ENERGY MANAGEMENT CIRCUIT BREAKER (EMCB)

PGE-EPRI SUPPLEMENTAL FIELD DEMONSTRATION PILOT

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1. Background

The Energy Management Circuit Breaker (EMCB) field demonstration pilot is an experimental exercise conducted by Portland General Electric Company (PGE) in collaboration with the Electric Power Research Institute (EPRI).

The goal of this document is to:

I. Provide operational insights that will enable PGE to understand the installation, configuration, monitoring, control and operation of the EMCB.

II. Identify PGE use cases, EMCB siting, performance data collection and benefit analysis.

III. Gather learnings that will facilitate the use of ECMB as a Demand Response (DR) or FLEX resource for PGE.

IV. Help PGE better understand its customers' energy usage patterns, keep costs down and increase service levels.

V. Explore opportunities to leverage technology as a design alternative to the incorporation of Critical Load Panels (CLP) in residential energy storage, and the capability to implement managed EV charging, including consideration for EV charging automation and responsive control.

VI. Prepare PGE for smart breaker functionalities for the grid of the twenty-first century including Advanced Metering Infrastructure (AMI), Home Area Networks (HAN), automated Demand Response (DR), grid- integrated storage and solar monitoring.

VII. Document performance characteristics and effectiveness in using EMCB for metering DR events.

2. Introduction

In the fall of 2016, Eaton Corporation began working with EPRI, the Electric Power Research Institute, to field test the EMCB in 12 regional utilities across the U.S., stretching from North Carolina to Hawaii. Eaton and EPRI designed the field test program to evaluate how this new technology for end-use energy/load monitoring and control can help improve utility service and optimize the grid.[1,2] This was the first phase of the EMCB project.

In the fall of 2019, EPRI launched phase 2, to focus the integration of EMCB devices into utility systems. EPRI extended participation to more utility companies, including PGE. According to EPRI, phase 2

[1] https://www.eaton.com/us/en-us/markets/innovation-stories/energy-management-circuit-breaker.html?wtredirect=www.eaton.com/emcb

[2] https://www.cablinginstall.com/data-center/article/16472894/eaton-epri-field-test-intelligent-circuit-breakers-for-smart-grids-utilities

continues with the investigation of the operation of the EMCB based and involves several key participants:

i. The EMCB vendor, Eaton Corporation[3]: Eaton manufactures the EMCB and provides the application programming interface (API) cloud service that allows remote access to the devices.
ii. A software as a service company, Virtual Peaker (VP) [4] : VP provides a web-based browser and companion software that allows for access to the EMCB data and breaker control functionality. PGE will have access to VP for the duration of the pilot.
iii. The program administrator, EPRI: EPRI will manage the project, create the test protocols, distribute the circuit breakers, hold routine project team meetings and will document results of the project, and,
iv. PGE: PGE will develop practical use cases, choose end use applications and install EMCB devices within its service territory.

3. Device Description

The EMCB is a UL-listed device packaged in standard circuit breaker form factor that can be installed in compatible low-voltage panelboards having single-pole (120 V) or double-pole (208 V or 240 V) branch circuits rated up to 50 A. Each EMCB has embedded revenue-grade power and energy metering, including the ability to measure and report power (real and reactive), voltage, current, and frequency, a remotely controllable on/off switch, an event-triggerable fast-waveform capture capability (for both voltage and current waveforms), and a Wi-Fi communications interface.[5]

The EMCB is a standard form-factor thermal-magnetic circuit breaker that includes communications, metering and control capabilities. There are two variants of the EMCB device: a standard device; and an electric vehicle device.

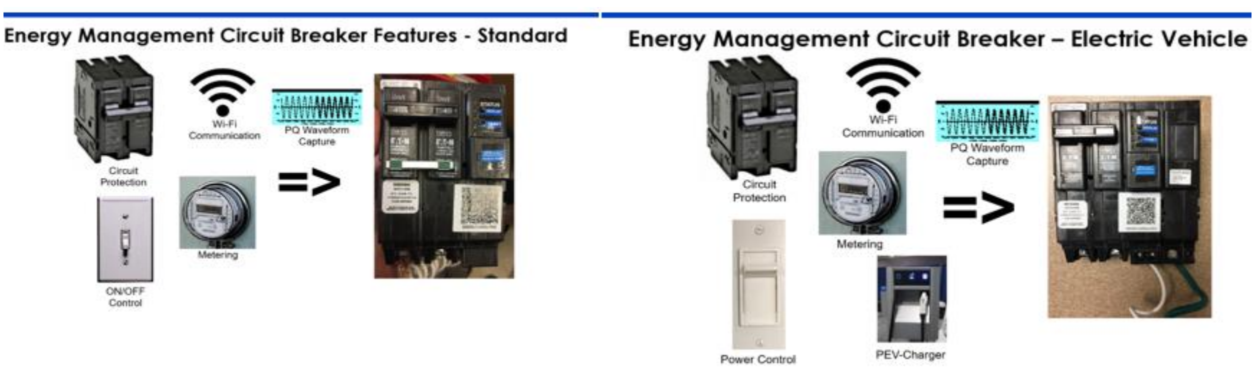

Figure 1: EPRI device diagram (source: EPRI)

