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Short Title	Alarm System Introduction
Full Title	Crosswind BLPH Project – FC Package Alarm System Introduction and Explanation
Abstract	*This document presents the details and reading guide for the FC Package Alarm System for the Crosswind BLPH project.*

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1.0 Purpose and Scope

This document presents the details and reading guide for the FC Package Alarm System for the Crosswind BLPH project.

2.0 Terminology

Table 1: List of Terminology

Abbreviation	Full Name
OT	Operational Technology
IACS	Industrial Automation and Control Systems
BLPH	Crosswind Hollandse Kust Noord Baseload Power Hub
HT	High Temperature
LT	Low Temperature
H2	Hydrogen
IsoMon	Isolation Monitor
CoolBreak	Coolant Breaker
P&ID	Process and Instrumentation Diagram
PSU	Power Supply Unit
SLD	Single Line Diagram (Electrical)
HV	High Voltage

3.0 Operator Expectations

The following is expected of the operator, which will be notified of the alarms and is responsible for reacting to the alarm codes

- Access to relevant documentation:
  - Fuel Cell Package P&ID
  - Fuel Cell Package SLD
  - Platform Safety Plan
- Understanding of the following:
  - Reading and understanding a P&ID
  - Reading and understanding a Single Line Diagram
  - Basic understanding of fuel cell package operation
  - Basic understanding of fuel cell fundamentals
  - Basic understanding of industrial control systems and electrical systems
  - Basic electrical troubleshooting knowledge is recommended.

4.0 Alarm System Introduction

An alarm is set up of several logical steps, to determine if an alarm is Active. The alarm is set up around a basic equation called the *Alarm Test*, where a process value is compared to a limit, with basic mathematical comparison-operators. An example below is shown with the Greater Than operator:

$$pv > limit$$

Here, *pv* is the Process Value – either a sensor value or a calculated value. If the equation yields True, the Alarm Test is True.

Please note that the pv and limit can be Boolean values. The operator will then always be the equality operator ('='). If the operator field is left blank, the equality operator is implicit.

When the Alarm Test is True, a timer denoted the Delay Time is started. If the Delay Time elapses, the alarm becomes Active. If the Alarm Test becomes False during the Delay Time, the Delay Time is reset. In other words, the Alarm Test must be true for the consecutive number of seconds denoted by the delay time.

An alarm can be Inactive in certain states. This means the Alarm Test is not evaluated. After the system transitions from a state where the alarm is Inactive to a state where the alarm is Active, the State Enable Delay must elapse before the Alarm Test is evaluated (and thus, before the Delay Time is started). Note that the State Enable Delay does not apply to a state transition where the alarm was Active in both states.

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5.0 Severities

The Severity has no effect on whether an alarm is Active or not, only how the system reacts to the alarm if it becomes Active. There are five different severities, from 0 to 4:

Severity 0 – Info: An information of a parameter being outside an optimal range but will not impair the system from running at full capacity. Action may be taken to restore optimal running conditions.

Severity 1 – Warning: A parameter is outside normal operating limits. System can still run, but possibly in a derated mode. Action should be planned to rectify the problem, as this parameter will likely lead to a shutdown of the system

Severity 2 – Delayed shutdown: A parameter is outside acceptable operating limits, but safe to operate for a short period. System will run normally for this short period, then perform a controlled shutdown. Problem must be rectified before a restart can be attempted.

Severity 3 – Controlled Shutdown: A parameter is outside safe operating limits. System will perform a controlled shutdown. Problem must be rectified before a restart can be attempted.

Severity 4 – Emergency Shutdown: A parameter is outside safe operating limits. This parameter would not allow a safe, controlled shutdown. Thus, the system will perform an immediate shutdown. Problem must be rectified before a restart can be attempted.

6.0 Corrective Action

The alarm list includes a column with a brief description of the suggested corrective action for each alarm. A column is also included with a yes/no indication of if the corrective action is plausible from a remote monitoring control station.

E.g., a high temperature warning might suggest reducing power requested from the FC package, which should be possible from a remote-operator station.

Another alarm might suggest inspection of a coolant system, which is not plausible from a remote-operator station.

