AMC-1DCx/AMC-DCx-L

Digital Gas Monitor

FUNCTIONAL SAFETY MANUAL

3550449B

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Contents

List of Figures

List of Tables

1 General Information

1.1 Scope

This document provides Functional Safety information for the 1DCx family of Gas Monitors.

It describes the intended safety function, operating states, alarm and fault behavior, self-test and diagnostic monitoring, safety-relevant configuration parameters, and limitations necessary for the safe application of the product within a gas detection system.

This Functional Safety Manual is intended for system designers, integrators, installers, service personnel, and assessors who require an understanding of how the 1DCx contributes to risk reduction through detection and annunciation of hazardous gas conditions.

The 1DCx provides gas monitoring and alarm signaling only and does not perform final control or mitigation actions. Achievement of overall system safety depends on correct installation, configuration, maintenance, and appropriate response by external systems.

1.2 Product List

The products covered by this Manual are listed below

MPN	Description
AMC-1DCx-L	Digital Gas Monitor, 4 Relays, 120VAC
AMC-1DCx-L-LV	Digital Gas Monitor, 4 Relays, 24VDC
AMC-1DCx-8-LV	Digital Gas Monitor, 8 Relays, 24VDC
AMC-1DCx-12-LV	Digital Gas Monitor, 12 Relays, 24VDC
AMC-1DCx-16-LV	Digital Gas Monitor, 16 Relays, 24VDC

1.3 Revision History

Document No./Revision	Release Date	Change Description	Author(s)	Reviewed by	Approved by
3550449A	May 2026	First Release	Aaron Watkins, Bruce Wu, Dylan Griffiths, Jeremy Nesbitt	Alan MacLennan	Aaron Watkins
3550449B	June 2026	Addition of Software Modification Procedures section	Dylan Griffiths	Alan MacLennan	Aaron Watkins

1.4 Glossary

Act Delay	The delay in seconds between the gas concentration reaching an alarm setpoint, and the corresponding alarm level activating.
Alarm	Alarm is an audible, visual, or physical presentation designed to warn the instrument user that a specific level of a dangerous gas/vapor concentration has been reached or exceeded.
BAC	Building Automation and Control
BACnet	BACnet is a communication protocol specifically designed for building automation and control (BAC) systems.
BAS	Building Automation System
BMS	Building Management System
Calibration	Calibration is the procedure used to adjust the instrument for proper response.
Calibration Gas	Calibration Gas is a gas of known concentration used in adjusting and testing gas detection equipment to ensure proper function and accurate readings.
CIDR	Classless Inter-Domain Routing
DNS	Domain Name System
DHCP	Dynamic Host Configuration Protocol
Gas Concentration	Gas Concentration can be measured in: • ppm • ppb • %LFL • %LEL • % Volume
Hysteresis	A user-set difference from an alarm's setpoint prevents frequent alarm activation. Hysteresis solely impacts alarm deactivation, not its activation tied to the setpoint.
LEL	Lower explosive limit is the lowest concentration (percentage) of a gas or a vapor in air capable of combusting in the presence of an ignition source (arc, flame, heat).
LFL	Lower Flammable Limit.
LPS	Limited Power Source. LPS or Class 2 power supplies are inherently limited power supply units and is an isolated circuit which cannot provide more than 100VA of continuous apparent power under any loading condition.
MPN	Marketing Part Number. The part number that the specific monitor variation is sold under.

Min Run	The minimum time in seconds that an alarm state will remain active, even if the gas concentration has returned above/below the setpoint +/– hysteresis (based on a decreasing or increasing alarm type).
ppb	Parts Per Billion (1% volume = 10,000,000ppb)
ppm	Parts Per Million (1% volume = 10,000ppm)
Percent by volume	Concentration of gas in a mixture expressed as a percentage of total volume.
PLC	Programmable Logic Controllers
Pollution Degree	Pollution Degrees per EC 60947-1 quantifies the amount of dry pollution and condensation present in an environment Degree 1: No pollution or only dry, non-conductive pollution. The pollution has no effect on the insulation. Degree 2: Normally, only non-conductive pollution occurs, but occasional temporary conductivity due to condensation may be expected. Degree 3: Conductive pollution occurs, or dry, non-conductive pollution that becomes conductive due to condensation. Degree 4: Persistent conductivity is generated by conductive dust, rain, or snow.
Span	The difference between the highest concentration and lowest concentration.
T90	Response Time in seconds to achieve 90% gas concentration reading.
T99	Response Time in seconds to achieve 99% gas concentration reading.
TTL	Time To Live
VFD	Variable Frequency Drive
Zero Buffering	Zero buffering is a function of the monitor which forces the gas concentration reading to zero when sensor is exposed to low concentration of a gas. The zero buffer is indicated in the sensor specification.
Zero Gas	Zero gas is gas in which the target gas is not present. The presence of oxygen is required. Clean air is an excellent source for zero calibration. A known gas concentration can be entered during zero calibration.

2 Product Information

2.1 Safety Function Description

The safety function of the AMC-1DCx Digital Gas Monitor is the detection of hazardous gas concentration conditions via connected sensors and the activation of alarm signaling outputs when defined alarm thresholds are exceeded.

The safety function includes:

- Continuous acquisition of gas concentration and status data from connected field devices
- Comparison of measured values against configured alarm and fault thresholds
- Activation of audible, visual, relay, and communication-based alarm indications
- Detection and indication of internal, communication, and sensor fault conditions

The AMC-1DCx provides alarm and fault signaling only and does not itself perform final control actions such as equipment shutdown or process isolation. Final mitigation actions are performed by external systems.

2.1.1 Intended Use and Safety Boundary

The AMC-1DCx is intended for use as a gas monitoring and alarm annunciation device within an overall risk-reduction system.

The device is not intended to independently achieve a safe state or perform safety-critical control actions. External systems such as PLCs, safety relays, or building automation systems are required to act upon the alarm outputs to implement final risk-mitigation measures.

2.2 1DCx-n-LV Product Description

The AMC-1DCx Digital Gas Monitor provides a highly configurable monitoring package for a multitude of applications. Incorporating Computer-on-Module based design, it provides accuracy, durability, and ease of use within a compact package. The Monitor will work with the full range of AMC Transmitters.

2.2.1 Product Specifications

The monitor must be installed where it is not exposed to rain or water spray, and the environmental conditions are within the noted specifications. Specifications for the range of environmental conditions for which the equipment is designed including the following:

- Pollution degree 2(macro), Pollution degree 2(micro); Indoor use
- Overvoltage category II.
- Mode of operation: continuous.
- Altitude 2000m.

System	
System Warranty Period	2 Years
Power Supply	24 VDC, 6A
Relays	8, 12 or 16x DPDT, 250 VAC, 6 A
Operating Temperature	-4° to 104°F (-20° to 40° C)
Operating Pressure	13.2 – 16.2 PSI (91.2 – 111.5 kPa)
Humidity Range	15 to 90% RH, non-condensing
Enclosure Rating	IPx5
Analog Out	
Topology	Sourcing
Voltage Range	0-10 VDC
Current Range	0-20mA
Corner Frequency	300 kHz
Analog In	
Voltage Range	0-30 VDC
Current Range	0-20 mA
Corner Frequency	250 kHz
Real Time Clock (RTC)	
Battery Size	CR1025, Field Replaceable. 3V Lithium; 30mAh
Expected Battery Life	> 8 Years

NOTE: For DC (24V) inputs the Monitor may only be powered by a power supply unit with a limited energy electric circuit in accordance with CAN/CSA C22.2 No. 61010-1-12 and ANSI/UL 61010-1, or Class 2 as defined in the Canadian Electrical Code C22.1, Section 16-200 and/or National Electrical Code (NFPA 70), article 725.121

2.2.2 External View

Figure 2-1 1DCx External View

1	Enclosure	Enclosure and Lid Assembly, UV Stabilized Polycarbonate, 17.75" L x 16.27" W X 7.41"H (451 x 413 x 188 mm)
2	Touchscreen Display	The LCD HDMI Touchscreen Display provides interface for monitor status and configuration menus.
3	Product Nameplate	Product label lists all product certifications and rating information.