[3] https://www.eaton.com/us/en-us/markets/innovation-stories/energy-management-circuit-breaker.html
[4] https://www.virtual-peaker.com/
[5] https://www.serdp-estcp.org/Program-Areas/Installation-Energy-and-Water/Energy/Conservation-and-Efficiency/EW19-5149

Both variants have the capability to capture waveform snapshots via remote control and via local configurable voltage and current triggers. The EV version of the device provides the full functionality of an SAE J1772™ [3] compliant electric vehicle charger.

Standard devices are available in two form factors: A plug-on version and a bolt-on version. In addition, there are single and two pole devices. The EV version is only available in a two-pole plug-on version. Communication from EMCB devices is via wireless interface (Wi-Fi). A smart phone app is used to configure device access to a wireless hotspot.

The EMCB is expected to be a low-cost tool for managing electric loads. It is simple to install and, as it operates at panel level, the EMCB is also load agnostic. These attributes create the potential for EMCBs to be installed across PGE facilities. The potential value of EMCBs in the near term includes enhancing energy resilience of critical systems, improving measurement and verification of Battery Energy Storage Systems (BESS), solar installations, and reducing utility bills through energy and demand savings. In the longer term, performance data collected by EMCBs could be used for predictive analytics and capture power quality events to enable preventative maintenance and increase reliability. The experience with EMCBs gained through this project will provide PGE and EPRI with viable information about the installation, operation, and value of EMCBs to inform future projects and requirements development.[6] Further, PGE acknowledges that more precise measurement of devices and electric services using smart devices like the EMCB can enhance demand response, inform more equitable rate design, and help integrate distributed energy resources.[7]

4. Data Collection

EMCB devices pass data via wi-fi to a cloud-based service provided by Eaton. External data access to the Eaton cloud service is via APIs that are documented on the Eaton Developers web portal[8]. Using Eaton's API, the EMCB data shall be gathered using Virtual Peaker and PGE's database server.

5. Site Qualification Matrix

PGE shall install the EMCB in accordance with the qualification matric in the table below:

EMCB Site Qualification Matrix	**Response**
1. List the use case(s) to which the site will relate. See Use Cases.	
2. Provide a description of the end-use device(s). See Use Cases.	
3. Verify that the circuit breaker being replaced is neither a ground fault current interrupting (GFCI) breaker nor an arc fault current interrupting breaker. Refer to the marking on the installed circuit breaker to ensure compatibility. See reference [9] for help in understanding the markings.	
4. Is the installation likely to require the purchase of a permit? Note, the requirement to upgrade a circuit to the latest code is subject to the discretion of local AHJ (see Authority Having Jurisdiction). However, it is	

[6] https://www.serdp-estcp.org/Program-Areas/Installation-Energy-and-Water/Energy/Conservation-and-Efficiency/EW19-5149
[7] https://eprijournal.com/data-driven-insights-for-electricity-customers/
[8] https://portal.developer.eatonem.com/

likely an electrician would be allowed to replace one or more circuit breakers without having to purchase a permit, provided doing so does not require additional wiring. The need to upgrade to the latest code typically becomes an issue if a permit is required. See also the section Authority Having Jurisdiction.	
5. List the number of needed EMCB/EV-EMCB as well as the voltage, current, and number-of-poles for the circuit(s).	
6. Inspect the panelboard to collect the following information:	
a. Is the panelboard on the approved list? See List of Compatible Panelboards.	
b. Describe the location of the panelboard (i.e. indoor/outdoor, northeast corner of the home).	
c. Is the panelboard locked? (You may wish to document separately how to access the keyholder.)	
d. Is it accessible? With or without permission?	
e. Is there room for the EMCBs/PEV-EMCBs?	
f. What modifications are needed in terms of moving circuit breakers around? Remember the EMCB/PEV-EMCB requires extra space. See Required Space.	
g. Is a sub-panel required? If yes, where will the electrician physically install the sub-panel?	
h. In cases of reverse power flow, such as a solar panel system, verify that a tie down screw for plug-on versions has been installed. Refer to the panelboard for the appropriate kit number.	
7. Where will the installer physically place the cellular modem?	
a. Is a box required?	
b. Is the location within 300 feet (line-of-site) of the panelboard? Is the location greater than 5 feet?	
c. Note any objects between the panelboard and the location of the cellular modem (line-of-sight) that will impact the quality of the WLAN. For example, walls and doors (note construction type) and large appliances.	
d. Is there a 120 VAC receptacle nearby? The power cord for the cellular modem is approximately five feet in length. Is an extension cord required?	
e. Is the 120 VAC receptacle on a circuit different from the one on which the PEV/PEV-EMCB is installed? (The answer should be yes.)	
f. Will the location for installation meet the temperature requirements? Note, installation in direct sunlight is not recommended.	
8. List the requirements for decommissioning the site (if known).	

