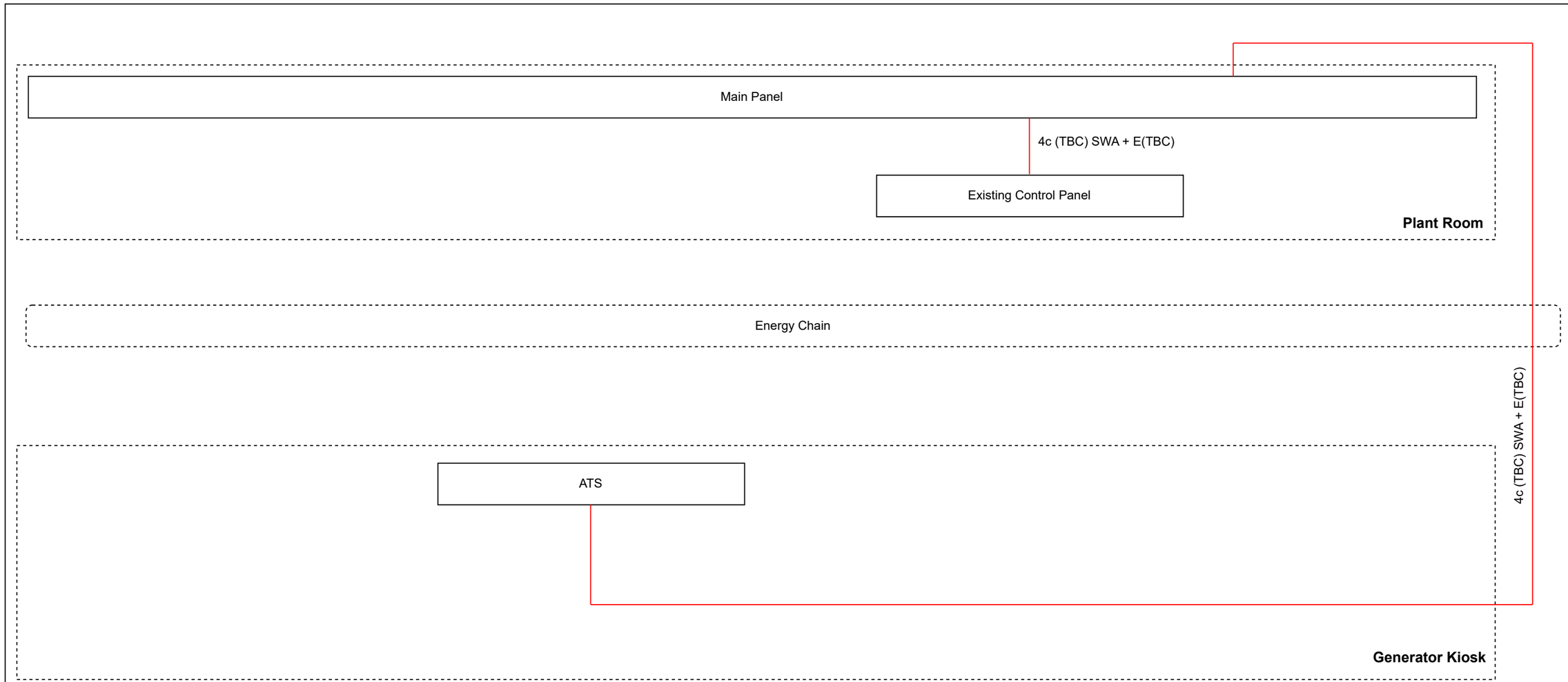


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Rev	Page Revision Description	Drawn	Ck'd	Date
A01	For Approval	RE	TS	08/01/2025
A02	Cable Types Added	TS	TS	04/02/2025
A03	Bridge Encoder Added	RE	TS	30/04/2025

Document Description: Cross Keys Swing Bridge Block Cable Diagram Control Room

Document Number	Job Number	Page
LINC10089-18-01	FES5241	06
Document Classification	Document Rev	
Commercial in Confidence	A03	



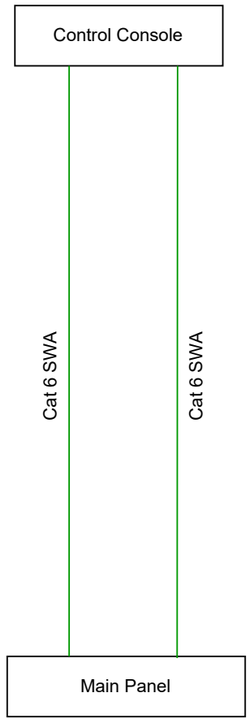
Key

- Power 400V/230V AC
- Digital Control 24V DC
- Analogue Control 4-20 mA
- Ethernet/IP

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Rev	Page Revision Description	Drawn	Ck'd	Date
A01	For Approval	RE	TS	08/01/2025
A02	Cable Types Added	TS	TS	04/02/2025

Document Description	Document Number	Job Number	Page
Cross Keys Swing Bridge Block Cable Diagram Generator	LINC10089-18-01	FES5241	07
	Document Classification	Document Rev	
	Commercial in Confidence	A03	



Key

Ethernet/IP

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Rev	Page Revision Description	Drawn	Ck'd	Date
A01	For Approval	RE	TS	08/01/2025
A02	Cable Types Added	TS	TS	04/02/2025
A03	RIO Panels Removed	RE	TS	30/04/2025

Document Description	Document Number	Job Number	Page
Cross Keys Swing Bridge Block Cable Diagram Network Overview	LINC10089-18-01	FES5241	08
	Document Classification	Document Rev	
	Commercial in Confidence	A03	

Revision A03

SAFETY REQUIREMENT SPECIFICATION

Cross Keys Swing Bridge
Electrical Upgrade

Lincolnshire County Council

Classification: Protected

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Precedence

As this specification may have been designed to take account of matters which had not been considered previously, this document once approved, will take precedence over any other specification in the event of a conflict.

Approval

When this document is submitted for approval, you should ensure that you are aware of its review period which unless stated within the contract document is 5 working days. If we either receive your written approval or have not received a written response from you prior to expiry of the review period, then this document will be deemed approved. However, if we receive written comments prior to the expiry of the review period, we will deal with them appropriately.

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1. Document Details

1.1. Project Details

FCS Project Ref:	LIN10089
Project Title:	Cross Keys Swing Bridge Electrical Upgrade
Customer:	Lincolnshire County Council
Document ref:	LIN10089-20-14-01

1.2. Revision History

Previous issues of this document are to be destroyed or marked superseded

Revision	Job Ref	Date	Description Of Amendment
P01	LIN10089	11/04/2024	Initial Draft
A01	LIN10089	09/05/2024	For Approval
A02	LIN10089	29/04/2025	Amended based on changes to the scope
A03	LIN10089	21/05/2025	Client comments incorporated (08/05/2025)

Table 1-1: Revision History

Revision	Author	Date	Checked By	Date
P01	Tom Silvester	11/04/2024	Daniel Rosen	08/05/2024
A01	Tom Silvester	09/05/2024	Daniel Rosen	17/05/2024
A02	Tom Silvester	29/04/2025	Daniel Rosen	29/04/2025
A03	Tom Silvester	21/05/2025	Daniel Rosen	22/05/2025

Table 1-2 - Author & Approval

1.3. Standards

The standards identified in the table below were referenced in the production of this document.

Reference	Description	Revision
EN ISO 12100:2010	Safety of machinery - General principles for design – Risk assessment and risk reduction	2010
EN ISO 13849-1:2023	Safety of machinery – Safety related parts of control systems – Part 1: General principles for design	2023
EN ISO 13849-2:2012	Safety of machinery - Safety-related parts of control systems - Part 2: Validation	2012
BS EN 60204-1:2018	Safety of machinery. Electrical equipment of machines. Part 1: General requirements	2018
BS EN ISO 13850:2015	Safety of machinery – Emergency Stop Function	2015

Table 1-3 - Standards

1.4. Reference Documents

The project documents identified in the table below were referenced in the production of this document.