2.2.3 Internal View

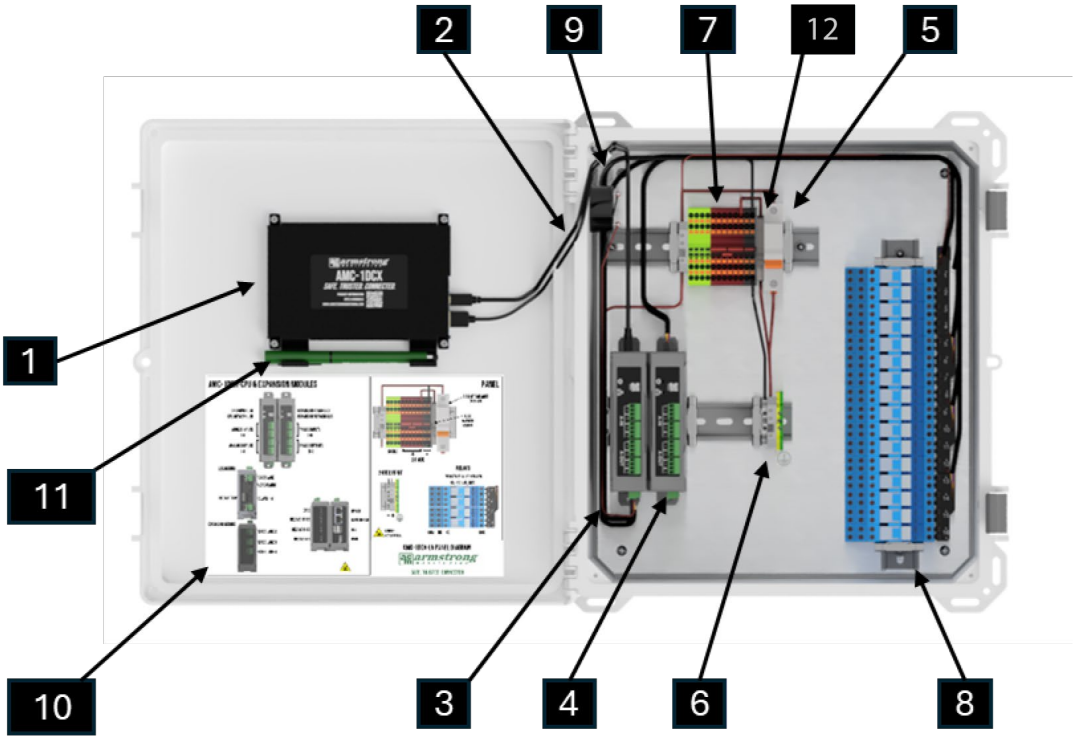

Figure 2-2 1DCx Internal View

1	HDMI Display	HDMI Display and Protective Cover **Note**: The Cover Incorporates Location for Storing Stylus.
2	Display Cables	HDMI and USB Cables Connecting Display to CPU Module
3	CPU Module	CPU Module
4	EXP Module	Expansion Module
5	Circuit Breaker	3A Circuit Breaker
6	Input Power Terminal	Terminal Blocks for DC Power and Ground Terminations
7	Power and Shield Terminal	Terminal Blocks for DC Power and Cable Shield Terminations
8	Relays	DPDT 6A 250VAC Relays
9	Buzzer	Provides Audible Indication Upon Alarm State
10	Product Label	Product Information Label
11	Stylus/Pen	A stylus/pen for the touchscreen display
12	Fuse and Fuse Holder	Fuse Holder with 5 A Fuse and Spare Fuse for Transmitters and Accessories

2.3 1DCx-L Product Description

The AMC-1DCx-L Digital Gas Monitor provides a highly configurable monitoring package for a multitude of applications. Incorporating Computer-on-Module based design, it provides accuracy, durability, and ease of use within a compact package. The Monitor will work with the full range of AMC Transmitters.

2.3.1 Product Specifications

The monitor must be installed where it is not exposed to rain or water spray, and the environmental conditions are within the noted specifications. Specifications for the range of environmental conditions for which the equipment is designed including the following:

- Pollution degree 2(macro), Pollution degree 2(micro); Indoor use
- Overvoltage category II.
- Mode of operation: continuous.
- Altitude 2000m.

System	
System Warranty Period	2 Years
Power Supply	120 VAC +/- 10%, 60 Hz, 75 VA or 24 VDC, 3A
Relays	4x DPDT, 250 VAC, 6 A
Operating Temperature	-4° to 104°F (-20° to 40° C)
Operating Pressure	13.2 – 16.2 PSI (91.2 – 111.5 kPa)
Humidity Range	15 to 90% RH, non-condensing
Enclosure Rating	IPx5
Analog Out	
Topology	Sourcing
Voltage Range	0-10 VDC
Current Range	0-20mA
Corner Frequency	300 kHz
Analog In	
Voltage Range	0-30 VDC
Current Range	0-20 mA
Corner Frequency	250 kHz
Real Time Clock (RTC)	
Battery Size	CR1025, Field Replaceable. 3V Lithium; 30mAh
Expected Battery Life	> 8 Years

NOTE: For DC (24V) inputs the Monitor may only be powered by a power supply unit with a limited energy electric circuit in accordance with CAN/CSA C22.2 No. 61010-1-12 and ANSI/UL 61010-1, or Class 2 as defined in the Canadian Electrical Code C22.1, Section 16-200 and/or National Electrical Code (NFPA 70), article 725.121

2.3.2 External View

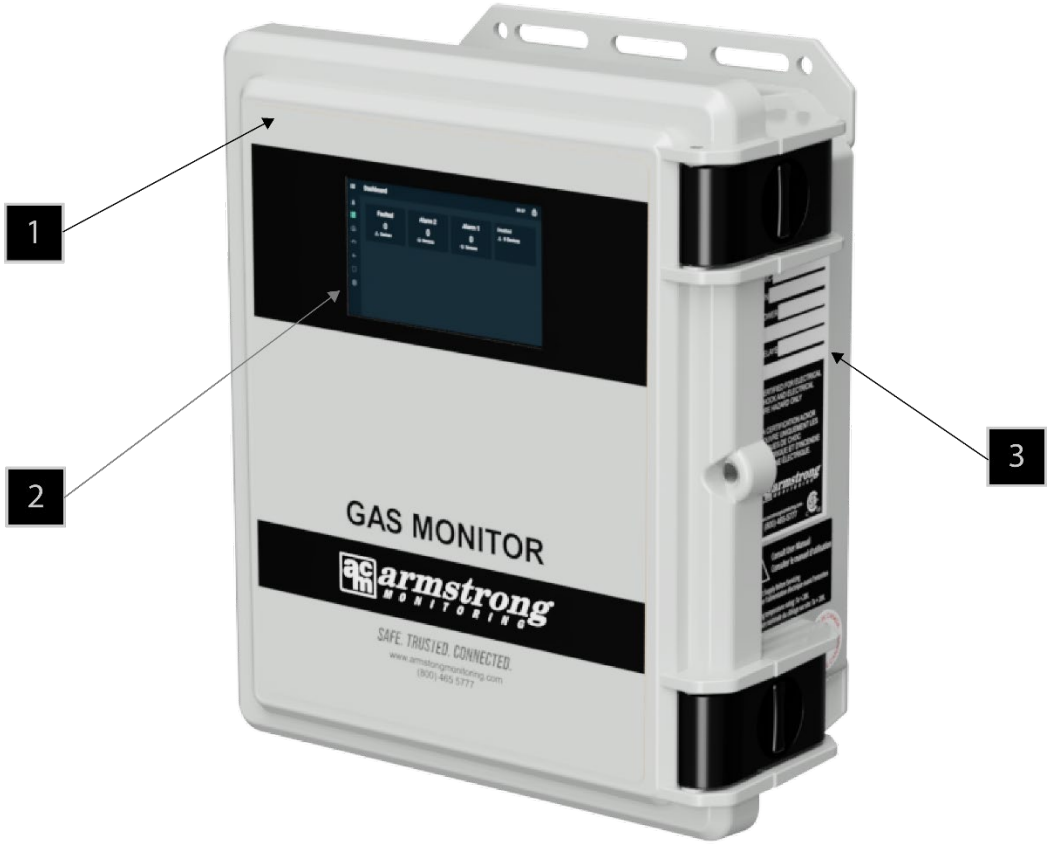

Figure 2-3 1DCx-L External View

1	Enclosure	Enclosure and Lid Assembly, UV Stabilized Polycarbonate, 11.750” L x 9.980” W x 5.460” (300mm x 250mm x 140mm)
2	Touchscreen Display	The LCD HDMI Touchscreen Display provides interface for monitor status and configuration menus.
3	Product Nameplate	Product label lists all product certifications and rating information.

2.3.3 Internal View

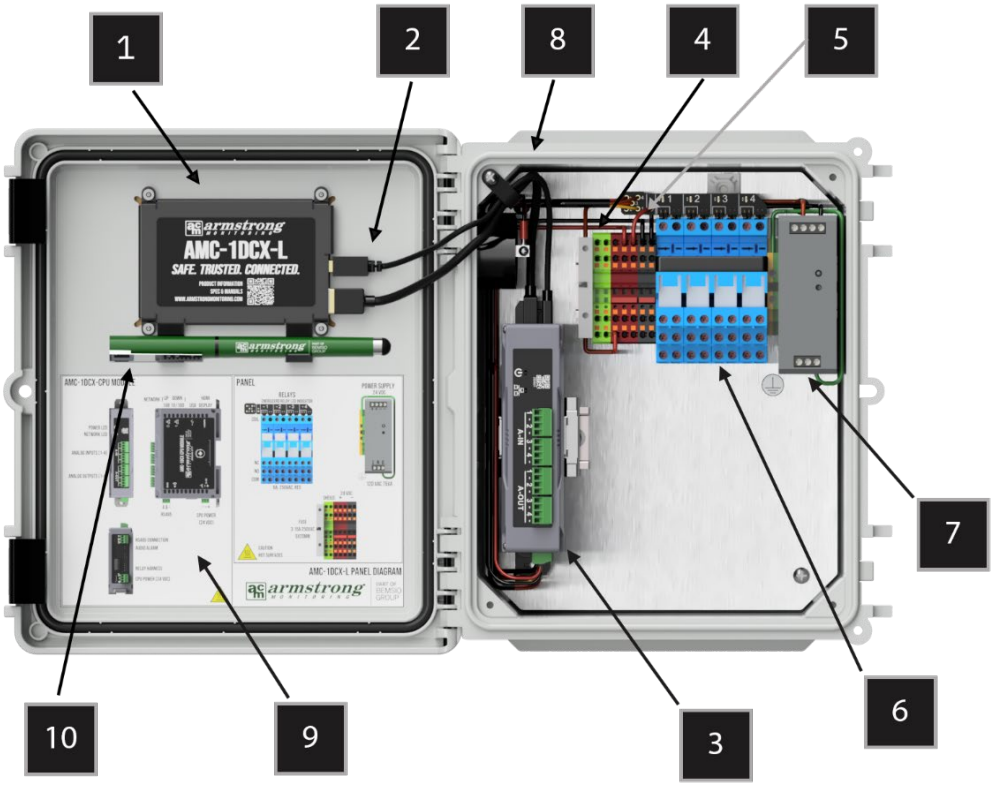

Figure 2-4 1DCx-L Internal View

1	HDMI Display	HDMI Display and Protective Cover **Note**: The Cover Incorporates Location for Storing Stylus.
2	Display Cables	HDMI and USB Cables Connecting Display to CPU Module
3	CPU Module	CPU Module
4	Fuse and Fuse Holder	Fuse Holder with 3.15 A Fuse and Spare Fuse
5	Power and Shield Terminal	Terminal Blocks for DC Power and Cable Shield Terminations
6	Relays	DPDT 6A 250VAC Relays
7	Power Supply	AC/DC Power Supply, 24 VDC, 3A Output
8	Buzzer	Provides Audible Indication Upon Alarm State
9	Product Label	Product Information Label
10	Stylus/Pen	A stylus/pen for the touchscreen display

3 Parameters

3.1 Safety-Relevant Configuration Parameters

Only a subset of system parameters directly affects the safety function. Safety-relevant parameters are those that influence alarm activation, fault detection, or output behavior.

