

Exhibit D

ELM MG2.1 Series
ESS Fire Safety
Design Analysis



MicroGrid Energy Storage System

MG2.1 Fire Safety Design Analysis

Energy Storage System

MG2.1-SITE-FSDA-0001

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Introduction

General

The ELM Microgrid Energy Storage System (ESS) is designed to be a stand-alone battery system that can provide its customers with on-grid peak shaving, demand response, PV smoothing, capabilities etc. The ESS can also operate in an off-grid environment to supply power to its site. The ESS also incorporates the ELM FieldSight Microgrid controller that manages the operations of the ESS as well as any other equipment at the site such as photovoltaic, wind, generators, grid connections, battery management systems, etc.

The ELM Microgrid ESS utilizes the latest in battery and storage inverter technologies to offer their customers the best, most efficient, and safest power systems. The batteries used in the BESS are a Lithium Iron Phosphate (LiFePO4) chemistry which provide high energy density, long lasting durability, and affordable solutions.

LiFePO4 and Lithium Ion Nickel Magnesium Cobalt (NMC) are different chemistries. NMC batteries are commonly used in electronic devices, while LiFePO4 batteries are newer and becoming more common in large battery applications (ESS, EVs)

LiFePO4 (Li Lithium, Fe Iron, PO4 Phosphate), have significant fire safety advantages over NMC. While LiFePO4 cells can experience thermal runaway, they are more stable, they have a higher thermal runaway temperature, and cells in thermal runaway are much less likely to propagate to nearby cells.

Due to the LiFePO4 chemistry, ELM has incorporated a series of fire safety features into their ESS solution to meet or exceed all current safety codes including NFPA 855. The purpose of this document is to outline those fire safety features and define their controls.

1. Level 1 – Site Controller monitoring
2. Level 2 – Battery Manage System (BMS)
3. Level 3 – E-Stop Buttons
4. Level 4 – Off gas detection system
5. Level 5 – Active Venting System
6. Level 6 – Smoke Sensors
7. Level 7 – Heat Detection
8. Level 8 – Battery Chemistry and Construction (UL9540A Certification)

Fire Safety Overview

General

The ELM ESS has 9 different levels of protection to prevent, mitigate, and contain any possible thermal runaway events.

Level 1 Protection – Site Controller

Every ELM ESS system is delivered with an ELM Microgrid site controller. The site controller is designed to communicate, monitor, and control all the equipment within the energy system.

Included in this communication architecture is the monitoring of the battery’s temperature and voltages along with the ambient temperature of the containers. Should the temperature or voltages within the battery modules exceed a maximum operating temperature or voltage that is predefined to be lower than the setpoint established by the battery manufacturer, the site controller will shut the system down by disabling the storage inverter and opening the rack level battery contactors and remain in this state until temperatures fall within the normal operating range again.

Notification:

- ELM Site Controller sends out an email/text alert that the system has faulted.
- If the temperatures fall back within the operating limits, the system will restart itself and the ELM Site Controller sends out an email/test alert that the system fault has been cleared.

Level 2 Protection - BMS

Every ELM ESS system is delivered with a Battery Management System (BMS) that is designed and UL tested by the battery manufacturer. The BMS is designed to monitor the status of all the battery modules and cells within the battery system and protect the batteries should any of its operating parameters exceed the allowable limits of the battery. The BMS protects the batteries by opening rack level contactors that will physically disconnect the batteries from the rest of the energy management system and thus shut down the ESS. Some of the operating parameters that the BMS monitors includes:

- Over and Under temperature limits
- Over and Under voltage limits
- Over current charge/discharge events
- Communications loss

Note: The level 1 temperature protection limits are more conservative than the level 2 protections.

Notification:

- ELM Site Controller sends out an email/text alert that the system has faulted.
- If the temperatures fall back within the operating limits and the battery BMS allows the site controller to close battery contactors, the system will restart itself and the ELM Site Controller sends out an email/test alert that the system fault has been cleared.

Level 3 Protection – E-Stop button

Each ESS, Main Interconnection Control Box (MICB), and storage inverter is equipped with an external e-stop button. If this button is pushed on any of the units it will immediately disable the storage inverter and open the rack level battery contactors on that system. The system will not restart until the button is pulled back out and the e-stop is cleared from the HMI on the ELM FieldSight Controller.