Reference	Description	Revision
LINC10089-20-12	Cross Keys Swing Bridge Design Risk Assessment	A02

Table 1-4 - Reference Documents

Classification: Protected

2. Executive Summary

This document's purpose is to describe the safety functions of the Cross Keys Swing Bridge Control System.

The evaluation of the Performance Level is in accordance with the requirements EN ISO 13849-1:2023 Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design and is completed using the IFA SISTEMA - Safety Integrity Software Tool for the Evaluation of Machine Applications v2.0.8 build 4.

3. Glossary of Terms and Acronyms

a	-	Years
B_{10D}	-	Number of cycles before 10% of components fail dangerously
CCF	-	Common Cause Failure
d_{op}	-	Average number of operating days per annum
DC	-	Diagnostic Coverage
DRA	-	Design Risk Assessment
E-Stop	-	Emergency Stop
FCS	-	Fairfield Control Systems
HAZID	-	Hazard Identification Study
HAZOP	-	Hazard and Operability Study
HMI	-	Human Machine Interface
h_{op}	-	Average number of operating hours per day
HPU	-	Hydraulic Power Unit
$MTTF_D$	-	Mean time to dangerous failure
n_{op}	-	Mean number of operating cycles annually
PFH_D	-	Average probability of dangerous failure per hour
PL	-	Performance Level. Ranges from PLa (lowest integrity) to PLe (highest integrity)
PL_r	-	Required Performance Level
SRP/CS	-	Safety Related Parts of Control System
SRS	-	Safety Requirements Specification (this document)
T_{10D}	-	Mean time until 10% of components fail dangerously

Classification: Protected

4. Introduction



Figure 4-1: Cross Keys Swing Bridge

The Cross Keys control system controls the operation of the Cross Keys Swing bridge. To initiate the opening/closing of the bridge the wig wags are operated and all traffic and pedestrian barriers are lowered, this is controlled by a separate control system. The Bridge Control System receives a signal from the Traffic Control system to enable movement of the bridge. Without the “all barriers down” signal, the bridge swing cannot commence.

When the bridge is closed, the bridge is left resting on top of rest blocks and secured to the span ends by two foot bolt locking pins located at each end. To swing the bridge open, the following sequence is performed:

- Bridge raised from the rest blocks by jacks
- Slip blocks retracted
- Bridge lowered by jacks
- Bridge swung open anti-clockwise to the open position

Once all river traffic has passed, the bridge is then closed by the following sequence:

- Locking pins extended using foot pedal
- Bridge swung to the closed position
- Bridge raised by jacks
- Slip blocks extended
- Bridge lowered by jacks
- Locking pins retracted using foot pedal

The control system and actuation for the bridge is to be completely upgraded. As part of the controls upgrade a Design Risk Assessment has been undertaken to identify the safety-related concerns and the required safety functions that shall mitigate these concerns.

5. System Definition

Cross Keys Swing Bridge is to be operated electrically and hydraulically by electric motors. The bridge swings on average 550 times per year. Each motor is assigned to power parts of the bridge specifically. A summary of which is given below:

HPU Pumps 1&2: Provides hydraulic power to the Jacks and Slip Blocks via Loading and Directional solenoids. The pumps are configured as a duty/standby pair. If one of the HPU Pumps fails, the Jacks/Slip Blocks can be powered by changing over to the standby HPU Pump.

Slewing Motor 1-4 VSDs: Provides actuation to rotate the bridge. In normal operation, all four motors shall operate simultaneously. Each motor is to be controlled via a VSD. Should one motor fault, all are stopped, and the healthy motors can be run to continue slewing the bridge. Each motor shall have an integral encoder for closed loop control, and there will be two standalone encoders to feed back the bridge position.

5.1. Personnel Definitions

- Operator:
  - Has overall control of the bridge using the SCADA PC and levers in the control room
  - In the scenario of PLC failure or emergency fault, can switch to Emergency Operations and operate the bridge bypassing necessary interlocks
  - Responsible for start-up checks.
  - Responsible for communicating with River Traffic and operating the Traffic Control system
- Engineer:
  - Adjust setpoints of the control system.
  - Responsible for periodic functional tests.
  - Carry out planned preventative maintenance of the machine.
  - Assist the operator to recover the bridge from faults and stoppages.
  - Can manually control the bridge using the Emergency Controls

5.2. System Scope

The Safety Requirement Specification is exclusively based upon improving the overall safety performance level of the Cross Keys Swing Bridge control system.

This document excludes the specification of the Traffic Control system.

5.3. System States and Modes

- Raising
  - The bridge swing span is being raised by the extending jacks on each end. The bridge swing span is raised to either retract the slip blocks underneath as part of the opening sequence or raised to extend the slip blocks as part of the closing sequence.
- Lowering
  - The bridge swing span is being lowered by retracting the jacks at each end. The bridge span can be lowered down with the slip blocks retracted so the bridge can be slewed open or lowered onto rest blocks as part of the closing sequence.

- Opening
    - The bridge has been released from its nose/tail ends by raising the bridge through extending the jacks, retracting the rest blocks, lowering the bridge by retracting the jacks and manually retracting the locking pins. The bridge is being slewed towards the open position.
    - The bridge is slewed until it reaches its operational open position and stops to allow river traffic to pass
- Closing
    - The bridge is closed by manually extending the locking pins and slewing the bridge from the open position back to the closed position. The bridge ends are secured by, raising the bridge by extending the jacks, extending the rest blocks, lowering the bridge onto the rest blocks by retracting the jacks.
- Emergency Operation
    - The PLC control system is bypassed and the bridge is operated using the emergency controls with limited interlocking

5.4. System Zones

The overall system has been divided into zones for assessment which is designated as follows:

- Zone 1: Water Traffic
- Zone 2: Road Traffic
- Zone 3: Environmental
- Zone 4: Bridge Operation
- Zone 5: Abutments
- Zone 6: Slew Drive Assembly including Rack
- Zone 7: Maintenance
- Zone 8: Electrical
- Zone 9: Faults
- Zone 10: Installation
- Zone 11: Decommissioning

5.5. Mission Time

The mission time for all safety functions covered in this document will be 20 years.

6. Risk Parameter Specification

The DRA has identified several required safety functions. The details from the DRA have been used to assess each safety function's required performance level (PL_r) to BS EN ISO 13849-1:2023. The assessment for severity and frequency is shown in the table below.

DRA Risk Parameter	BS EN ISO 13849-1:2023 Risk Parameter
Severity	
Catastrophic: Multiple deaths and/or multiple severe injuries and/or major damage to the environment.	**S2:** Serious (normally irreversible injury or death)
Critical: One dead and/or seriously injured person and/or serious damage to the environment.	**S2:** Serious (normally irreversible injury or death)
Marginal: Minor injuries and/or serious threat to the environment.	**S1:** Slight (normally reversible injury)
Insignificant: Possibly slightly injured.	**S1:** Slight (normally reversible injury)
Frequency	
Frequent: Likely to occur frequently. The dangerous situation is encountered continuously. (Daily)	**F2:** Frequent-to-continuous and/or exposure time is long
Probable: Likely to occur repeatedly. The dangerous situation can be encountered often. (Monthly)	**F2:** Frequent-to-continuous and/or exposure time is long
Occasional: May occur repeatedly. The dangerous situation can be encountered repeatedly. (Yearly)	**F2:** Frequent-to-continuous and/or exposure time is long
Rare: Likely to occur at some point in the system life cycle. One can reasonably assume that the dangerous situation is encountered.	**F1:** Seldom-to-less-often and/or exposure time is short
Improbable: Unlikely to occur but possible. Presumably the dangerous situation will be exceptionally encountered.	**F1:** Seldom-to-less-often and/or exposure time is short
Unrealisable: Extremely unlikely. Presumably the dangerous situation will not occur.	**F1:** Seldom-to-less-often and/or exposure time is short

Table 6.1 - Risk Parameter Relations

The 'possibility of avoiding hazard or limiting harm' risk parameter of BS EN ISO 13849-1:2023 has been assessed based on each hazard listed in the DRA. The possibility of avoidance criteria are as follows:

- **P1:** Possible under specific conditions
- **P2:** Scarcely possible

The selection of the P value shall be determined by using tables A.1 and A.2 from BS EN ISO 13849-1:2023.