Parameter	Safety Relevance	Safe Limits / Constraints	Misconfiguration Impact
Alarm Setpoints (Alarm1/2/3, Set Point)	Defines threshold at which hazardous gas levels are detected and mitigation actions are initiated	Must be within sensor range (Zero Scale ≤ Set Point ≤ Full Scale); must maintain correct ordering (e.g., Alarm1 < Alarm2 < Alarm3); must align with sensor type characteristics	Incorrect configuration of alarm setpoints may delay or prevent hazard detection; alarms may trigger too late, too early, or not at all
Alarm Delay	Prevents transient spikes from triggering alarms; ensures stable detection	Limited to defined ranges (e.g., 0–3600 seconds) and must not exceed acceptable response time for hazards	Excessive delay may prevent timely response to hazards; insufficient delay may cause nuisance alarms
Alarm Hysteresis	Prevents oscillation of alarm states near threshold values	Typically constrained (e.g., ~2–5% of sensor span) and derived from sensor type scaling	Too low → alarm chattering; too high → delayed alarm clearing or masking of hazardous trends
Sensor Scaling (Zero Scale, Full Scale)	Determines correct interpretation of sensor readings used for safety decisions	Full Scale must exceed Zero Scale; values must match physical sensor characteristics	Incorrect scaling leads to inaccurate readings, which may cause failure to detect hazardous conditions
Fault Limit (sensor fault detection)	Detects sensor failures (e.g., negative drift, invalid readings)	Typically below Zero Scale (e.g., ~−12.5% of span); must remain within validated calculation bounds	Sensor faults may go undetected, resulting in false “safe” conditions or excessive fault alarms
Zero Buffer	Provides tolerance near zero to prevent false alarms or faults	Typically small percentage of span (e.g., ~2%)	Too small → nuisance alarms; too large → reduced sensitivity to low-level hazards

Relay Minimum Run Time	Ensures safety outputs (e.g., fans, valves) operate long enough to mitigate hazards	Discrete predefined values (e.g., 0, 300, 600, 900 seconds)	Minimum run time prevents transient missed alarms; if too low → mitigation may be ineffective; if too high → unnecessary prolonged activation
Relay Post Run Time	Maintains mitigation action after alarm clears	Must be > 0 and within defined operational limits	If too short → hazard may persist after outputs stop; if too long → energy/equipment impact
Relay Normal State	Defines fail-safe behavior of outputs (energized/de-energized)	Must align with system safety design (fail-safe vs fail-operational)	Incorrect configuration may cause unsafe conditions during power loss or faults
Relay Latching Configuration	Determines whether alarms must be manually reset	Must match site safety procedures and regulatory expectations	Improper latching may prevent clearing alarms or allow unsafe automatic reset
Alarm-to-Relay Mapping	Defines which mitigation outputs activate during alarms	Each alarm must be mapped to appropriate relays; fault relays must be assigned	Alarm detected without corresponding output activation → loss of hazard mitigation
Zone Configuration (sensor grouping, aggregation)	Aggregates multiple sensors for coordinated alarm decisions	Sensor assignments must be valid; aggregation type (peak/average) must reflect application	Incorrect grouping may mask localized hazards or cause unnecessary global alarms
Service Mode	Allows maintenance and configuration without triggering outputs	Time-limited (e.g., auto-exit ≤ 1 hour); must be clearly indicated; restricted access	Service mode disables outputs → safety function degraded; hazards may not trigger alarms during this mode
Power-Up Alarm Delay	Prevents alarms during system startup stabilization	Limited duration; enabled only during startup or controlled conditions	Excessive delay may prevent detection of hazards immediately after startup
Polling / Sampling Interval	Determines how frequently sensor data is updated	Must be within defined sampling intervals; must not exceed detection time requirements	Slow polling may delay hazard detection; excessive changes may introduce instability

BACnet Device ID / Network Settings	Enables communication of alarms/faults to external systems	Must comply with BACnet limits; valid IP/network configuration required; restart required after changes	Misconfiguration may prevent alarm transmission to external systems or monitoring platforms
BACnet Port / BBMD / TTL Settings	Controls communication routing and device visibility	Must remain within allowed port ranges and valid addressing formats	Loss of network communication or unintended network conflicts
Modbus Address / Channel Configuration	Ensures correct communication with field devices	Address range typically 1–247; channel/device limits must be enforced	Address conflicts may result in incorrect or lost sensor data
Configuration Validation / Integrity	Ensures only valid configurations are applied to safety system	Configuration must pass validation before acceptance; relationships must remain consistent	Invalid configurations may cause undefined behavior, loss of alarms, or incorrect system operation
Fault Relay Assignment	Ensures system-level faults activate mitigation devices	Must assign at least one relay for fault indication	Fault conditions may not trigger any response if unassigned
Title 24 / Advanced Fault Conditions	Detects abnormal sensor behavior over time (e.g., drift, calibration issues)	Time thresholds (e.g., multi-hour conditions) must remain enforced	Advanced faults may not be detected, reducing reliability of safety system

The above parameters are safety-critical as they directly influence hazard detection, alarm annunciation, and mitigation response.

Configurable limits are enforced through validation logic and constrained ranges; however, incorrect configuration may degrade system performance or disable safety functions.
In particular:

- **Incorrect configuration of alarm setpoints may delay or prevent hazard detection**
- **Minimum run time prevents transient missed alarms and ensures effective mitigation**
- **Service mode disables outputs and therefore degrades the safety function while active**

Therefore, configuration access is controlled, validated, and intended for qualified personnel only.

Other configuration parameters relating to display behavior, communication settings, naming, or identification do not directly affect the safety function and are considered non-safety-related.

3.2 Lock Screen

Field Label	Input Type	Constraints
Password	Text	≤ 100 characters
New Password	Text	≤ 100 characters

3.3 Sensors

Add Sensor Wizard

Field Label	Input Type	Constraints
Modbus Address	Numeric	1–247

Sensors – Details / Edit

Field Label	Input Type	Constraints
Modbus Address	Numeric	1–247
Number of Alarm Levels	Numeric	1-3

3.4 Sensor Alarm Set Points

Universal Physical Range Constraint
All alarm set points must first satisfy the physical range of the sensor:
Zero Scale ≤ Set Point ≤ Full Scale

Error Message:
"Invalid alarm set point. Valid range is {Zero Scale} to {Full Scale}."

Increasing Alarms

Alarms trigger when values **rise above** setpoints.

Relationship: Alarm 1 ≤ Alarm 2 ≤ Alarm 3

Editing	Validation Rule	Error Message
Alarm 1	Must be ≤ Alarm 2	Invalid alarm set point. Alarm 1 must be less than or equal to Alarm 2.
Alarm 1	Must be ≤ Alarm 3	Invalid alarm set point. Alarm 1 must be less than or equal to Alarm 3.
Alarm 2	Must be ≥ Alarm 1	Invalid alarm set point. Alarm 2 must be greater than or equal to Alarm 1.
Alarm 2	Must be ≤ Alarm 3	Invalid alarm set point. Alarm 2 must be less than or equal to Alarm 3.
Alarm 3	Must be ≥ Alarm 1	Invalid alarm set point. Alarm 3 must be greater than or equal to Alarm 1.
Alarm 3	Must be ≥ Alarm 2	Invalid alarm set point. Alarm 3 must be greater than or equal to Alarm 2.

Decreasing Alarms

Alarms trigger when values **fall below** setpoints.

Relationship: Alarm 1 ≥ Alarm 2 ≥ Alarm 3

Editing	Validation Rule	Error Message
Alarm 1	Must be ≥ Alarm 2	Invalid alarm set point. Alarm 1 must be greater than or equal to Alarm 2.
Alarm 1	Must be ≥ Alarm 3	Invalid alarm set point. Alarm 1 must be greater than or equal to Alarm 3.
Alarm 2	Must be ≤ Alarm 1	Invalid alarm set point. Alarm 2 must be less than or equal to Alarm 1.
Alarm 2	Must be ≥ Alarm 3	Invalid alarm set point. Alarm 2 must be greater than or equal to Alarm 3.
Alarm 3	Must be ≤ Alarm 1	Invalid alarm set point. Alarm 3 must be less than or equal to Alarm 1.
Alarm 3	Must be ≤ Alarm 2	Invalid alarm set point. Alarm 3 must be less than or equal to Alarm 2.

Windowed Alarms

Alarms trigger when values are **outside a range** (below Alarm 1 OR above Alarm 2).

Relationship: Alarm 1 < Alarm 2

Editing	Validation Rule	Error Message
Alarm 1 (Lower Bound)	Must be < Alarm 2	Invalid alarm set point. Alarm 1 (lower bound) must be less than Alarm 2 (upper bound).
Alarm 2 (Upper Bound)	Must be > Alarm 1	Invalid alarm set point. Alarm 2 (upper bound) must be greater than Alarm 1 (lower bound).
Alarm 3	Not used	N/A

Unless otherwise configured through minimum run time and hysteresis settings, alarms automatically clear when the measured value returns within the defined non-alarm range.