- ELM Site Controller sends out an email/text alert that the system has an e-stop/fire event
 - ELM Site Controller also sends out a Modbus register that an e-stop/fire event has occurred
- If the system is restarted manually, ELM Site Controller sends out an email/text alert that the system e-stop/fire event has cleared.
 - ELM Site Controller also sends out a Modbus register that an e-stop/fire event has cleared

Level 4 Protection – Off-Gas Sensor

If the previous layers have failed to successfully shut down the system, the battery may begin to off-gas hydrogen before it enters a runaway condition. ELM has integrated an Off-Gas Sensor into their system. The off-gas sensor is designed to detect hydrogen levels that exceed 10% LFL. Off-gas events occur early in the failure mode of LiFe Po batteries and can mitigate the hazards of a runaway battery cell.

When the off-gas sensor detects this off-gassing event, it sends a signal to the Fire Panel. When the ELM site controller sees the signal go true for the off-gas sensor, it shuts the system off by disabling the storage inverter and opening the rack level battery contactors. Before the system can resume, the off-gassing event has to clear AND a person has to push the resume button on the system touchscreen. The system will not restart on its own without manual intervention.

Notification:

- ELM Site Controller sends out an email/text alert that the system has an e-stop/fire event
 - ELM Site Controller also sends out a Modbus register that an e-stop/fire event has occurred
- Fire Panel:
 - Display and Sound event on panel
 - Supervisory signal to building fire panel (if available)
- If the system is restarted manually, ELM Site Controller sends out an email/text alert that they system e-stop/fire event has cleared.
 - ELM Site Controller also sends out a Modbus register that an e-stop/fire event has cleared

Level 5 Protection – Active Venting

The active venting system on the battery energy storage system can be activated by two means.

- First, when the off-gas sensor detects an off-gassing event, it will send a signal to the fire panel which in turn will close a relay that provides power to all active venting units in the system. The active venting units will remain on until the gas sensor no longer detects an event and the event is cleared from the fire panel.
- Second, the active venting system can be turned on remotely by a switch that is located away from the ESS system. If the system is restarted manually, ELM Site Controller sends out an email/text alert that the system e-stop/fire event has cleared.

This method is optional at the site.

When the active venting system is turned on, it will circulate the air inside the container with external air at a rate of more than 165 CFM to prevent the buildup of explosive gases. The Active Venting system has embedded dampers to prevent leakage with outside air when the active venting system is not activated.

Notification:

- ELM Site Controller sends out an email/text alert that the system has an e-stop/fire event
 - ELM Site Controller also sends out a Modbus register that an e-stop/fire event has occurred
 - ELM Site Controller also sends out a Modbus register that an e-stop/fire event has cleared
- Fire Panel:
 - Display and Sound event on panel
 - Supervisory signal to building fire panel (if available)

Level 6 Protection – Smoke Sensors

Each ESS is equipped with a smoke sensor that is tied back into the systems fire panel. If the smoke sensor is activated, the ELM Site Controller will receive an alarm signal from the fire panel and will immediately disable the storage inverter and open rack level contactors. The system will not restart until the fire alarm has cleared and the e-stop is cleared from the HMI on the ELM FieldSight Controller. In addition, an audible and visual horn/strobe will be activated on the unit where the smoke sensor was activated and the active venting system will be activated until the smoke sensor no longer detects an event and the event is cleared from the fire panel.

Notification:

- ELM Site Controller sends out an email/text alert that the system has an e-stop/fire event
 - ELM Site Controller also sends out a Modbus register that an e-stop/fire event has occurred
- Fire Panel:
 - Display and Sound event on panel
 - Activates horn/strobe in area of activation
 - Alarm signal to building fire panel (if available)
 - Activate active venting system
- If the system is restarted manually, ELM Site Controller sends out an email/text alert that the system e-stop/fire event has cleared.

- ELM Site Controller also sends out a Modbus register that an e-stop/fire event has cleared

Level 7 Protection – Heat Detectors

Each ESS is equipped with a heat detector. If the heat detector is activated, the ELM Site Controller will receive an alarm signal from the fire panel and will immediately disable the storage inverter and open rack level contactors. The system will not restart until the fire alarm has cleared and the e-stop is cleared from the HMI on the ELM FieldSight Controller. In addition, an audible and visual horn/strobe will be activated on the unit where the heat sensor was activated and the active venting system will be activated until the heat sensor no longer detects an event and the event is cleared from the fire panel.