7. System Safety Functions

The following safety functions have been identified from the site visit and subsequent DRA.

Ref	Name	Type	PL_r Calculation	PL_r
SF1	Emergency Stop	Emergency Stop Function	BS EN 13850*	d
SF2	Traffic Barriers Interlock	Safety-Related Stop Function initiated by safeguard	S2 / F2 / P2	e
SF3	Maintenance Access	Safety-Related Stop Function initiated by safeguard	S2 / F2 / P2	e
SF4	Ultimate Open	Safety-Related Stop Function initiated by safeguard	S2 / F2 / P2	e
SF5	Ultimate Close	Safety-Related Stop Function initiated by safeguard	S2 / F2 / P2	e

Table 7.1 - Safety Function List

*Note: For SF1, the standard BS EN 13850 section 4.1.5 identifies a minimum of PLr c for emergency stop functions. Due to the PLr of other safety functions in the system all being PLr d or higher, it has been deemed that in this case the emergency stop function shall also be specified at PLr d.

Classification: Protected

7.1. SF1 – Emergency Stop

Description		
Hazard Description:	Emergency scenario	
Description	Upon actuation of any emergency stop device, all operations of the bridge shall shut down in a controlled manner to avoid damage to the bridge equipment and bridge structure.	
Safe State:	Bridge immobilised (HPU and Slew Motors de-energised)	
Performance Level Required:	PL_r= d	
Mission Time:	20 years	
Response Time and Distance		
Distance to Hazard:	N/A	
Response Time:	HPU Pumps de-energise immediately. (Category 0 Stop) Bridge Slewing VSDs motors to ramp down at fast speed to avoid damage to the bridge equipment and bridge structure. (Category 1 Stop)	
Operational Information		
Applicable Operating Modes of the Machine:	Raising:	Applicable
	Lowering:	Applicable
	Opening:	Applicable
	Closing:	Applicable
	Emergency Operation:	Applicable
Number of Operations Per Year:	4	
Demand Mode:	High demand (more than once per year) ~~Low demand (once per year or less)~~ ~~Continuous (SF continuously maintained)~~	
Fault Reaction Function	1. Safe state achieved 2. Alarms generated on the SCADA 3. Energisation of equipment inhibited until: a. Fault cleared b. Fault reset by Safety Fault Reset pushbutton on the Control Room Console	
Reset Requirements:	1. Safe state achieved 2. Reset Emergency Stop (Twist release pushbutton) 3. E-Stop Reset pushbutton illuminated on the Control Room Console 4. E-Stop Reset pushbutton pressed on the Control Room Console	
Tests and Required Test Equipment	Validation according to 13849-2. Each emergency device should be operationally tested every three months.	
Interfaces to Other Systems		
Interfaces to other SFs:	None	
Priority:	This SF shall have the highest priority and is equal in priority to SF2 and SF3	

Classification: Protected

Interfaces to Other Control Systems:	SCADA indication for safety alarms and faults via PLC
Environmental and EMC Considerations	
Environmental Influences:	Control panel is located in the Motor House away from the elements. The emergency stop locations are on the control panels and at stations on the bridge. Both the panels and the emergency stop stations are outside in the elements and will require an ingress rating of IP65 at a minimum. Temperature ranges from -5 to 40 degrees Celsius.
EMC Influences:	N/A
Applicable Standards	
BS EN ISO 13849-1:2023	Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design
BS EN ISO 13849-2:2012	Safety of machinery — Safety-related parts of control systems — Part 2: Validation
BS EN ISO 13850:2015	Safety of machinery – Emergency Stop Function
BS EN IEC 60204-1:2018	Safety of machinery – Electrical equipment of machines – Part 1: General Requirements
Additional Information	
Emergency Stops and Locations Main Control Panel Control Room Console Slew Motor 1 Slew Motor 2 Slew Motor 3 Slew Motor 4 Bridge Encoder 1 Bridge Encoder 2 Emergency stops shall not inhibit the Traffic Control system*	

*The Traffic Control System is out of scope for the safety requirements of the bridge control system.

Classification: Protected

7.2. SF2 – Traffic Barriers Interlock

Description		
Hazard Description:	Bridge slewing while vehicles/pedestrians are approaching the bridge Bridge slewing while vehicles/pedestrians are on the bridge	
Description	If any of the traffic barriers are not proven closed, all operations of the bridge shall shut down in a controlled manner.	
Safe State:	Bridge immobilised (HPU and Slew Motors de-energised)	
Performance Level Required:	PL_r= e	
Mission Time:	20 years	
Response Time and Distance		
Distance to Hazard:	N/A	
Response Time:	HPU Pumps de-energise immediately. (Category 0 Stop) Bridge Slewing VSDs motors to ramp down at fast speed to avoid damage to the bridge equipment and bridge structure. (Category 1 Stop)	
Operational Information		
Applicable Operating Modes of the Machine:	Raising:	Applicable
	Lowering:	Applicable
	Opening:	Applicable
	Closing:	Applicable
	Emergency Operation:	Not Applicable
Number of Operations Per Year:	550	
Demand Mode:	High demand (more than once per year) ~~Low demand (once per year or less)~~ ~~Continuous (SF continuously maintained)~~	
Fault Reaction Function	1. Safe state achieved 2. Alarms generated on the SCADA 3. Energisation of equipment inhibited until: a. Fault cleared b. Fault reset by Safety Fault Reset pushbutton on the Control Room Console	
Reset Requirements:	1. Safe state achieved 2. All barriers detected as down	
Tests and Required Test Equipment	Validation according to 13849-2.	
Interfaces to Other Systems		
Interfaces to other SFs:	None	
Priority:	This SF shall have the highest priority and is equal in priority to SF1 and SF3	

Classification: Protected

Interfaces to Other Control Systems:	SCADA indication for safety alarms and faults via PLC The control system shall interface with the Traffic Control system to confirm the traffic barriers are down.
Environmental and EMC Considerations	
Environmental Influences:	Traffic management control equipment is installed in a IP65 enclosure Temperature ranges from -5 to 40 degrees Celsius. Temperature ranges from -5 to 40 degrees Celsius.
EMC Influences:	N/A
Applicable Standards	
Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design	Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design
Safety of machinery — Safety-related parts of control systems — Part 2: Validation	Safety of machinery — Safety-related parts of control systems — Part 2: Validation
BS EN IEC 60204-1:2018	Safety of machinery – Electrical equipment of machines – Part 1: General Requirements
Additional Information	
When Emergency Operations are enabled, this safety function shall be bypassed. A barrier override switch shall allow operations in the scenario of a barrier limit switch failure. This is to be implemented as part of the safety function, such that a failure of the override switch will not cause the safety function to be bypassed. Measures will be required to mitigate the possibility of the switch being left in the override position. E.g. automatically cancelling the override once the barriers are reopened, or having to be time-limited/ requiring a positive edge to re-trigger the override.	