3.5 Relays

Add Relay Wizard

Field Label	Input Type	Constraints
Modbus Address	Numeric	1–247

Relays – Details / Edit

Field Label	Input Type	Constraints
Modbus Address	Numeric	1–247

3.6 Analog Outputs

Add Analog Output Wizard

Field Label	Input Type	Constraints
Scale Factor	Numeric	0.001-1000
Modbus Address	Numeric	1–247

Analog Outputs – Details / Edit

Field Label	Input Type	Constraints
Scale Factor	Numeric	0.001-1000
Modbus Address	Numeric	1–247

Analog Outputs – Bulk Configuration

Field Label	Input Type	Constraints
Scale Factor	Numeric	0.001-1000

3.7 Zones

Zones – Add / Edit

Field Label	Input Type	Constraints
Zone Name	Text	≤ 25 characters; must be unique
Sample Period	Numeric	0-60

Zones – Bulk Configuration

Field Label	Input Type	Constraints
Sample Period	Numeric	0-60

3.8 Bulk / Utility Dialogs

Duplication Dialog

Field Label	Input Type	Constraints
Number of times to duplicate	Numeric	Total of new devices created as a result of duplication must be below 1482

Auto-Increment Dialog

Field Label	Input Type	Constraints
Starting Address	Numeric	1–247

3.9 System / General Settings

Field Label	Input Type	Constraints
Site Name	Text	≤ 100 characters

3.10 Network Settings

Field Label	Input Type	Constraints
Hostname	Text	RFC hostname rules
IPv4 Address	Text	Valid IPv4
Gateway	Text	Valid IPv4
DNS Server	Text	Valid IPv4

3.11 BACnet Settings

Field Label	Input Type	Constraints
Device Name	Text	≤ 100 characters
Device ID	Numeric	0-4194302
Port	Numeric	47808-47823, 59152–65535
BBMD Address	Text	IP address
Foreign Device TTL	Numeric	0-65535

3.12 Sensor Types

The parameters defined in this section establish sensor-type–specific configuration values that influence sensor behavior and alarm evaluation. To protect the integrity of the safety function, these parameters are restricted to authorized service personnel and are not editable during normal operation.

Field Label	Input Type	Constraints
Zero Scale	Numeric	0 - 100
Full Scale	Numeric	**Unit-Specific Limits:** • **ppm, Pa, psi:** 0 to 10,000 • **%LEL, %LFL, %vol, %RH, DiffP, %FS:** 0 to 100 • **DegC:** -150 to 150 • **" WC (inches water column):** -10 to 100
Zero Buffer	Numeric	Lower limit: 0 Upper limit: 25% of Full Scale
Fault Limit	Numeric	Lower limit: –25% of Full Scale Upper limit: 0
Alarm Hysteresis	Numeric	Lower limit: -5% of Full Scale Upper limit: 5% of Full Scale

3.13 Sensor Type Alarm Set Points

Sensor Type Alarm Set Points serve as template values that define the default number of alarms and corresponding threshold values for sensors of that type.

Upon sensor creation or sensor type assignment, these values are inherited by the sensor and stored as sensor-specific alarm setpoints. The safety function evaluates alarm conditions exclusively based on the sensor-specific alarm setpoints.

Modifying Sensor Type Alarm Set Points does not retroactively alter the alarm configuration of existing sensors.

All alarm set points must first satisfy the **physical range constraint**:
Zero Scale ≤ Set Point ≤ Full Scale

Increasing Alarms

Alarms trigger when values **rise above** setpoints.
Relationship: Alarm 1 ≤ Alarm 2 ≤ Alarm 3

Editing	Must Be	Compared To	Error Message
Alarm 1	≤	Alarm 2	Alarm 1 must be less than or equal to Alarm 2.
Alarm 1	≤	Alarm 3	Alarm 1 must be less than or equal to Alarm 3.
Alarm 2	≥	Alarm 1	Alarm 2 must be greater than or equal to Alarm 1.
Alarm 2	≤	Alarm 3	Alarm 2 must be less than or equal to Alarm 3.
Alarm 3	≥	Alarm 1	Alarm 3 must be greater than or equal to Alarm 1.
Alarm 3	≥	Alarm 2	Alarm 3 must be greater than or equal to Alarm 2.

Decreasing Alarms

Alarms trigger when values **fall below** setpoints.

Relationship: Alarm 1 ≥ Alarm 2 ≥ Alarm 3

Editing	Must Be	Compared To	Error Message
Alarm 1	≥	Alarm 2	Alarm 1 must be greater than or equal to Alarm 2.
Alarm 1	≥	Alarm 3	Alarm 1 must be greater than or equal to Alarm 3.
Alarm 2	≤	Alarm 1	Alarm 2 must be less than or equal to Alarm 1.
Alarm 2	≥	Alarm 3	Alarm 2 must be greater than or equal to Alarm 3.
Alarm 3	≤	Alarm 1	Alarm 3 must be less than or equal to Alarm 1.
Alarm 3	≤	Alarm 2	Alarm 3 must be less than or equal to Alarm 2.

Windowed Alarms

Alarms trigger when values are **outside a defined range**.

Relationship: Alarm 1 < Alarm 2 (defines window boundaries)

Editing	Must Be	Compared To	Error Message
Alarm 1	<	Alarm 2	Invalid alarm setpoint. Alarm 1 (lower bound) must be less than Alarm 2 (upper bound).
Alarm 2	>	Alarm 1	Invalid alarm setpoint. Alarm 2 (upper bound) must be greater than Alarm 1 (lower bound).

Key Difference:

No Alarm 3 validation for windowed sensors

Only validates the relationship between Alarm 1 and Alarm 2

Alarm 3 is **not validated** against other alarms in windowed mode

4 System Inputs and Outputs

This section defines all the system operational inputs and outputs and describes how the inputs affect system alarming and output signaling.

4.1 System Inputs

The monitor collects sensor readings from both Modbus devices and local analog input channels based on the configured settings. Readings obtained from Modbus devices are inherently digital. Signals from local analog input channels are converted to digital values via the onboard A/D circuitry and translated into corresponding sensor readings using a calibrated linear regression model. This conversion applies when the analog input channels are configured within one of the supported ranges:

- 0–10 V
- 2–10 V
- 0–20 mA
- 4–20 mA

The following tables show the relationship between all possible sensor reading values and the device status, system state and system indication.

4.1.1 Sensor Reading & Status

4.1.1.1 Modbus sensors and local analog input sensors with voltage or current range

*Only if the sensor has 3 alarm set points.

Reading	Sensor Status	System State	UI Status
reading < fault limit	Negative drift fault	Fault	Fault level
Fault limit <= reading < alarm 1	Normal	Normal	Normal
Alarm Set Point (SP) 1 <= reading < alarm SP 2	Alarm 1	Normal	Alarm 1
Alarm SP 2 <= reading < 110% range (SP 3*)	Alarm 2	Normal	Alarm 2
Alarm SP 3* <= reading < 110% range*	Alarm 3	Normal	Alarm 3
110% Range <= reading	Over range fault	Fault	Over range

Table 4-1 Sensor reading and status for Modbus sensors and local analog input sensors with voltage or current range

4.1.1.2 Local Analog Input Sensors with Multidrop Voltage Mode

If the local analog input channels are configured to have a range as multidrop voltage or multidrop current, the raw voltage or current signals are directly evaluated for alarming and fault. The following two tables show the relationships between input signals and pre-defined alarm set points and fault thresholds.

Reading	Sensor Status	System State	UI Status
reading < 0.5V	Negative drift fault	Fault	Fault level
0.5V<= reading < 1.5V	Normal	Normal	Normal
1.5V <= reading < 2.5V	Alarm 1	Normal	Alarm 1
2.5V <= reading < 3.5V	Alarm 2	Normal	Alarm 2
3.5V <= reading	Over range fault	Fault	Over range

Table 4-2 Sensor reading and status for local analog input sensors with multidrop voltage mode

4.1.1.3 Local Analog Input Sensors With Multidrop Current Mode

Reading	Sensor Status	System State	UI Status
reading < 2mA	Negative drift fault	Fault	Fault level
2mA<= reading < 6mA	Normal	Normal	Normal
6mA <= reading < 10mA	Alarm 1	Normal	Alarm 1
10mA <= reading < 13mA	Alarm 2	Normal	Alarm 2
13mA <= reading	Over range fault	Fault	Over range

Table 4-3 Sensor reading and status for local analog input sensors with multidrop current mode

4.2 System Outputs

The monitor is equipped with both analog outputs and digital outputs (relays). These outputs are configured on a per-zone basis, such that each output is controlled by the sensor inputs and associated statuses within the same zone. The behavior of the analog outputs is determined using a configurable algorithm, which can be based on either peak or average sensor readings.

4.2.1 Analog Outputs

The Modbus analog output device is limited to a fixed signal range of 4–20 mA. In contrast, the local analog output channels support multiple configurable signal ranges, including 0–10 V, 2–10 V, 0–20 mA, 4–20 mA, multidrop voltage, and multidrop current modes.

The following tables define the relationship between analog output values and faults/system status for each supported signal range.