Notification:

- ELM Site Controller sends out an email/text alert that the system has an e-stop/fire event
 - ELM Site Controller also sends out a Modbus register that an e-stop/fire event has occurred
- Fire Panel:
 - Display and Sound event on panel
 - Activates horn/strobe in area of activation
 - Alarm signal to building fire panel (if available)
 - Activate active venting system
- If the system is restarted manually, ELM Site Controller sends out an email/text alert that the system e-stop/fire event has cleared.
 - ELM Site Controller also sends out a Modbus register that an e-stop/fire event has cleared

Level 8 Protection – Battery Module UL9540A certified

If the previous protection levels have failed to prevent a runaway thermal event within a battery module, the battery modules themselves have been UL 9540A tested by their manufacturer. The UL9540A testing is performed by the manufacturer to demonstrate that a fire within the battery will not propagate and spread throughout the system. Thus, it should contain a fire to the point it started.

Fire Panel Overview

General

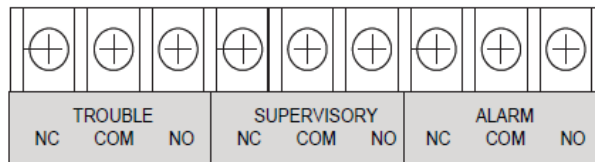
The ELM ESS utilizes a Potter AFC-50 fire panel to monitor the gas, smoke, and heat sensors. The fire panel is also utilized to activate the venting system(s) within a string of containers.

The fire panel has three signals that it can provide to the ELM controller and the site or building fire system.

1. Trouble: Any fault or off normal condition that would impair the system is annunciated as a trouble condition.
 - a. This could be a wiring issue, loss of AC power, loss of DC power, etc.
2. Alarm: If any of the smoke or heat detectors go into an alarm state, this will trigger the alarm signal on the fire panel
3. Supervisory: If any of the gas sensors detect an alarm state, this will trigger the supervisory signal on the fire panel

If the fire panel needs to be connected to a site or building fire monitoring system, the relay outputs on the Potter fire panel can be used as shown:

Relay Outputs



DWG #593-26

Figure 18. Panel's Dedicated Relay Outputs

The panel has three dedicated common relays. The dedicated trouble relay is a failsafe trouble relay that changes position anytime a trouble condition occurs.

The contact rating is 24VDC / 3.0A, 125VAC / 3A, Power Factor: 1.0. These outputs are non-power limited and not supervised. However, they are power-limited if the power supply to the connected devices is power-limited.

Sequence of Events

Sequence of Events Matrix

Since the events of a fire situation do not necessarily happen in a linear fashion, the following matrix shows the sequence of events that should occur for different stages of the fire safety system.

	ESS and Fire Panel Operation										
Use this matrix to determine the sequence of safety features built into the ELM Energy Storage System	Disable Storage Inverter	Open Rack Level Battery Contactors	ELM text and email notifications are sent	ELM Modbus Register List signal is sent	Display and Sound Event on the Fire Panel	Activate Horn Strobe in Area of Activation	Send an Alarm Signal to Building Fire Panel System and ELM controller	Send a Trouble Signal to Building Fire Alarm System and ELM Controller	Send a Gas Detector/Supervisory Signal to Building Fire Panel System ELM Controller	Activate Active Venting System	Battery system is 9540A tested
ELM Temperature Protection	x	x	x	x							
Battery BMS Temperature Protection	x	x	x	x							
Off-Gas Sensor Alarm Fault	x	x	x	x	x				x	x	
Active Venting with Remote Switch	x	x	x	x	x				x	x	
e-stop button is engaged	x	x	x	x							
Smoke Sensor	x	x	x	x	x	x	x			x	
Heat Detector	x	x	x	x	x	x	x			x	
Field Wiring or System Component Fault			x	x	x			x			
Loss of Primary AC Power to ESS Fire Panel			x	x	x			x			
Thermal Runaway Prevention											x

System trip

All the responses to the system conditions noted in the SOE Matrix happen immediately when the condition is met. The following items show additional setpoints and delay timers that are implemented for the system conditions:

- ELM Temperature Protection setpoint: 50C
- Battery BMS Temperature Protection setpoint:
 - Great Power: 56 C