7.3. SF3 – Maintenance Immobilisation

Description		
Hazard Description:	Engineer being near moving parts when the bridge is operating (entrapment, crushing)	
Description	A Maintenance Immobilisation trapped key shall be stored in the control room console, and should an engineer be required to access the bridge, the key is released to immobilise the bridge to access the equipment underneath.	
Safe State:	Bridge immobilised (Jack, Slip Block and Slew Motors de-energised)	
Performance Level Required:	PL_r= e	
Mission Time:	20 years	
Response Time and Distance		
Distance to Hazard:	N/A	
Response Time:	HPU Pumps de-energise immediately. (Category 0 Stop) Bridge Slewing VSDs motors to ramp down at fast speed to avoid damage to the bridge equipment and bridge structure. (Category 1 Stop)	
Operational Information		
Applicable Operating Modes of the Machine:	Raising:	Applicable
	Lowering:	Applicable
	Opening:	Applicable
	Closing:	Applicable
	Emergency Operation:	Not Applicable
Number of Operations Per Year:	4	
Demand Mode:	High demand (more than once per year) ~~Low demand (once per year or less)~~ ~~Continuous (SF continuously maintained)~~	
Fault Reaction Function	1. Safe state achieved 2. Alarms generated on the SCADA 3. Energisation of equipment inhibited until: a. Fault cleared b. Fault reset by Safety Fault Reset Pushbutton on the Control Room Console	
Reset Requirements:	1. Access Key Inserted into Control Room Console 2. Access Safety Key Reset pushbutton illuminated 3. Access Safety Key Reset pushbutton pressed	
Tests and Required Test Equipment	Validation according to 13849-2. Access Safety Key should be operationally tested every three months.	
Interfaces to Other Systems		
Interfaces to other SFs:	None	

Classification: Protected

Priority:	This SF shall have the highest priority and is equal in priority to SF1 and SF2
Interfaces to Other Control Systems:	HMI indication for safety alarms and faults via PLC
Environmental and EMC Considerations	
Environmental Influences:	The Maintenance Access Key is to be housed in the Control Room away from the elements. Temperature ranges from -5 to 40 degrees Celsius. Temperature ranges from -5 to 40 degrees Celsius.
EMC Influences:	N/A
Applicable Standards	
Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design	Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design
Safety of machinery — Safety-related parts of control systems — Part 2: Validation	Safety of machinery — Safety-related parts of control systems — Part 2: Validation
BS EN IEC 60204-1:2018	Safety of machinery – Electrical equipment of machines – Part 1: General Requirements
Additional Information	
It is recommended that an interlocked access gate be installed underneath the bridge that the released key would unlock. With this in place, this ensures the trapped key is released and taken with the engineer when immobilising the bridge. This then removes the vulnerability of relying on operator/engineer procedure discipline. When Emergency Operations are enabled, this safety function shall be bypassed.	

7.4. SF4 – Ultimate Open

Description		
Hazard Description:	Bridge opens beyond its range of motion causing damage to the energy chain system and rendering the bridge inoperable.	
Description	If the bridge opens beyond the operating open position, the ultimate limit switch shall be activated which shall inhibit the opening of the bridge	
Safe State:	Slew Motors de-energised	
Performance Level Required:	PL_r= e	
Mission Time:	20 years	
Response Time and Distance		
Distance to Hazard:	N/A	
Response Time:	Open direction relay de-energised instantly Bridge Slewing VSDs motors to ramp down at fast speed to avoid damage to the bridge equipment and bridge structure. (Category 1 Stop)	
Operational Information		
Applicable Operating Modes of the Machine:	Raising:	Not Applicable
	Lowering:	Not Applicable
	Opening:	Applicable
	Closing:	Not Applicable
	Emergency Operation:	Not Applicable
Number of Operations Per Year:	4	
Demand Mode:	High demand (more than once per year) ~~Low demand (once per year or less)~~ ~~Continuous (SF continuously maintained)~~	
Fault Reaction Function	1. Safe state achieved 2. Alarms generated on the SCADA 3. Energisation of Slew Motors and Open relay inhibited until: a. Fault cleared b. Fault reset by Safety Fault Reset Pushbutton on the Control Room Console	
Reset Requirements:	1. Ultimate Position Recovery Enable pushbutton illuminated 2. Ultimate Position Recovery Enable pushbutton pressed 3. Slew Motor Energised – Open direction relay still de-energised 4. Bridge slewed towards operational Open position by pressing and holding the Bridge Recovery button 5. Ultimate Open Limit Switch deactivated 6. Ultimate Position Reset pushbutton illuminated 7. Ultimate Position Reset pushbutton pressed	
Tests and Required Test Equipment	Validation according to 13849-2. Ultimate open interlock should be operationally tested every three months.	

Classification: Protected

Interfaces to Other Systems	
Interfaces to other SFs:	None
Priority:	This shall be of lower priority. SF1, SF2, and SF3 shall have a higher priority
Interfaces to Other Control Systems:	SCADA indication for safety alarms and faults via PLC
Environmental and EMC Considerations	
Environmental Influences:	The ultimate open limit switch is to be installed in the chamber and shall be exposed to the elements and will require an ingress rating of IP65 at minimum. Temperature ranges from -5 to 40 degrees Celsius.
EMC Influences:	N/A
Applicable Standards	
Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design	Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design
Safety of machinery — Safety-related parts of control systems — Part 2: Validation	Safety of machinery — Safety-related parts of control systems — Part 2: Validation
BS EN IEC 60204-1:2018	Safety of machinery – Electrical equipment of machines – Part 1: General Requirements
Additional Information	
When Emergency Operations are enabled, this safety function shall be bypassed.	

7.5. SF5 – Ultimate Close

Description		
Hazard Description:	Bridge closes beyond its range of motion causing damage to the energy chain system and rendering the bridge inoperable.	
Description	If the bridge closes beyond the operating closed position the ultimate limit switch shall be activated which shall inhibit the closing of the bridge	
Safe State:	Slew Motors de-energised	
Performance Level Required:	PL_r= e	
Mission Time:	20 years	
Response Time and Distance		
Distance to Hazard:	N/A	
Response Time:	Close direction relay de-energised instantly Bridge Slewing VSDs motors to ramp down at fast speed to avoid damage to the bridge equipment and bridge structure. (Category 1 Stop)	
Operational Information		
Applicable Operating Modes of the Machine:	Raising:	Not Applicable
	Lowering:	Not Applicable
	Opening:	Not Applicable
	Closing:	Applicable
	Emergency Operation:	Not Applicable
Number of Operations Per Year:	4	
Demand Mode:	High demand (more than once per year) ~~Low demand (once per year or less)~~ ~~Continuous (SF continuously maintained)~~	
Fault Reaction Function	1. Safe state achieved 2. Alarms generated on the SCADA 3. Energisation of Slew Motors and Close relay inhibited until: a. Fault cleared b. Fault reset by Safety Fault Reset Pushbutton on the Control Room Console	
Reset Requirements:	1. Ultimate Position Recovery Enable pushbutton illuminated 2. Ultimate Position Recovery Enable pushbutton pressed 3. Slew Motor Energised – Close direction relay still de-energised 4. Bridge slewed towards the operational Close position by pressing and holding the Bridge Recovery button 5. Ultimate Close Limit Switch deactivated 6. Ultimate Position Reset pushbutton illuminated 7. Ultimate Position Reset pushbutton pressed	
Tests and Required Test Equipment	Validation according to 13849-2. Ultimate close interlock should be operationally tested every three months.	

Classification: Protected

Interfaces to Other Systems	
Interfaces to other SFs:	None
Priority:	This shall be of a lower priority. SF1, SF2, and SF3 shall have a higher priority.
Interfaces to Other Control Systems:	SCADA indication for safety alarms and faults via PLC
Environmental and EMC Considerations	
Environmental Influences:	The ultimate close limit switch is to be installed in the chamber and shall be exposed to the elements and will require an ingress rating of IP65 at minimum. Temperature ranges from -5 to 40 degrees Celsius.
EMC Influences:	N/A
Applicable Standards	
Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design	Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design
Safety of machinery — Safety-related parts of control systems — Part 2: Validation	Safety of machinery — Safety-related parts of control systems — Part 2: Validation
BS EN IEC 60204-1:2018	Safety of machinery – Electrical equipment of machines – Part 1: General Requirements
Additional Information	
When Emergency Operations are enabled, this safety function shall be bypassed.	