4.2.1.1 0-10V Range

Fault/System Status	Output Value	UI Status
No fault in zone, calculated AO value is [0, 10V]	0V <= value <= 10V	Normal
Fault in Zone	0V	Fault level
No fault in zone, value < 0V	0V	Under range
Value > 10V	Min (value, 11V)	Over range

Table 4-4 Relationship between analog output values and faults for 0-10V range

4.2.1.2 2-10V Range

Fault/System Status	Output Value	UI Status
No fault in zone, calculated AO value is [2, 10V]	2V <= value <= 10V	Normal
Fault in Zone	1V	Fault level
No fault on zone, value < 2V	value	Under range
Value > 10V	Min (value, 11V)	Over range

Table 4-5 Relationship between analog output values and faults for 2-10V Range

4.2.1.3 0-20mA range

Fault/System Status	Output Value	UI Status
No fault in Zone, calculated AO value is [0, 20mA]	0mA <= value <= 20mA	Normal
Fault in Zone	0mA	Fault level
No fault in zone, value < 0mA	0mA	Under range
Value > 20mA	Min (value, 22mA)	Over range

Table 4-6 Relationship between analog output values and faults for 0-20mA range

4.2.1.4 4-20mA range

Fault/System Status	Output Value	UI Status
No fault in Zone, calculated AO value is [4, 20mA]	4mA <= value <= 20mA	Normal
Fault in Zone	2mA	Fault level
No fault in zone, value < 4mA	value	Under range
Value > 20mA	min(value, 22mA)	Over range

Table 4-7 Relationship between analog output values and faults for 4-20mA range

4.2.1.5 Multidrop Current Mode

Fault/System Status	Output Value	UI Status
No fault in zone, normal	4 mA	Normal
No fault in zone, Alarm 1	8 mA	Normal
No fault in zone, Alarm 2	12 mA	Normal
Fault in zone	0 mA	Fault level

Table 4-8 Relationship between analog output values and faults for multidrop current mode

4.2.1.6 Multidrop Voltage Mode

Fault/System Status	Output Value	UI Status
No fault in zone, normal	1V	Normal
No fault in zone, alarm 1	2V	Normal
No fault in zone, alarm 2	3V	Normal
Fault in Zone	0V	Fault level

Table 4-9 Analog output values for multidrop voltage mode

4.2.2 Total error from Analog A/D and D/A

The A/D analog inputs and D/A analog outputs are within ±5% Measuring Range.
All channels of the DCx analog inputs, A/D, and outputs, D/A are calibrated at the time of manufacture. A 10 bit ADC and an 8bit DAC are used resulting in small quantization errors.

$$Maximum\ Quantization\ Error = \frac{(v_H - v_L)}{2(2^n)}$$

Where:
n = number of bits of resolution of the ADC

Example: VH=3V, VL=0V, n=10: --> 1.465 mV
Example VH=10V, VL=0V, n=8: --> 5.8mV

The temperature changes on the DAC will result in a few ppm ~-3ppm.
Aging of components will result is very little change over lifetime of product.

4.2.3 Relays

The relays of the system can be triggered by sensor alarms, zone faults, and system faults if the relays are configured to link with certain sensor alarms and/or faults.

5 System States

This section defines all the system operating states and describes their effect on sensor alarming, output signaling, and user indication. For each state, the conditions for entry, duration or timing, and display behavior are identified to clarify how the safety function is affected.

States	Description	Duration/Timing	Display Behavior
Warm up	State entered after a configuration is loaded or reloaded. During this state, the system initializes internal functions, performs startup checks, and waits for the stabilization of monitored devices.	User-configurable duration (2 or 5 minutes).	Shows countdown timer and 'Warm Up' status. Analog outputs are set to their zero-scale value and relays are set to de-energized state.
Normal	State which the system continuously polls all configured sensor and controls all relays and analog outputs according to the application logic.	Continuous operation until a fault condition is detected, or Service mode or auto-config is activated.	Normal sensor readings, analog output value, relay status, and alarms are displayed.
Fault	State entered when any system submodule reports a fault.	Maintained until the fault condition is cleared and acknowledged, where applicable.	Fault indicator shown with specific fault details and affected subsystems.
Service Mode	User-controlled state intended for maintenance, calibration, or servicing activities. Service Mode may only be entered when the system is in Normal operation. All relays are returned to their normal (non-alarm) state for the duration of Service Mode.	Service Mode has a maximum countdown duration of 60 minutes per activation. The countdown timer may be **manually reset by the user**, which restarts the full Service Mode duration. Service Mode may be exited manually at any time.	'Service Mode' and remaining time indicator is displayed.
Auto-Config	State during which the system automatically discovers Modbus devices on selected Modbus lanes.	Duration depends on number of lanes and devices to scan. Progress indicator shown. Per-device timeout for Modbus discovery (typically 4-5 seconds per address)	Shows discovery progress, found devices count, and scanning status.

5.1 State Transition and Precedence

The monitor may transition from one state to another based on pre-defined rules. Their effects on alarms and outputs are governed by defined precedence rules to ensure deterministic and safe behavior.

State transition is described as follows:

1. **Warm-up State**

   The system enters the warm-up state immediately after powerup initialization and configuration loading. During warm-up, normal sensor alarm processing is inhibited, the analog outputs are set to their zero-scale value, and all relays are set to their de-energized state. Only a certain number of system level faults are monitored and reported visually.

   a. **Warm-up (in progress)**
   If the configurable warm-up period is not timed out, the system remains in the **Warm-up** state and displays the remaining time.

   b. **Warm-up timeout**
   Upon completion of the pre-defined warm-up period, the system enters the **Normal** state, if the **Service Mode** is not enabled during the warm-up period. Otherwise, the system enters the **Service Mode** state.

   c. **Start Auto-Configuration**
   If the auto-configuration function is started via the UI, the system enters the **Auto-config** state.

   d. **Reload Configuration**
   If a new configuration file is loaded, the system enters the **Warm-up** state again with pre-configured timeout.

2. **Normal State**
   During normal operation, all the configured sensors are polled, and alarms and faults for all sub systems of the monitor are evaluated. The analog outputs output values based on a pre-defined algorithm according to the configuration. The relays operate based on the configuration and alarms evaluation. The siren is visually and audibly OFF in the Normal state.

   a. **No Faults Detected**
      If no faults are detected by the system, the monitor stays in the **Normal** state. If only pre-defined sensor alarms are triggered, or the analog output value is out of its range, the system stays in the Normal state while indicating the specific alarms and warning visually. The relays configured for system fault or zone fault stay in de-energized state. The relays configured for sensor alarms are energized if the associated alarms are triggered.

   b. **Fault Detected**
      If a fault occurs in any part of the system, the system enters the **Fault** state.

   c. **Enable Service Mode**
      If the **Service Mode** toggle switch is turned on via the UI, the system enters the **Service Mode** state.

   d. **Start Auto-configure**
      If the auto-configuration function is started via the UI, the system enters the **Auto-config** state.

   e. **Reload Configuration**
      If a new configuration file is loaded, the system enters the **Warm-up** state.

3. **Fault State**
   During the **Fault** state, all the configured sensors are polled, and alarms and fault for all sub systems of the monitor are evaluated. The analog outputs and relays operate based on the configuration and defined algorithm. The siren is visually and audially ON if it is enabled.

   a. **Sensor Fault**
      If a fault occurs on any sensor within a zone, the specific fault code, fault reason, and sensor ID are displayed on the **Alerts** page. The faulty sensor is clearly indicated through visual cues in the user interface. The analog output for the affected zone outputs a fault-level value, and a warning message is displayed on the UI. All relays associated with the affected zone are energized. The system remains in the Fault state until the condition is resolved.

   b. **Analog Output Fault**
      If a Modbus analog output experiences communication errors or configuration issues, the specific fault code, fault reason, and associated device ID are displayed on the Alerts page. The faulty analog output device is visually indicated in the user interface. The affected Modbus analog output reverts to its configured default value. The system remains in the Fault state until the issue is resolved.

   c. **Relay Fault**
      If a Modbus relay encounters communication errors or configuration issues, the specific fault code, fault reason, and associated device ID are displayed on the Alerts page. The affected Modbus relay operates using its configured default state. The system remains in the Fault state until the fault condition is cleared.

   d. **System Fault**
      If a defined system-level fault occurs, the corresponding fault code and fault reason are displayed on the Alerts page. All relays associated with system-level faults are set to the energized state. Analog outputs are not affected by system-level faults. The system remains in the Fault state until the condition is resolved.

   e. **Fault Resolved**
      If all faults are resolved, the system enters the Normal state.

   f. **Enable Service Mode**
      If the service mode toggle switch is turned on via the UI, the system enters the **Service Mode** state.

   g. **Start Auto-Configure**
      If the auto-configuration function is started via the UI, the system enters the **Auto-config** state.

   h. **Reload config**
      If a new configuration file is loaded, the system enters the **Warm-up** state.

4. **Service Mode**
   During the **Service Mode** state, all configured sensors are continuously polled, and alarms and fault conditions for all subsystems of the monitor are evaluated and displayed in the user interface in the same manner as in the Normal or Fault states. However, while the system is in Service Mode, **all relays are forcibly set to their de-energized state**, regardless of alarm or fault conditions.

   NOTE: System shall not be relied upon for hazard mitigation during service mode.

   a. **Reset Service Mode Timer**
      The Service Mode countdown timer can be reset to 60 minutes by clicking the Reset button on the Service Mode indicator. Resetting the timer extends the Service Mode duration, and the system remains in the **Service Mode** state.

   b. **Disable Service Mode**
      If the Exit button on the Service Mode indicator is selected, the system exits Service Mode and transitions to the **Normal** state.

   c. **Service Mode Timeout**
      If the Service Mode countdown timer expires, the system automatically exits Service Mode and transitions to the **Normal** state.

   d. **Reload configuration**
      If a new configuration file is loaded, the system enters the **Warm-up** state.

5. **Auto-Config**
   During the **Auto-Config** state, normal polling of Modbus devices is suspended. Modbus communication is temporarily dedicated exclusively to device discovery and address assignment activities. As a result, sensor alarm processing, fault detection, and fault reporting are not active during this state.

   a. **Auto-config in Progress**
      While the system is discovering Modbus devices on the selected lanes and assigning addresses to applicable AMC transmitters, the system remains in the Auto-Config state.

   b. **Cancel Auto-config**
      If the Cancel button on the Auto-Config user interface is selected while the auto-configuration process is in progress, the system exits the Auto-Config state and transitions to the Warm-up state.

   c. **Complete Auto-config**
      Upon successful completion of the auto-configuration process, the system automatically transitions from the Auto-Config state to the Warm-up state.