Table 1.0: EMCB site qualification matrix.

6. Use Cases

The functionality of the EMCB and PEV-EMCB offer a new way to operate, manage and control disparate customer loads. PGE has identified several use cases that are designed to provide insights into the operational practices of the proposed BESS pilot which will maximize outcomes for PGE and the pilot's participants:

6.1. Electric vehicle Managed Charging: The PEV-EMCB is specifically designed to safely deliver power to an electric vehicle. This can enable the implementation of an alternative managed charging solution without the need to install a standalone EVSE equipment. By using the PVE-EMCB to toggle between the ON/OFF states, manage EV charging and to throttle the charge rate, the EV responses will be observed and characterized. The value to PGE will be for demand response applications and load shifting during peak hours.

6.2. Direct Load Control: (ad-hoc, responsive to utility control signal) a reduction in electricity use during the time when the price of electricity is high, or the reliability of the grid is threatened.

- **6.2.1.** Load shifting and demand response observations for water heater and other flex loads. PGE shall remotely use the EMCB to progressively shift and cycle the operation of these loads in no more than 15 minutes time intervals, once per day. The value here shall be used to inform PGE of the ability of the EMCB to quickly respond to grid related events like frequency response in over-generation conditions.
- **6.2.2.** AMI and central load management: PGE will attempt to throttle multiple EMCBs using the energy profile obtained from remote sources like PGE's AMI meters or other remote third-party applications.
- **6.2.3.** Time schedule control and management of various end use loads: This use case will help PGE further investigate the application of the EMCB to PGE's Time of Use (TOU) tariffs, with the potential of studying any benefit of a change in PGE's TOU structure.

6.3. Programmable Load Control: PGE shall operate and locally control loads connected to the EMCB in a manner that is repeatable and automatically programmable. This shall be applicable in such applications like Time of Use load control.

6.4. Cold Load Pickup mitigation: The EMCB may be used to avert the high current and excessive inrush following an extended outage by forcing some loads to remain off immediately following power restoration, consequently, the EMCB will be used to minimize the effects of cold load pickup upon re-energization: PGE plans to use the EMCB to study and mitigate excessive initial inrush upon re-energization and sustained inrush in excess of normal continuous load of certain motor loads. The value here is to introduce a timed delay, progressively, via the EMCB on motor starts following restoration of service, thus improving PGE's cold load pickup performance. Other secondary impacts of cold load pickup such as Magnetizing inrush, loss of diversity and capacity inrush may be independently explored by using the EMCB to trip and restore services to affiliated loads.

6.5. **PV Hosting Capacity:** This is the ability of the EMCB to throttle the total PV power that can be accommodated on a given feeder without any adverse impacts. The EMCB shall demonstrate how PGE can leverage EMCB to control, throttle or direct trip PV solar during times of hosting capacity constraint. PGE may control PV output to respect hosting capacity limits, avoid the need to implement system upgrades

6.6. **Islanding Support:** The EMCB can be used to monitor energy usage, voltage and current levels at the local site thereby avoiding the need for an external Critical Load Panel (CLP). When power is detected on the feeder, the EMCB can be forced off to prevent damage to downstream equipment and ensure the safety of personnel.

6.7. **Energy measurement and verification:** PGE shall use the EMCB to develop techniques to measure and verify the reduction or resumption of load in response to a signal from a demand response program. This use case shall also be applied to the energy profiles of PGE owned residential Battery Energy Storage Systems (BESS). The following activities shall be measured and evaluated based on the EMCB's metering capability for the purpose of understanding the value of DR events to PGE:

i. Residential energy storage battery systems
ii. Sub-metering and separating EV and DR loads from traditional loads
iii. Monitoring the charging/charge rate of EVs
iv. Load research – plug loads
v. Onsite solar PV generation
vi. End-use technology metering for end-use rates
vii. Monitoring power factor.
viii. Fixed time monitoring
ix. PGE plans to measure in-tandem the effectiveness of EV controls via the EV-EMCB and traditional EMCBs.