Classification: Protected

LINC10089-01-02

Revision A03

SOFTWARE DESIGN SPECIFICATION

Cross Keys Swing Bridge
Electrical Upgrade

Lincolnshire County Council

Classification: Protected

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As this specification may have been designed to take account of matters which had not been considered previously, this document once approved, will take precedence over any other specification in the event of a conflict.

Approval

When this document is submitted for approval, you should ensure that you are aware of its review period which unless stated within the contract document is 5 working days. If we either receive your written approval or have not received a written response from you prior to expiry of the review period, then this document will be deemed approved. However, if we receive written comments prior to the expiry of the review period, we will deal with them appropriately.

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1. Document Details

1.1. Project Details

FCS Project Ref:	LINC10089
Project Title:	Cross Keys Swing Bridge Electrical Upgrade
Customer:	Lincolnshire County Council
Document ref:	LINC10089-01-02

1.2. Revision History

Previous issues of this document are to be destroyed or marked Superseded

Revision	Job Ref	Date	Description Of Amendment
P1.0	FES5241	25/06/2024	Initial Draft
P1.1	FES5241	26/06/2024	Updated following peer review
P02	FES5241	17/12/2024	Updated following clarified requirements
A01	FES5241	07/01/2025	Issue for Approval
A02	FES5241	29/04/2025	Updated based on changes to scope
A03	FES5241	19/05/2025	Updates based on LCC comments 08/05/2025

Table 1-1 - Revision History

Revision	Author	Date	Checked By	Date
P1.0	A Smith	25/06/2024	T Silvester	25/06/2024
P1.1	A Smith	26/06/2024	T Silvester	26/06/2024
P02	A Smith	17/12/2024	D Rosen	17/12/2024
A01	A Smith	07/01/2025	D Rosen	07/01/2025
A02	A Smith	29/04/2025	T Silvester	29/04/2025
A03	T Silvester	19/05/2025	D Rosen	22/05/2025

Table 1-2 - Author & Approval

1.3. Standards

The standards identified in the table below were referenced in the production of this document.

Reference	Description	Revision

Table 1-3 - Reference Documents

1.4. Reference Documents

The project documents identified in the table below were referenced in the production of this document.

Reference	Description	Revision
LINC10089-01-01	Function Design Specification	A03
LINC10089-01-05	User Requirement Specification	A01
LINC10089-20-12	Design Risk Assessment	A02
LINC10089-20-14	Safety Requirement Specification	A03
N/A	Electrical Manual (Dodd Group)	N/A
N/A	Operating Manual (Dodd Group)	N/A
N/A	Generator Manual (Dodd Group)	N/A

Table 1-4 - Reference Documents

1.5. Foreword

The purpose of this document is to describe and outline the functionality of the control software for the Cross Keys Swing Bridge.

This document will outline both the functionality of the control system software and the associated SCADA screens to be programmed for the Cross Keys Swing Bridge. Safety considerations are not covered within this document.

2. Glossary of Terms and Acronyms

AOP	-	Add-on Profile
CPU	-	Central Processing Unit
HMI	-	Human Machine Interface
HPU	-	Hydraulic Power Unit
I/O	-	Input/Output
IP	-	Internet Protocol
PLC	-	Programmable Logic Controller
RIO	-	Remote Input/Output
SCADA	-	Supervisory Control and Data Acquisition
VSD	-	Variable Speed Drive

3. Introduction

Fairfield Control Systems (Fairfields/FCS) have been tasked to supply the Control System elements of the Cross Keys Swing Bridge, which carries the single carriageway A17 over the River Nene. The proposed solution is an Allen-Bradley CompactLogix PLC platform including remote IO, a dedicated Safety Controller for the safety operation, and VSDs. Also included is an upgraded version of the existing SCADA system for operating and monitoring purposes.

4. Control System Architecture

The topology of the control system is summarised below:

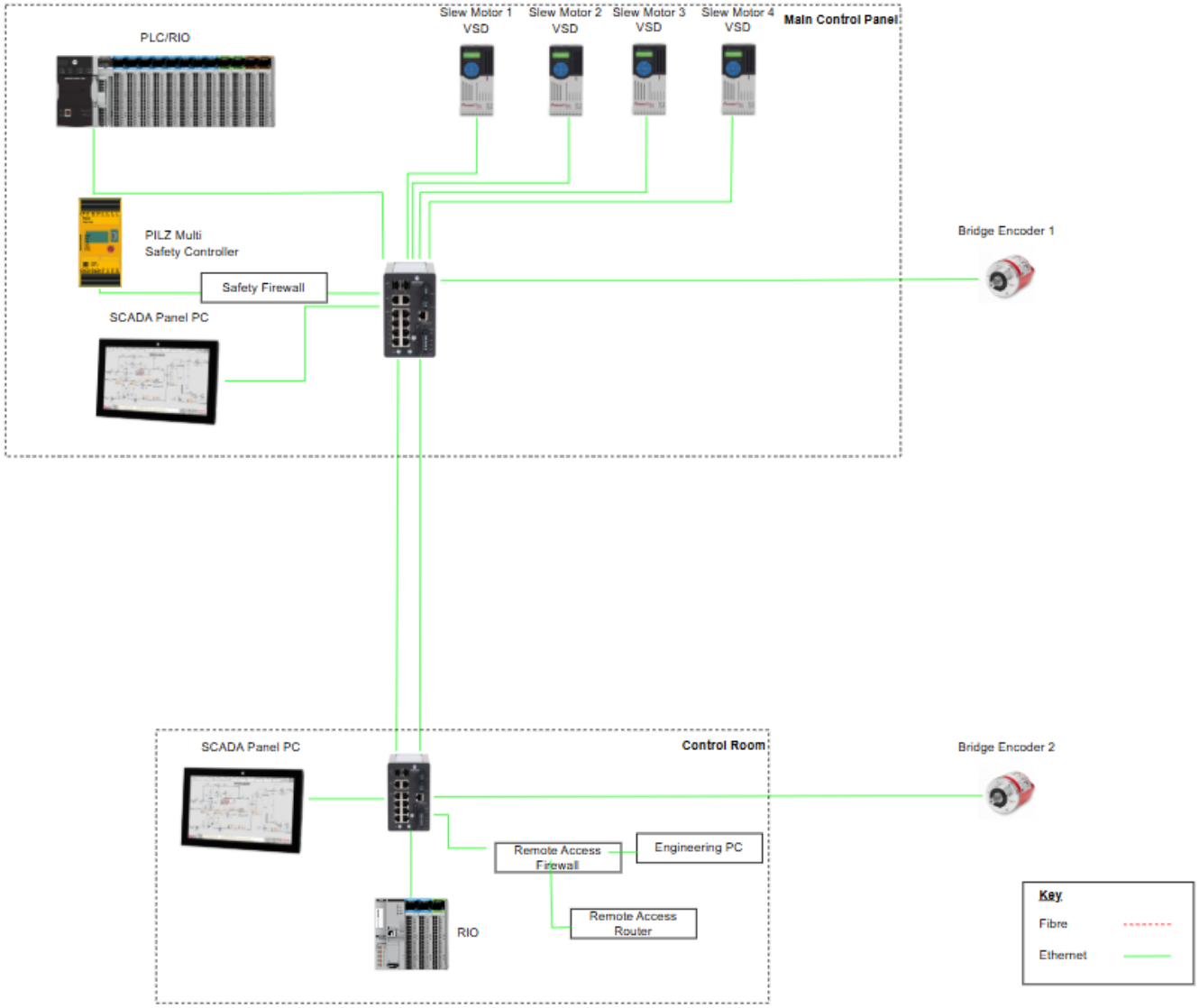


Figure 4-1 - Control System Topology

The control system comprises an Allen Bradley CompactLogix system that shall be the basis of the control system which will handle the operation of the bridge. The CompactLogix system shall utilise the Remote IO nodes located in the Main Control Panel and the Control Room via Ethernet communications.