NOTE: Auto-config is:

- **Not intended during normal operation**
- System enters **non-operational state**
- User must ensure:
  - Safe environment
  - System not relied on for protection

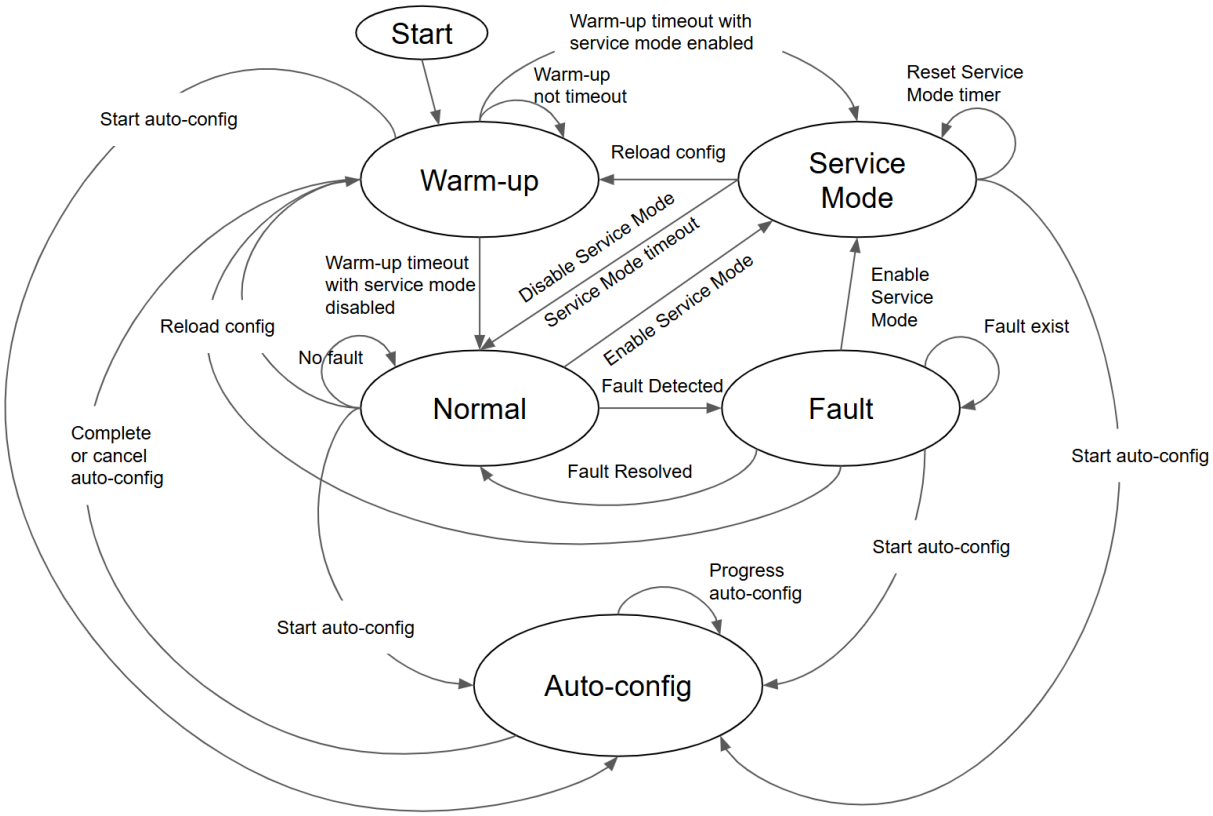

Figure 5-1 1DCx System State Transition Diagram

6 Faults

This section identifies all alarm and fault conditions detected by the system and describes the resulting indications and outputs. For each fault or alarm condition, the associated system response and required corrective action are defined to support proper operation of the safety function.

Alarms indicate that a monitored gas concentration or process condition has exceeded a configured threshold requiring operator attention or response. Faults indicate internal system issues, communication failures, or sensor conditions that may impair correct operation of the monitoring function. Alarm and fault conditions result in distinct system indications and outputs as defined in this section.

All possible faults that are monitored by the system are defined in the following table. The faults with fault code between F001 and F014 are system level faults. The remaining faults are device level faults. All faults are listed on the alerts page of UI, and all device level faults are indicated at the faulty device status as well. All faults and sensor high alarms trigger the siren if the siren is enabled. The system level fault energizes a relay if the relay is configured for system fault. The device level fault energizes a relay if the relay is configured for a zone, where the device fault is located in.

If any of the defined fault occurs, the system enters the Fault state, and the BACnet Multistate value object for the system state has the present value which is associated to the text “Fault”.

6.1 Fault Codes and Resolutions

Fault Code	Description	Resolution
F001 Expansion Module Count Error	This fault occurs when the expansion board count is not 1.	Power off the system and check the connectivity between the main module and expansion board.
F002 RTC Error	This fault occurs when the RTC time was not properly set, backup battery was lost, backup battery voltage is low, or the reading of RTC status failed and so on.	If the detailed fault info shows the battery voltage is low, replace the battery. Check the connectivity of the backup battery after shutting down the system.
F003 FW Upgrade Check	This fault occurs when checking if there is a firmware upgrade package on the USB mass storage drive (MSD).	Properly eject the USB and check if it was formatted properly and firmware upgrade package was prepared properly or not.
F004 USB Data Logging Error	This fault occurs when an exception happens during the data logging on the USB MSD.	Properly eject the USB and check if the USB MSD for data logging was formatted properly.
F005 Config Checksum Creation Error	This fault occurs when the creation of checksum for config files fails.	Restart the system. Contact manufacturer if this fault reoccurs.
F006 Project Integrity Check Error	This fault occurs when the process of checking the project integrity fails.	Restart the system. Contact manufacturer if this fault reoccurs.
F007 Project Integrity Error	This fault occurs when any project files were altered or missing.	Restart the system. Contact manufacturer if this fault reoccurs.
F008 Config Integrity Check Error	This fault occurs when the process of checking config integrity fails.	Restart the system. Contact manufacturer if this fault reoccurs.
F009 Config Integrity Error	This fault occurs when any config files were altered in an unauthorized method.	Restart the system. Contact manufacturer if this fault reoccurs.
F010 Initial Config Integrity Check Error	This fault occurs when the process of checking the config files at the first time after system restarts fails.	Restart the system. Contact manufacturer if this fault reoccurs.

F011 Initial Config Integrity Error	This fault occurs when the initial config files were altered in an unauthorized method.	Contact manufacturer to get configuration checked by service staff.
F012 Expansion EEPROM Fault	This fault occurs when the expansion board parameters stored in its EEPROM is corrupted.	The unit must be returned to the factory or authorized service center for repair.
F013 System Power Supply Under Voltage Fault	This fault occurs when the system power supply voltage is under 18V.	Check the power supply voltage and its monitoring cable. If issue persists, return the unit to the factory or the authorized service center for repair.
F014 System Power Supply Over Voltage Fault	This fault occurs when the system power supply voltage is over 27 V.	Check the power supply voltage and its monitoring cable. If issue persists, return the unit to the factory or the authorized service center for repair.
F015 Other System Level Fault	This fault occurs when other fault conditions not covered above happen.	The unit must be returned to the factory or authorized service center for repair.
F101 Sensor Missing Fault	This fault occurs when the Modbus wiring between the sensor and the monitor is disconnected or faulty.	Check the Modbus RS485 wiring and settings.
F102 Sensor Not Ready Fault	This fault occurs when the configuration of this sensor in the monitor mismatch with that in the sensor.	Check the sensor detail information on both the sensor and the monitor.
F104 Sensor Other Fault	This fault occurs when the sensor reports a fault code or the environmental sensors report unusual reading.	Check the sensor detail information on both the sensor and the monitor.
F105 Sensor Negative Drift Fault	This fault occurs when the sensor reading is less than the fault limit of a specific sensor gas type.	Check the status and sensor reading on the transmitter.
F106 Sensor Over Range Fault	This fault occurs when the sensor reading is larger than the 110% of the full scale of the sensor.	Check the sensor detail information on both the sensor and the monitor.
F107 Sensor Occupancy Fault	This fault occurs when there is at least one sensor in the zone is faulty under the condition of Title24 in the occupancy period.	Check the sensor detail information on both the sensor and the monitor.

F108 Sensor Unoccupancy Fault	This fault occurs when any device associated with a specific zone is faulty under the condition of Title24 in the unoccupancy period.	Check the sensor detail information on both the sensor and the monitor.
F109 Calibration Fault	This fault occurs when the Title24 is enabled and any sensor has expired calibration date.	Contact manufacturer to get configuration checked by service staff.
F201 Relay Missing Fault	This fault occurs when the Modbus wiring between the Modbus relay device and the monitor is disconnected or faulty.	Check the Modbus RS485 wiring and settings.
F202 Relay Config Fault	This fault occurs when the Modbus relay device was not configured properly.	Check the Modbus register content of the relay device.
F301 Analog Output Missing Fault	This fault occurs when the Modbus wiring between the Modbus analog output device and the monitor is disconnected or faulty.	Check the Modbus RS485 wiring and settings.
F302 Analog Output Config Fault	This fault occurs when the Modbus analog output device was not configured properly.	Check the Modbus register content of the relay device.

Table 6-1 Fault Codes and Resolutions

7 Alarms

7.1 Overview

The AMC-1DCx generates alarms when measured gas concentrations or system conditions exceed predefined thresholds. Alarm functionality is part of the safety function and provides **audible, visual, relay, and communication-based indication** of hazardous conditions.

Alarm behavior is deterministic and governed by configured alarm setpoints, hysteresis, timing parameters, and output mappings.

7.2 Alarm Generation

Alarm conditions are generated by continuously comparing measured gas concentration values against configured alarm setpoints.

The following alarm evaluation modes are supported:

- **Increasing alarms**: Triggered when measurement rises above setpoint thresholds
- **Decreasing alarms**: Triggered when measurement falls below setpoint thresholds
- **Windowed alarms**: Triggered when measurement is outside a defined range

Up to three alarm levels (Alarm 1, Alarm 2, Alarm 3) may be configured per sensor channel.