Some alarms direct the operator to contact Ballard, either on occurrence or recurrence

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Alarm Examples

6.1 Example 1

As an example, we take alarm ID 22038. This has the following definition:

Table 2 - Alarm Example 1

ID	Sub-system	Alarm Name	Tagname	Unit	Oper-ator	Limit	Sev	Delay Time	State Enable Delay	Corrective Action	Remote Friendly
22038	LT Cooling	Return Temp High-High	=HE03+DA01-BT01	°C	>	55	3	20	0	Coolant System temperature is too high, maximum ambient temperature is 25°C	Yes

This alarm belongs to the LT Cooling subsystem and is activated if the Return Temperature becomes too high. The sensor which measures this is called =HE03+DA01-BT01. If this temperature is above 55 °C for 20 consecutive seconds, the alarm becomes Active. As it is a Severity 3 alarm, it would trigger a controlled shutdown of the LT Cooling subsystem. The Corrective action is a text for the operator, indicating what is possible to mitigate the issue – in this case waiting until the ambient temperature is reduced. The remote friendly text indicates if the alarm is plausibly fixed by a remote operator, in this case no action on the platform is needed.

6.2 Example 2

For another example, let's look at alarm 1014:

Table 3 - Alarm Example 2

ID	Sub-system	Alarm Name	Tagname	Unit	Oper-ator	Limit	Sev	Delay Time	State Enable Delay	Corrective Action	Remote Fiendly
1015	Main Control	Smoke Detector OutletB	=JA01+DA01-BQ06		=	TRUE	4	3	3	Remove the cause of smoke. Reset sensor by disconnecting from base and reconnect.	No

This alarm belongs to the Main Control System. It is activated if Smoke Detector B in the 40 ft container is activated. The detector is called =JA01+DA01-BQ06. When this detector returns TRUE (high) for 3 consecutive seconds, the alarm becomes Active. As it is a Severity 4 alarm, it will trigger an emergency shutdown of the Main Control System.

This alarm is reset by removing and reseating the smoke detector, which is not feasible by a remote operator.