A PILZ Multi safety controller is to be installed, which will handle the safety elements of the bridge, inhibiting operation of the bridge should an unsafe scenario occur.

Enclosures shall be installed in the Plant Room and control Room to cater for IO and instrumentation, such as encoders. The control system, including VSDs SCADA, and Safety Controller shall communicate with one another via Ethernet communications.

Classification: Protected

Two SCADAs are to be installed in the Main Control Panel, located in the Plant Room, and the Control Console in the Control Turret and shall be used for the operation and indication of the control system.

Classification: Protected

5. Communication Configuration

The following section outlines the different communication networks that are part of the Cross Keys Swing Bridge control system.

5.1. Control Network

The control network consists of the control PLC equipment, SCADA, bridge encoders, and the Slewing Motor VSDs.

Description	Device	IP Address
PLC	Allen-Bradley CompactLogix 5069-L330ER	10.62.1.20
Main MCC Safety Network Firewall	Siemens SCALANCE S615 LAN	10.62.1.1
Main MCC Switch	Allen-Bradley Stratix 5200	10.62.1.11
Control Room Switch	Allen-Bradley Stratix 5200	10.62.1.10
Control Room RIO Rack	Allen-Bradley CompactLogix 5069-AENTR	10.62.1.30
Slewing Motor 1 VSD	Allen-Bradley PowerFlex 755T	10.62.1.100
Slewing Motor 2 VSD	Allen-Bradley PowerFlex 755T	10.62.1.101
Slewing Motor 3 VSD	Allen-Bradley PowerFlex 755T	10.62.1.102
Slewing Motor 4 VSD	Allen-Bradley PowerFlex 755T	10.62.1.103
Bridge Encoder 1	TR Electronic	10.62.1.110
Bridge Encoder 2	TR Electronic	10.62.1.111
Control Room SCADA PC	Nexcom XPPC24-200A	10.62.1.60
Plant Room SCADA PC	Nexcom XPPC24-200A	10.62.1.61

Table 5-1 - IP Addresses - Control Network

5.2. Safety Network

Description	Device	IP Address
Main MCC Safety Network Firewall	Siemens SCALANCE S615 LAN	10.62.3.1
Safety Controller	PILZ PNOZmulti	10.62.3.20

Table 5-2 - IP Addresses - Safety Network

5.3. Remote Access Network

Description	Device	IP Address
Control Console Remote Access Router	Cisco 927-4P	10.62.2.1
Control Console Engineering PC	Nexcom NISE70-204	10.62.2.2
Control Console Remote Access Firewall	Siemens SCALANCE S615 LAN	10.62.2.10

Table 5-3 - IP Addresses - Remote Access Network

5.4. Network Segregation and Security

The network has been segregated into three distinct zones: Safety Network, Control Network, and Remote Access Network, with zone boundaries to be achieved using industrial firewalls. The firewall between the Safety Network and Control Network will permit traffic between the Pilz Safety Controller and the Control PLC. All other traffic will be blocked.

The firewall between the Control Network and Remote Access Network will permit traffic between the Engineering PC and the Control PLC, and also between the Engineering PC and SCADA PCs. All other traffic will be blocked.

6. PLC Control Software

6.1. Programming Software

The PLC software will be written in the latest version of Rockwell Studio 5000 Logix Designer, which will be installed on the Engineering PC. Lincolnshire County Council will retain ownership of all related perpetual licenses.

6.2. I/O Mapping

An Input Mapping routine will be created to map the physical digital and analogue inputs into internal PLC memory tags. Similarly, an Output Mapping Routine will be created to map internal PLC Memory Tags to the digital and analogue physical outputs.

6.3. Function Blocks

The PLC software will be constructed in a modular fashion, such that each piece of equipment (Jacks, Slew Motors, Slip Blocks etc.) will have a derived function block, which may be inserted into a program multiple times as determined by the individual site requirements. This approach will ensure that there is consistency, and that future expansion is readily achievable.

In the interests of achieving this, several blocks have been chosen from the Fairfields Function Block Library for utilisation.

6.3.1. VSD

The VSD block handles status monitoring and control data for Variable Speed Drives, including the setting of relevant outputs and triggering of associated alarms.

This block will be used in the control routines for all Bridge Slewing Motor VSDs.

6.3.2. Cylinder

The Cylinder block handles derivation of positions from digital sources, directional control to digital devices, the setting of relevant output and triggering of associated alarms.

This block will be used in the control routines for all Jacks and Slip Blocks.

6.3.3. HPU

The HPU block handles status monitoring and control data for Soft-Start Hydraulic Pumps, including the setting of relevant outputs and triggering of associated alarms.

This block will be used in the control routines for all HPU Pumps.

6.4. Safety Software

Safety software will run within the Safety Controller, using dedicated safety blocks.

Any communications interfacing between the Safety Controller and Control PLC will be mapped using the Safety Controller's add-on profile (AOP).

Safety software will be implemented to achieve the logic elements of the safety functions specified in the SRS.

Safety software will be arranged generally with blocks for input mapping, safety function inputs, safety function outputs, output mapping, and common functions.

6.5. Control Software

In this section the operation control software shall be described.

In normal operating conditions, the Cross Keys swing Bridge control system shall operate in SCADA mode. This is when the bridge is controlled using lever mimics on the Control Levers screen of the SCADA. In Manual Mode, the physical levers will be used instead.

6.5.1. SCADA Mode Interlocks

6.5.1.1. SCADA Open Available

The bridge is available for SCADA opening when the following conditions are true:

- Normal Operations key switch is on (i.e. Emergency Controls are not active)
- The bridge is not fully open
- No safety functions are active
- All required equipment is available, healthy, not isolated etc
- SCADA Mode is selected
- The road traffic barriers are down

6.5.1.2. SCADA Close Available

The bridge is available for SCADA closing when the following conditions are true:

- Normal Operations key switch is on (i.e. Emergency Controls are not active)
- The bridge is not fully closed
- No safety functions are active
- All required equipment is available, healthy, not isolated etc
- SCADA Mode is selected
- The road traffic barriers are down

6.5.2. Manual Mode Interlocks

6.5.2.1. Manual Open Available

The bridge is available for Manual opening when the following conditions are true:

- Normal Operations key switch is on (i.e. Emergency Controls are not active)
- The bridge is not fully open
- No safety functions are active
- All required equipment is available, healthy, not isolated etc
- Manual Mode is selected

- The road traffic barriers are down

6.5.2.2. Manual Close Available

The bridge is available for Manual closing when the following conditions are true:

- Normal Operations key switch is on (i.e. Emergency Controls are not active)
- The bridge is not fully closed
- No safety functions are active
- All required equipment is available, healthy, not isolated etc
- Manual Mode is selected
- The road traffic barriers are down

6.5.3. Operational Sequence

6.5.3.1. Opening

During operation, regardless of whether in SCADA or Manual mode, the bridge will be opened as follows:

1. The hydraulic pumps are started to supply hydraulic power to the jacks & slip blocks
2. The jacks lever is pulled to the 'Jacks Extend' position
3. The jacks extend until fully extended
4. The jacks lever is returned to its neutral position
5. The slip blocks lever is pulled to the 'Blocks Off' position
6. The slip blocks retract until fully retracted
7. The slip blocks lever is returned to its neutral position
8. The jacks lever is pushed to the 'Jacks Home' position
9. The jacks retract until fully retracted
10. The jacks lever is returned to its neutral position.
11. After a delay, the hydraulic pumps will automatically run off load
12. The bridge slew lever is pulled to either the 'Min Open Speed' or 'Open Bridge' position, depending on the speed required
13. The bridge will rotate anti-clockwise until it reaches the open position.
    a. If the Bridge Slew Lever is at "Min Open Speed" the bridge will continue at creep speed only and stop at the open position.
    b. If the Bridge Slew Lever is at the "Open Bridge" position, the bridge will initially travel at creep speed before ramping up to full speed. When the bridge enters the Open Slowdown position the bridge shall ramp down to creep before stopping at the Open position.
14. The bridge slew lever is returned to its neutral position

At any point during an open operation an active operation can be stopped by moving the associated lever to its neutral position, and the sequence can be stepped back providing the necessary interlocks are healthy.