Alarm generation is subject to:

- Validation of setpoints within sensor measurement range
- Logical ordering constraints between alarm levels
- Continuous real-time evaluation of incoming sensor data

7.3 Alarm Levels and Escalation

Alarm levels provide graded indication of hazard severity:

- **Alarm 1** – Lower threshold; early warning condition
- **Alarm 2** – Intermediate threshold; elevated hazard condition
- **Alarm 3** – Highest threshold; critical hazard condition (if configured)

Alarm escalation is monotonic:

- Once a higher alarm level is active, all lower levels are considered active

- De-escalation occurs only when the measured value returns below the respective setpoint, accounting for hysteresis

7.4 Alarm Outputs and Indication

When an alarm condition is detected, the system activates one or more of the following outputs:

a) Audible Indication

- Internal buzzer provides audible alarm signaling
- Audible output is activated upon entry into an alarm state and may be user-configurable (e.g. mute, delay, or disable where permitted)

b) Visual Indication

- Alarm conditions are displayed on the LCD interface
- Alarm status is continuously visible to the operator

c) Relay Outputs

- Configured relays activate based on alarm level and mapping
- Relay outputs provide discrete signals for external systems (e.g. ventilation control, shutdown systems)

d) Communication Outputs

- Alarm states are transmitted via communication interfaces (e.g. BACnet, Modbus) to external supervisory systems

These outputs ensure that alarm conditions are both locally and remotely indicated.

7.5 Output Behavior

Alarm outputs are controlled by configurable timing and behavior parameters:

- **Activation delay (Act Delay)**: Defines delay between threshold exceedance and alarm activation
- **Minimum run time (Min Run)**: Ensures alarms remain active for a defined minimum duration
- **Hysteresis**: Prevents rapid toggling of alarm states near setpoint thresholds

Alarm outputs are automatically cleared when:

- The measured value returns within the non-alarm range
- Minimum run time has elapsed
- Hysteresis conditions are satisfied

Relay outputs may be configured as:

- **Latching** (manual reset required)
- **Non-latching** (automatic reset)

7.6 Alarm Interaction with System States

Alarm behavior exists within the broader system state model, which includes:

- Normal
- Alarm
- Fault
- Warm-up
- Service

When alarm and fault conditions occur simultaneously:

- **Fault conditions take precedence for system state indication**
- Alarm outputs may be suppressed or overridden depending on configuration and system design

System state transitions and precedence are defined in Section 5 (System States).

7.7 Operator Awareness and Acknowledgment

Alarm conditions are communicated to the operator through:

- Visual display on the monitoring interface
- Audible signaling via internal buzzer
- Indication through connected external systems via relays and communication protocols

Operator interaction may include:

- Acknowledging alarms (if enabled)
- Muting audible signals
- Clearing latching outputs

7.8 Relationship to Faults

Alarm conditions represent **hazardous gas levels**, while faults indicate **device or system malfunctions**.

Examples of fault conditions include:

- Sensor failure
- Communication loss
- Out-of-range or invalid signal

7.9 Validation and Testing

Alarm functionality is validated through:

- Verification of alarm threshold detection
- Testing of audible and visual indicators
- Validation of relay and communication outputs
- System self-test at startup and cyclic intervals

Validation evidence is documented in the **DCx Integration Validation Plan**, including:

- Alarm activation tests
- Output signal verification
- Audible/visual indicator tests

7.10 User Configuration Reference

Detailed configuration of alarm setpoints, delays, and output mappings is provided in:

- **User Manual (AMC-1DCx)**

- Sensor Alarm Settings
- Relay Configuration
- System Settings

The Functional Safety Manual defines the behavior and constraints of alarms, while the User Manual provides configuration procedures.

8 Self-Test and Diagnostic Monitoring

The AMC-1DCx incorporates startup and runtime self-test routines to verify correct operation of safety-related system functions. These diagnostics are intended to detect internal failures that could impair gas monitoring, alarm annunciation, or fault detection.

The following self-test and monitoring functions are implemented:

- **Visual and audible indicator test**
  Performed once during system startup to verify operation of the display indicators and audible alarm (siren).

- **Power supply monitoring**
  System power supply voltage is continuously monitored for over-voltage and under-voltage conditions at a rate of **once per second**.

- **Watchdog monitoring**
  The built-in BCM2835 watchdog timer on raspberry Pi CM4 is used to monitor a file which should be updated by the software every 1 mins. Failure to service the watchdog-monitored file within the defined timeout (**2 minutes**) results in a system reset.

- **Program file and configuration integrity monitoring**
  Program files and configuration data stored in non-volatile memory are periodically checked for integrity at the start of the program and at a frequency of **once per hour** to detect corruption or unauthorized modification.

If any self-test or diagnostic check fails, the system enters the fault state and provides a corresponding fault indication as described in the previous section. Fault conditions remain active until the underlying issue is resolved.

9 Safety Related Communication Timing

9.1 Safety Function Overview

As defined in Section **2.1 Safety Function Description**, alarm and fault annunciation relies on data acquired via Modbus communication.

9.2 Assumed Alarm and Fault Response Time

The alarm response time is defined as the maximum elapsed time between a hazardous condition occurring at a field device and the activation of the corresponding alarm indication and safety outputs.

The fault response time is defined as the maximum elapsed time between a communication or device fault occurring and the system indicating a fault condition.

9.3 Contribution of Modbus Communication to Response Time

Modbus communication latency contributes to the overall alarm and fault response time by determining the maximum interval between a change in field condition and its availability to the system safety logic.

This latency includes normal transaction time as well as retry behavior under degraded communication conditions.

9.4 Worst-Case Modbus Timing Assumptions

Worst-case Modbus polling latency has been analyzed, including transaction duration, number of transactions per device, and maximum retry limits.

The resulting worst-case communication delay defines the maximum time by which alarm and fault detection may be delayed due to Modbus communication.

9.4.1 Timing Assumptions

Polling behavior: Each transmitter is expected to be polled within a time interval of T90 + 1/3 T90.

If a valid response is not received within this interval, the system shall enter a defined **communication delay (waiting) state**, indicating that the input data is not current.

If communication is not re-established within the allowed retry and timeout conditions, the system shall transition to the corresponding **fault state** in accordance with the safety requirements.

9.4.2 Configuration Dependency

The value of **T90** is dependent on the system configuration, including the number of connected devices and the number of communication lanes.

For configuration-specific timing analysis, contact AMC support.

9.4.3 T90 Calculation

The following equations define the best-case and worst-case bounds for system timing performance.

Best-Case Equation:

$$T_{min/lane} = 0.05(n_{UTxM400}+n_{UTXREF}+n_{DTX}+n_{UTXM}+n_{ITXM}) + 0.2n_{DTR} + 0.10n_{BC8AII} + 0.10R(n_{BC8AOI} + n_{ERE}) + 0.15(n_{LocalAO} + n_{LocalAI} + n_{LocalRelay})$$

Worst-Case Equation:

$$T_{max/lane} = X\begin{bmatrix} n_{UTxM400} + n_{UTXREF} + n_{DTX} + n_{UTXM} + n_{ITXM} + n_{DTR} + n_{BC8AII} \\ +n_{LocalAO} + n_{LocalAI} + n_{LocalRelay} + R(n_{BC8AOI} + n_{ERE}) \end{bmatrix}$$

Definitions

$T_{min/lane}, T_{max/lane}$ Minimum and maximum polling times per lane (seconds)

Where:
X=4.199 when lane have DTR
X=1.199 when lane doesn't have DTR

$$R = 1 + \left\lfloor \frac{n_i}{8} \right\rfloor$$

n_i= sum of total number of devices excluding BC8AOI and ERE

$n_{UTxM400}$ = total number of UTxM400 devices

n_{UTxREF} = total number of UTxREF devices

n_{DTX} = total number of DTX devices

n_{UTxM} = total number of UTxM devices

n_{ITXM} = total number of ITXM devices

n_{DTR} = total number of DTR devices

n_{BC8AII} = total number of BC8AII devices

$n_{LocalAO}$ = total number of LocalAO devices

$n_{LocalAI}$ = total number of LocalAI devices

$n_{LocalRelay}$ = total number of LocalRelay devices

n_{BC8AOI} = total number of BC8AOI devices

n_{ERE} = total number of ERE relays

The minimum and maximum polling times shall first be calculated independently for each Modbus Lane. As the Modbus lanes operate in parallel, the system-level minimum polling time is taken as the lowest calculated minimum lane time, while the system-level maximum polling time is taken as the highest calculated maximum time.

$$T_{min/system} = \max(T_{min/lane1}, T_{min/lane2}, T_{min/lane3}, T_{min/lane4})$$

and:

$$T_{max/system} = \max(T_{max/lane1}, T_{max/lan2}, T_{max/lane3}, T_{min/lane4})$$

Examples

If the customer had a configuration/lane x 4 lanes of:

Sensor Type	Qty	Best Time (s)	Worst Time (s)
UTx-M-400	0	0.00	0.00
UTX-REF	0	0.00	0.00
DTX	0	0.00	0.00
UTX-M	0	0.00	0.00
Itx-M	0	0.00	0.00
DTR	247	98.80	2074.31
BC8AII	0	0.00	0.00
BC8AOI	0	0.00	0.00
ERE	0	0.00	0.00
Local AI	2	0.30	0.30
Local AO	2	0.30	0.30
Local Relay	4	0.60	0.60

Worst Case T90 is ~2075 seconds.