6.8. **Load research:** The EMCB shall inform PGE of customer load profiles by measuring and analyzing the time and amount of customer electricity usage either individually or in aggregate.

6.9. **Power Quality:** PGE plans to use the lower-resolution PQ capabilities of the EMCB for the following power quality applications:

I. End use device health and maintenance monitoring (non-traditional power quality application based on use of current waveform captures)
II. Monitoring of voltage power quality beyond the point of common coupling at high value customer sites
III. Detection and location of incipient faults (geospatial placement and voltage data on a feeder)
IV. Troubleshooting customer complaints related to (EV charging fails, HVAC equipment, and other loads) that might be related to voltage quality

6.10. Sub-metering: PGE shall demonstrate the use the EMCB to effectively differentiate critical loads from non-critical loads, thereby avoiding the need to install a separate CLP for islanding capability, consequently allowing for the EMCB to act as a sub-meter. The monitoring and control of individual loads, specifically solar panel systems and storage systems, in order to account for their actual energy use. This use case shall benefit PGE's customers by reducing the total costs of ownership and implementation of customer owned DER like PV solar and residential batteries.

7. Device Locations

The EMCBs shall be installed in the following locations at PGE's facilities in accordance with the table below:

	Site	Feeder	Location	Equipment	Pole	Size	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	6.10
1	Oregon City, LC Office	TBD	PANEL: DOCK-1	EV CHARGING STATION	2	30A	X	X	X	X				X		X
2	Oregon City LC Office	TBD	PANEL: DOCK-1	EV CHARGING STATION	2	30A	X	X	X	X				X		X
3	Gresham Cust. Service	TBD	PANEL: GARAGE	AIR COMPRESSOR	2	20A		X	X	X				X	X	
4	TCC	TBD	PANEL: EM2	HVAC COMPUTER ROOM	3	50A		X	X	X				X	X	
5	TCC	TBD	PANEL: EM2	AC #2	3	50A		X	X	X				X	X	
6	TCC	TBD	PANEL: F	WATER HEATER SOUTH	2	30A		X	X	X			X	X		
7	TCC	TBD	PANEL: F	WTR HEATER OVER QUIET RM	2	30A		X	X	X			X	X		
8	TCC	TBD	PANEL: C	WTR HEATR OVER W. COUNTER	1	30A		X	X	X						
9	Gresham Line Center	TBD	PANEL: STOREROOM	EV CHARGER 1	2	40A	X	X	X	X				X		X
10	Gresham Line Center	TBD	PANEL: STOREROOM	EV CHARGER 2	2	40A	X	X	X	X				X		X
11	Gresham Line Center	TBD	PANEL: STOREROOM	EV CHARGER 3	2	40A	X	X	X	X				X		X

	Site	Feeder	Location	Equipment	Pole	Size	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	6.10
12	Gresham Line Center	TBD	PANEL: STOREROOM	EV CHARGER 4	2	40A	X	X	X	X				X		X
13	Gresham Line Center	TBD	PANEL: STOREROOM	INFRARED HEATER	2	20A		X	X	X			X	X		
14	Gresham Line Center	TBD	PANEL: STOREROOM	INFRARED HEATER	2	20A		X	X	X			X	X		
15	Gresham Line Center	TBD	PANEL: D-1 (POLE BLDG)	HEATER	2	30A		X	X	X			X	X		
16	PSC	TBD	PANEL: NW LOT	NW LOT LIGHTS	2	20A		X	X	X			X	X		
17	PSC	TBD	PANEL: B	LIGHTS	1	20A		X	X	X			X	X		
18	BESS 1	TBD	SSPC - CLP1	BESS1	3	50A		X	X	X		X	X	X	X	X
19	BESS 2	TBD	SSPC -CLP 1	BESS2	3	50A		X	X	X		X	X	X	X	X
20	BESS 3	TBD	SSPC -CLP 1	BESS3	3	50A		X	X	X		X	X	X	X	X
21	BESS 4	TBD	SSPC -CLP 1	BESS4	3	50A		X	X	X		X	X	X	X	X
22	BESS5	TBD	Rose City - MAIN 1	BESS5	3	50A		X	X	X		X	X	X	X	X

Table 2.0: Device Location list