6.5.3.2. Closing

During operation, regardless of whether in SCADA or Manual mode, the bridge will be closed as follows:

1. The locking pins foot bolt is disengaged to extend the locking pins – this is not being replaced as part of this project, so operation of the locking pins will remain manual
2. The bridge slew lever is pushed to either the 'Min Close Speed' or 'Close Bridge' position, depending on the speed required
3. The bridge will rotate clockwise until it reaches the closed position
    a. If the Bridge Slew Lever is at "Min Close Speed" the bridge will continue at creep speed only and stop at the closed position.
    b. If the Bridge Slew Lever is at the "Close Bridge" position, the bridge will initially travel at creep speed before ramping up to full speed. When the bridge enters the Close Slowdown position the bridge shall ramp down to creep before stopping at the Closed position.
4. The bridge slew lever is returned to its neutral position
5. The jacks lever is pulled to the 'Jacks Extend' position
6. The jacks extend until fully extended
7. The jacks lever is returned to its neutral position
8. The slip blocks lever is pushed to the 'Blocks On' position
9. The slip blocks extend until fully extended
10. The slip blocks lever is returned to its neutral position
11. The jacks lever is pushed to the 'Jacks Home' position
12. The jacks retract until fully retracted
13. The jacks lever is returned to its neutral position
14. The locking pins foot bolt is engaged to retract the locking pins – this is not being replaced as part of this project, so operation of the locking pins will remain manual
15. The hydraulic pumps stopped

At any point during a close operation, an active operation can be stopped and the sequence can be stepped back providing the necessary interlocking is healthy.

6.5.4. Routines List

As the software will be developed using the Fairfields Standard Software Development document, the anticipated routine list is as follows:

- Lad_0001_Input_Mapping – this routine will handle the mapping of all physical inputs to the PLC, including those on the Remote I/O unit
- Lad_0002_Set_Points – this routine will contain default setpoint values for storage and retrieval in case of power/memory loss
- LAD_0005_Analogue_Input_Processing – this routine will handle scaling of any analogue inputs into engineering units for use elsewhere in the program
- Lad_0010_Equip_Jacks_Hyd – this routine will handle the control, status, and alarms of the hydraulic pumps for the jacks on the bridge
- Lad_0020_Equip_HPU_Motors – this routine will handle the control, status, and alarms of the motors for the jacks on the bridge
- Lad_0030_Equip_Slip_Blocks – this routine will handle the control, status, and alarms of the slip blocks on the bridge
- Lad_0070_Equip_Bridge_Status_Lights – this routine will handle the control, status, and alarms of the water traffic lights on the bridge
- Lad_0100_Equip_Slew_Motor_1 – this routine will handle the control, status, and alarms of the first bridge slewing motor
- Lad_0110_Equip_Slew_Motor_2 – this routine will handle the control, status, and alarms of the second bridge slewing motor
- Lad_0120_Equip_Slew_Motor_3 – this routine will handle the control, status, and alarms of the third bridge slewing motor
- Lad_0130_Equip_Slew_Motor_4 – this routine will handle the control, status, and alarms of the fourth bridge slewing motor
- Lad_0500_System_Status – this routine combines IO to create system-wide status tags and interlocks
- Lad_0510_System_Alarms – this routine will handle system-wide alarms not covered by the individual equipment routines
- Lad_0520_System_Control – this routine will contain the sequence and operational mode controls
- Lad_0600_Comms – this routine will monitor the various communication routes in the system
- Lad_0605_Comms_Alarms – this routine will handle communication-specific alarms using the monitoring statuses
- Lad_0900_SCADA_Mapping – this routine will contain button press conditioning, setpoint confirmation, and any tag collation for display on the SCADA
- Lad_0905_Lamps – this routine manages the conditions required to drive any lamps, excluding the Water Traffic Lights
- Lad_0995_Analogue_Output_Processing – this routine will contain scaling of any engineering values required for output from the system
- Lad_1000_Output_Mapping – this routine will handle the mapping of all control system outputs to their physical counterparts

Classification: Protected

- Lad_2000_Simulation – this routine is separate from the main structure of the software, and is required to simulate physical responses to the control system outputs for testing purposes

7. SCADA Software

The existing SCADA will be migrated into FactoryTalk View Site Edition to facilitate control of the Cross Keys Swing Bridge. Operators will be able to interact with screens using the touchscreen mounted on the Control Panel.

7.1. Programming Software

The SCADA will be migrated into the latest version of FactoryTalk View Site Edition, which will be installed on the Engineering PC. Lincolnshire County Council will retain ownership of all related perpetual licenses.

7.2. Visualisation

The following elements are planned for inclusion in the SCADA.

7.2.1. Standard Elements

All screens shall have a Bottom banner and a side banner.

7.2.1.1. Bottom Banner

The bottom banner shall provide an alarm summary of any current alarms. Two navigation buttons shall also be part of the alarm banner to navigate to the Alarm Summary page and the Alarm History page.

7.2.1.2. Status Banner

The Status Banner shall always remain on the right-hand portion of the screen. This shall display the following:

System Status: This displays the generic state of the traffic management system and the bridge. The Barrier Override control button shall be migrated to the FactoryTalk View application.

Navigation Lights: This shall display the status of the nav lights. The green, amber and red light indicators shall be re-drawn as one column to mimic the actual light system. The commercial/recreational button is available for the operators to press and timestamp river traffic that passes the bridge. This shall be recorded on a new boat log page.

Screen Selection: This shall contain the navigation buttons to the take the operator to the other pages of the SCADA application.

1. **Reset Blocks:** Navigates to reset blocks page. Shall change to red if any of the Slip Blocks are in fault.
2. **Reset Jacks**: Navigates to reset jacks page. Shall change to red if any of the Jacks are in fault
3. **Reset Bridge**: Navigates to the reset Bridge page. Shall change to red colour if any of the bridge slewing equipment is in fault
4. **Blocks**: Navigates to the Blocks page. This button shall also change colour depending on the state of the blocks when the traffic barriers are down. Green for if the blocks are on, red for when the blocks are in travel and yellow for when the blocks are off.
5. **Jacks**: Navigates to the Jacks page. This button shall also change colour depending on the state of the jacks when the traffic barriers are down. Green for if the Jacks are home, red for when the jacks are in travel and yellow for when the Jacks are extended

6. **Bridge:** Navigates to the Bridge page. This button shall also change colour depending on the state of the bridge when the traffic barriers are down. Green for if the bridge is closed, red for when the bridge is in travel and yellow for when the bridge is in the open position.
7. **Override:** Navigates to the Override page
8. **Intro:** Navigates to the start-up page
9. **Levers:** Navigates to the Levers page

7.2.2. Alarm Summary Page

The alarms summary page shall display all active alarms on the control system. The Alarm Summary page shall display the date and time the alarm is triggered as well as a description of the alarm. From the Alarm Summary page, the user will be able to acknowledge and reset alarms using the associated push buttons.

7.2.3. Alarm History Page

The Alarm History page shall display all historical alarm entries for when an alarm was triggered, reset and acknowledged. All entries on the page shall display the date and time this occurred. A filter button shall also be available for the user to filter the Alarm History based on the user's requirements. Alarms shall be logged indefinitely.