If the customer had a configuration/lane x 4 lanes of:

Sensor Type	Qty	Best Time (s)	Worst Time (s)
UTx-M-400	0	0.00	0.00
UTX-REF	0	0.00	0.00
DTX	0	0.00	0.00
UTX-M	10	1.50	35.97
Itx-M	0	0.00	0.00
DTR	0	0.00	0.00
BC8AII	0	0.00	0.00
BC8AOI	0	0.00	0.00
ERE	0	0.00	0.00
Local AI	2	0.30	0.30
Local AO	2	0.30	0.30
Local Relay	2	0.30	0.30

Worst Case T90 is ~36 seconds.

9.5 Alignment with Alarm Response Time Claim

The claimed alarm response time ***includes*** the worst-case Modbus communication delay identified by the timing analysis. Even under maximum retry conditions, the combined communication delay and internal processing time remain within the specified alarm response time.

No alarm response time claim relies on nominal or average Modbus performance.

9.6 Alignment with Fault Response Time Claim

Loss of communication, excessive retries, or invalid Modbus data are treated as fault conditions. The worst-case detection time for such faults is bounded by the same Modbus timing assumptions used for alarm detection.

Fault indication and associated outputs are therefore guaranteed to occur within the specified fault response time.

10 Software Modification Procedures

10.1 Software Feature Request and Change Management Process

10.1.1 Purpose

This section defines the controlled process used for managing software feature requests, modifications, enhancements, and defect corrections.

The objective of this process is to ensure that:

- All software changes are formally reviewed, approved, and documented
- Functional safety requirements are maintained throughout the software lifecycle
- The impact of all changes is understood prior to implementation
- Appropriate verification and validation activities are performed

10.1.2 Process Overview

All software changes shall follow a structured change management process consisting of the following stages:

- Feature Request Initiation
- Change Logging
- Comments/Impact Analysis
- Review and Approval
- Implementation Planning
- Development and Version Control
- Verification and Validation
- Review and Closure

This process is applied within an iterative development framework where periodic review activities are performed to ensure continuous evaluation of changes and their potential impact.

10.1.3 Feature Request Initiation and Logging

All proposed software changes are recorded in a controlled change request record.

Each change request includes, at a minimum:

- Description of the proposed change
- Reason for the change
- Identification/category of affected software components/features
- Identification of functional safety relevance (if applicable)

All change requests are maintained in a controlled tracking system to ensure traceability throughout the lifecycle.

10.1.4 Review and Approval

All change requests are reviewed by appropriate personnel during structured development review activities. These may include:

- Project planning meetings
- Sprint planning meetings
- Sprint review meetings
- Dedicated change review meetings

During the review, the following are evaluated:

- Technical feasibility
- Impact on existing functionality
- Functional safety implications
- Affected software components
- Required verification and validation activities

Each request is assigned one of the following dispositions:

- Approved
- Rejected
- Deferred (to a future sprint or software release)

The decision and its rationale are recorded as part of the change request record.

10.1.5 Impact Analysis

For each approved change request, an impact analysis is performed prior to implementation.

The impact analysis may evaluate:

- Whether safety-related functionality is affected
- Which software architecture and design elements are affected
- Which software features are impacted
- Which hardware is impacted
- Which verification and validation activities must be performed or repeated

10.1.6 Implementation Planning and Assignment

Approved changes are prioritized and assigned to qualified personnel.

Where appropriate, development tasks are created within a project tracking system to:

- Track implementation progress
- Create test steps (if applicable/needed)
- Record completion status

10.1.7 Change Implementation and Version Control

Software changes are implemented in accordance with the defined software development process.

Changes are maintained under revision control. Revision control records provide traceability between:

- The implemented code changes
- The individual responsible for the change
- The date of modification

If necessary, modifications include sufficient description to identify:

- The nature of the change
- The reason for the change
- The associated change request record (if applicable)

10.1.8 Verification and Validation

Verification and validation activities are performed based on the results of the impact analysis.

These activities may include:

- Code review
- System testing/regression testing
- Functional safety verification

10.1.9 Review and Change Closure

A change request is considered closed only when:

- Implementation is complete
- All required verification and validation activities have been successfully completed
- Functional safety impacts have been addressed
- Review and approval activities have been completed

10.1.10 Process Flow

The software feature request and change management process may follow a structured workflow. This workflow ensures that all software changes are systematically controlled and evaluated.

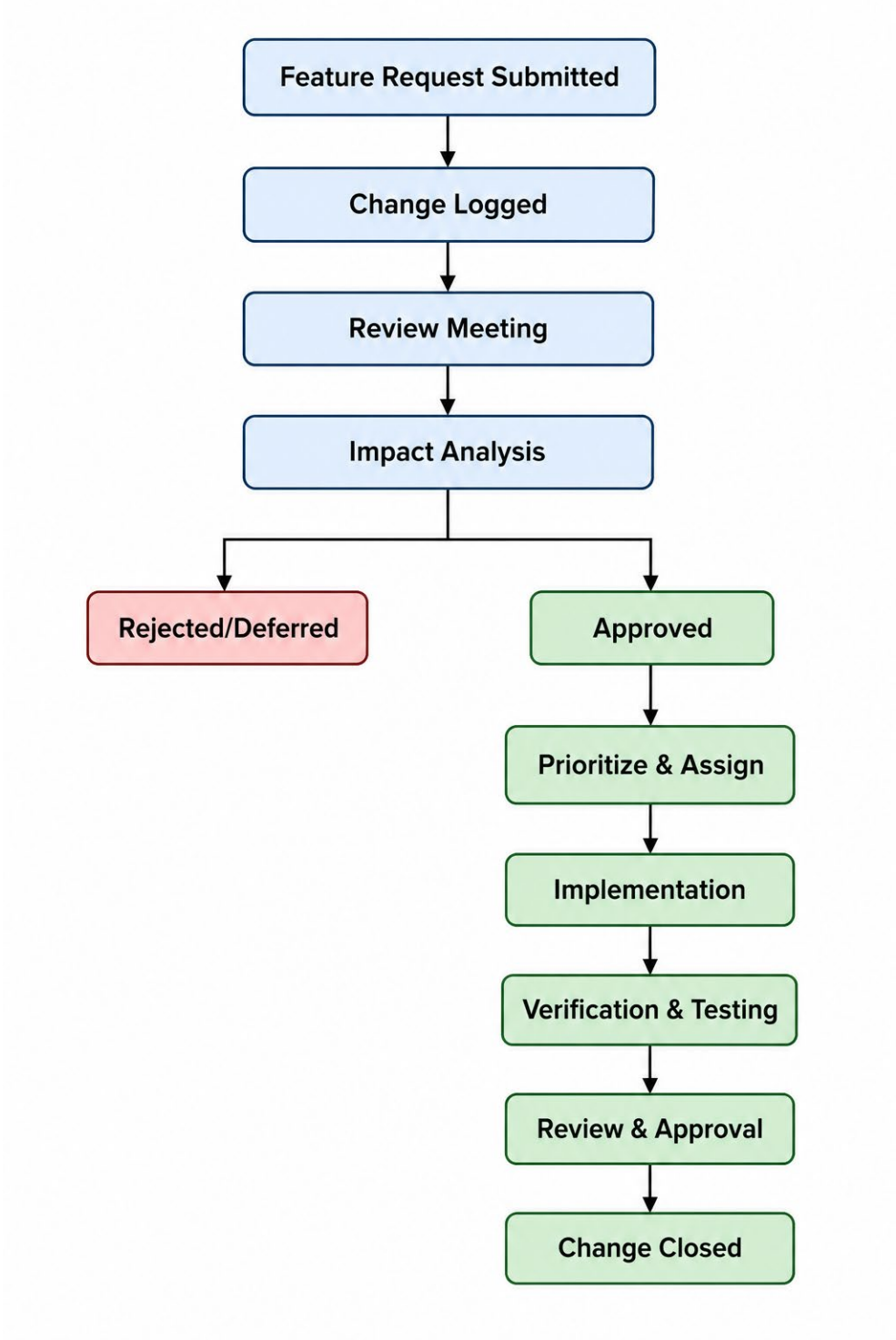

Figure 10-1 Software Change Request and Impact Analysis Workflow

10.2 Software Upgrade Safety and Control

10.2.1 Purpose

This section defines the controlled process and safeguards implemented for software upgrade activities.

The objective is to ensure that:

- Only authorized personnel can perform software updates
- Unauthorized or unintended software changes are prevented
- Software integrity is verified prior to installation
- Functional safety is maintained throughout the upgrade process

10.2.2 Access Control and Physical Security

Software upgrades require physical access to the equipment and are restricted to authorized personnel only.

The following physical access controls apply:

- The device is installed within a controlled location (e.g., mechanical room)
- The enclosure has the ability to be locked with a padlock
- Physical access to the system interface is therefore restricted to qualified personnel

These measures reduce the risk of unauthorized modification.

10.2.3 Controlled Upgrade Method

Software upgrades are performed using a controlled and defined method:

- The software upgrade package is delivered as a **password-protected archive**
- The package must be transferred to the device using a **USB storage medium**
- The USB device must be correctly formatted and prepared for use with the system

This ensures that:

- Only properly prepared upgrade media can be used
- The upgrade method is consistent and repeatable

10.2.4 Integrity Verification

Prior to installation, the software performs integrity checks on the upgrade package.

- The system verifies the **integrity of the software package** before allowing execution
- Invalid, corrupted, or modified packages are rejected

This ensures that:

- Only valid and approved software versions are installed
- The risk of corrupted or compromised software is mitigated

10.2.5 Safety Considerations

The combination of:

- Physical access control
- Password-based authorization
- Controlled upgrade media
- Software integrity verification

ensures that software upgrades are performed in a **controlled and secure manner**, maintaining the integrity of safety-related functions.

11 Safety Function Limitations

The safety function provided by the AMC-1DCx is limited to detection and annunciation. Incorrect installation, improper configuration of alarm thresholds, disabled outputs, or prolonged use of Service Mode may reduce the effectiveness of risk reduction.

The overall safety integrity of the installation depends on correct system design, periodic testing, and appropriate response by external systems.