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AlarmID	ID Prefix	ID Suffix	SubSystem	Alarm Name	Tagname	Unit	Operator	Limit	Severity	Description	Delay Time	State Enable Delay	Corrective Action	Remote Friendly	Modbus Address	Modbus Bit
1001	1	1	MainControl	MainSafetyOK	=LA01+UC20-KE10			FALSE	4	Main Safety needs Reset	3	3	Reset Main Safety Controller once it is safe to do so	No	1140	0
1002	1	2	MainControl	SafetymodbusCommsDriverError				TRUE	4	Safety Controller - Com Error	3	3	Inspect network connection between Safety Controllers and main controller, and fix loose cables, replace broken cables and check network switches	No	1140	1
1003	1	3	MainControl	ESTOPCustomer	<RM/BLPH Scope>			FALSE	4	E STOP BLPH Platform	3	3	ESTOP from BLPH - Correct BLPH error and reset safety system	No	1140	2
1004	1	4	MainControl	ESTOPcontrolCabinet	=LA01+UC20-SG10			FALSE	4	E STOP Control Cabinet	3	3	Release the safety button once it is safe to do so	No	1140	3
1005	1	5	MainControl	ESTOPContainerDoor	=LB02+DA01-SG23			FALSE	4	ESTOP Container Door	3	3	Release the safety button once it is safe to do so	No	1140	4
1006	1	6	MainControl	ESTOPcoolantSkid	=LB02+DA04-SG4			FALSE	4	E STOP Coolant Skid	3	3	Release the safety button once it is safe to do so	No	1140	5
1007	1	7	MainControl	EFIBusStatus1	=LA01+UC20-KE10			FALSE	4	Safety Controller - 40/10ft Com Ch 1	3	3	Inspect CANBus cables between Safety Controllers in UC20 and UC30, and fix loose cables or replace broken cables		1140	6
1008	1	8	MainControl	EFIBusStatus2	=LA01+UC20-KE10			FALSE	4	Safety Controller - 40/10ft Com Ch 2	3	3	Inspect CANBus cables between Safety Controllers in UC20 and UC30, and fix loose cables or replace broken cables		1140	7
1009	1	9	MainControl	ESTOP10ft	n/a			FALSE	4	Not Applicable	3	3	Not Applicable		1140	8
1010	1	10	MainControl	DoorRight_10ft	=LB02+DA03-BG01			FALSE	4	10ft Container - Door Right Open	3	3	Close door and check safety switch	No	1140	9
1011	1	11	MainControl	DoorLeft_10ft	=LB02+DA03-BG02			FALSE	4	10ft Container - Door Left Open	3	3	Close door and check safety switch	No	1140	10
1012	1	12	MainControl	smokeDetectorIntake	=JA01+DA01-BQ04			FALSE	4	Smoke Detector, 40ft Middle	3	3	Remove the cause of smoke. Reset sensor by disconnecting from base and reconnect.	No	1140	11
1013	1	13	MainControl	smokeDetectorOutletA	=JA01+DA01-BQ05			FALSE	4	Smoke Detector, 40ft Left	3	3	Remove the cause of smoke. Reset sensor by disconnecting from base and reconnect.	No	1140	12
1014	1	14	MainControl	smokeDetectorOutletB	=JA01+DA01-BQ06			FALSE	4	Smoke Detector, 40ft Right	3	3	Remove the cause of smoke. Reset sensor by disconnecting from base and reconnect.	No	1140	13
1015	1	15	MainControl	smokeDetector10ft	=JA01+DA03-BQ01			FALSE	4	Smoke Detector, 10ft	3	3	Remove the cause of smoke. Reset sensor by disconnecting from base and reconnect.	No	1140	14
1016	1	16	MainControl	hydrogenSensorVentIntakeok	=JA01+DA01-BQ01			FALSE	4	Hydrogen Detector, 40ft Middle	3	3	Check and fix any hydrogen leak.	No	1140	15
1017	1	17	MainControl	hydrogenSensorOutletAok	=JA01+DA01-BQ02			FALSE	4	Hydrogen Detector, 40ft Left	3	3	Check and fix any hydrogen leak.	No	1141	0
1018	1	18	MainControl	hydrogenSensorOutletBok	=JA01+DA01-BQ03			FALSE	4	Hydrogen Detector, 40ft Right	3	3	Check and fix any hydrogen leak.	No	1141	1
1019	1	19	MainControl	FCwave 1 Error				TRUE	3	FCwave 1 Control Error	0	0	Mitigate alarms in relevant subsystem	Yes	1141	2
1020	1	20	MainControl	FCwave 2 Error				TRUE	3	FCwave 2 Control Error	0	0	Mitigate alarms in relevant subsystem	Yes	1141	3
1021	1	21	MainControl	FCwave 3 Error				TRUE	3	FCwave 3 Control Error	0	0	Mitigate alarms in relevant subsystem	Yes	1141	4
1022	1	22	MainControl	FCwave 4 Error				TRUE	3	FCwave 4 Control Error	0	0	Mitigate alarms in relevant subsystem	Yes	1141	5
1023	1	23	MainControl	FCwave 5 Error				TRUE	3	FCwave 5 Control Error	0	0	Mitigate alarms in relevant subsystem	Yes	1141	6
1024	1	24	MainControl	FCwave 6 Error				TRUE	3	FCwave 6 Control Error	0	0	Mitigate alarms in relevant subsystem	Yes	1141	7
1025	1	25	MainControl	HT Cool 1 Error				TRUE	3	HT Coolant System 1 Error	0	0	Mitigate alarms in relevant subsystem	Yes	1141	8
1026	1	26	MainControl	HT Cool 2 Error				TRUE	3	HT Coolant System 2 Error	0	0	Mitigate alarms in relevant subsystem	Yes	1141	9
1027	1	27	MainControl	LT Cool Error				TRUE	3	LT Coolant System Error	0	0	Mitigate alarms in relevant subsystem	Yes	1141	10
1028	1	28	MainControl	Microgrid Error				TRUE	3	Microgrid Error	0	0	Mitigate alarms in relevant subsystem	Yes	1141	11
1029	1	29	MainControl	Nanogrid Error				TRUE	3	Nanogrid Error	0	0	Mitigate alarms in relevant subsystem	Yes	1141	12
1030	1	30	MainControl	Ventilation Error				TRUE	3	Ventilation Error	0	0	Mitigate alarms in relevant subsystem	Yes	1141	13
1031	1	31	MainControl	Climate 40ft Error				TRUE	3	40ft Climate Control Error	0	0	Mitigate alarms in relevant subsystem	Yes	1141	14
1032	1	32	MainControl	Climate 10ft Error				TRUE	3	10ft Climate Control Error	0	0	Mitigate alarms in relevant subsystem	Yes	1141	15
1033	1	33	MainControl	H2 Heating Error				TRUE	3	Hydrogen Heating System Error	0	0	Mitigate alarms in relevant subsystem	No	1142	0