7.2.4. Control Levers Page

The Control Levers page shall display the status of the Jacks, Blocks and Swing Levers. The user will click on the required lever position when operating the bridge.

SCADA Control, Manual Control and Reset Lever control buttons shall be retained. The SCADA Control button shall place the control system in SCADA control meaning the bridge is controlled exclusively using the two SCADA machines. The Manual Control button, when pressed shall control the bridge exclusively using the control levers in the Control Room. The Reset Levers button shall reset all SCADA Levers back to their neutral positions.

7.2.5. Blocks Page

The Blocks page shall display the position and fault status of the Slip Blocks.

7.2.6. Jacks Page

The Jacks page shall display the position and fault status of the Jacks and their motors.

7.2.7. Hydraulics Page

The Hydraulics page shall display the status and fault status of the Hydraulic Pumps.

7.2.8. Bridge Page

The Bridge page shall display the position of the bridge as well as status of the Slewing Motors.

7.2.9. Override Page

The Override page shall display the control overrides for the control system. Overrides can only be applied if the user is logged in with the correct login.

7.2.10. Intro Page

The Intro page shall be the first page shown when the SCADA is booted up.

7.2.11. Reset Blocks

The Reset Blocks page shall enable the user to reset any Slip Block actuator position limits.

7.2.12. Reset Bridge

The Reset Bridge page shall enable the user to reset any Bridge instrumentation faults.

7.2.13. VSD Pages

A page shall be assigned to each VSD for the Slewing Motors. This shall display more detailed diagnostics and alarms and will aid in pinpointing any faults associated with the VSDs.

7.2.14. Boat Log Page

The Boat Log Page shall display the vessels that have been logged as passing through the bridge The vessel type is logged and timestamped by pressing the Commercial/Recreational Boat button that is on the Status Banner

7.2.15. Setpoints Page

The Setpoints page shall contain several displays for equipment setpoints and scaling information, which will be modifiable with the correct level of privileges.

7.3. Security

As security is required for managing access to inputs that can affect the bridge control, the following security levels are recommended:

- View-only – when not logged in as a user, all screens (excluding the User Management screen) can be viewed but no further interaction is possible
- Operator – a common login with operator-level privileges, elements required for day-to-day operation (i.e. operation of the bridge, acknowledgement of alarms) can be interacted with in addition to any access granted by lower-level login/s
- Engineer – when logged in as a user with Engineer-level privileges, modification access will be granted to control variables (such as setpoints) in addition to any access granted by lower-level logins. This access will typically be given to Fairfields/Dodds personnel and Bridge Managers. Engineer users are assigned a login per person.
- Administrator – when logged in as a user with Administrator-level privileges, access will be granted to a User Management screen and any access provided by lower-level logins. This is the highest tier of security. Administrator logins are assigned a login per person.

Appendix A Reversing the Control Sequence

When attempting to interrupt and reverse the operational sequence, certain operational interlocks must be true before action can proceed. These are detailed below:

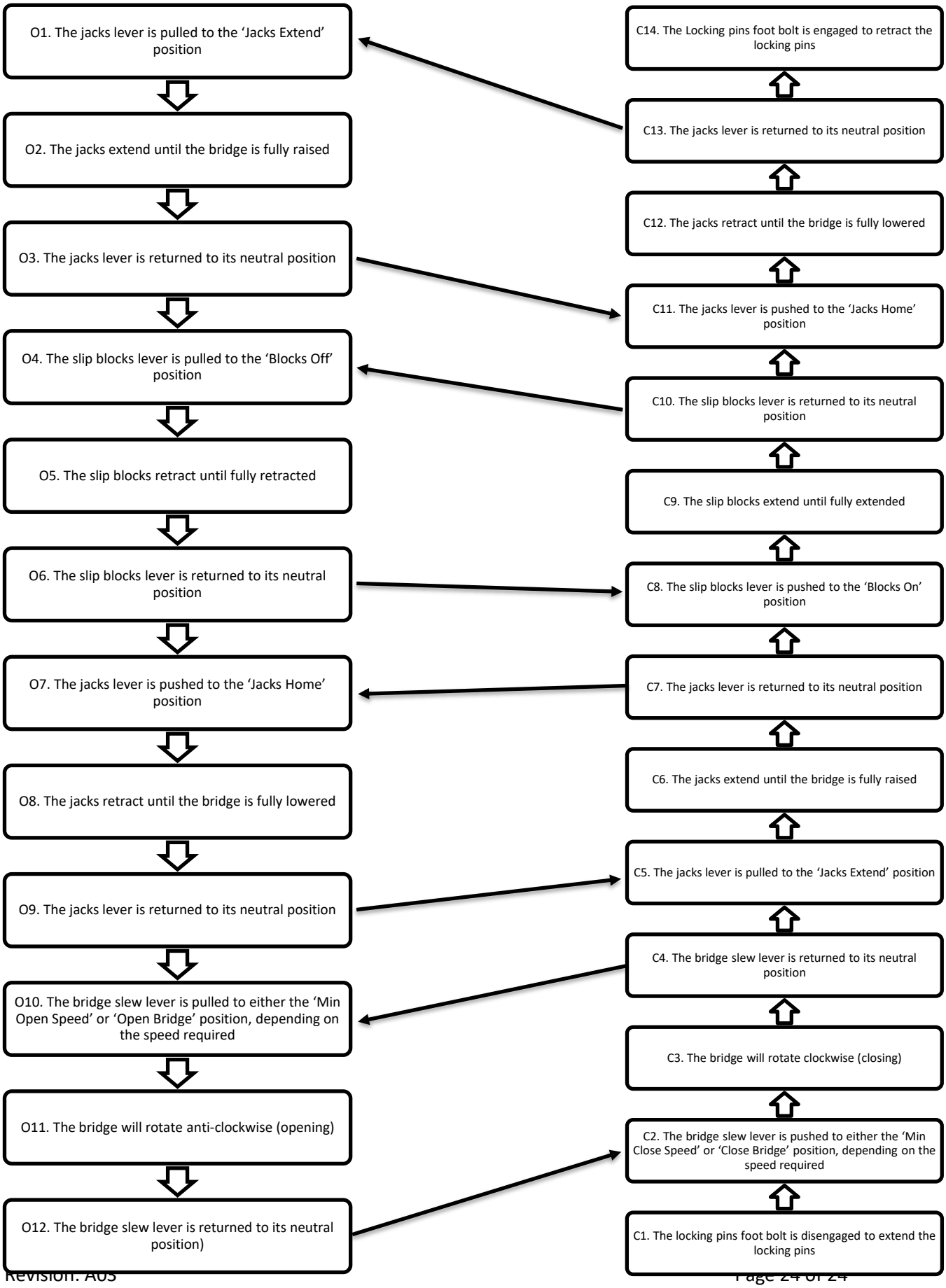
1. Extend or retract (home) jacks
    a. Bridge must be closed and not moving
    b. Hydraulic pressure must be healthy
2. Extend (blocks on) or retract (blocks off) slip blocks
    a. Bridge must be closed and not moving
    b. Bridge must be fully raised (jacks extended)
3. Open or close bridge at either full or creep speed
    a. Jacks must be retracted (homed) and the bridge lowered
    b. Slip blocks must be retracted (blocks off)
    c. Hydraulic pumps must not be running on load i.e. no Jack or Slip Block movements in progress

Some examples of this are as follows, using the sequence steps laid out in Section 6.5.3:

The operator is performing an open sequence and reaches step O9, which is returning the jacks lever to its neutral position. Before moving on to the Open lever, it is realised that the operation needs to be cancelled. As the bridge is closed and not in a move operation a close sequence can be performed starting from step C5, which is extending the jacks.

The operator is performing a close sequence and reaches step C2. While the bridge is closing, a high-priority vessel approaches that requires immediate passage. The operator must return the bridge slew lever is returned to its neutral position, and can then proceed with an open operation from step O10.

Classification: Protected



Classification: Protected