TECHNICAL NOTE

Measuring Circuit Breaker Opening Times with *CyTime Event Recorders*

Summary

CyTime Sequence of Event Recorders (SERs) measure circuit breaker opening times by recording the exact time of both the initiating event (e.g., relay trip signal) and resulting state change (tripped).

This document explains some of the benefits of knowing breaker opening times under different load conditions and describes how to implement the solution, either as a stand-alone device or part of a complete EPMS.

Sequence of Event Recorder

Introduction

Modern industrial/commercial Electrical Power Monitoring Systems (EPMS) report real-time status of circuit breakers throughout the electrical network. CyTime™ Sequence of Event Recorders (SERs) monitor the status of up to 32 digital inputs and record state changes with 1-ms time-stamping. By recording the exact time of both the starting event (control action) and ending event (status), the Sequence of Event Recorder measures circuit breaker opening times—to 1 ms.

Advance Warning of Slow Breakers

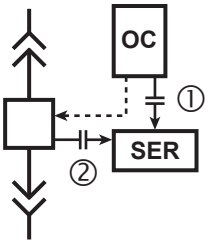
Over the lifetime of medium- and low-voltage power breakers, contact wear, arcing, temperature changes and mechanical stresses can cause increasing opening and closing times. These can affect automatic transfer timing and selective time-current coordination. In addition, interruption times that are longer than expected increase arc flash hazard. Rated opening times range from just one cycle up to 3 or 5 cycles.

Compare Opening Times Under Different Load Conditions

Opening times vary as a result of many factors, and so it's helpful to compare under similar load conditions. By monitoring several start/end pairs—open, close or trip command (from a relay, PLC or switch)—and the status change (breaker trip, a or b contacts), the SER reports opening times under different loading:

- No load (initiated by manual control switch)
- Normal load (initiated by control scheme)
- Overcurrent trip (initiated by relay trip signal)

In addition, event data is time-stamped for correlation with data logs and waveforms captured by advanced power meters. Accurate measurements of operating times are an essential part of circuit breaker maintenance, contributing to the reliability, efficiency and safety of the electrical power system.



① *Overcurrent relay trip signal (Breaker starts to open)*

② *Breaker trip contact (Breaker tripped open)*

Delta time (Breaker opening time)

② END EVENT

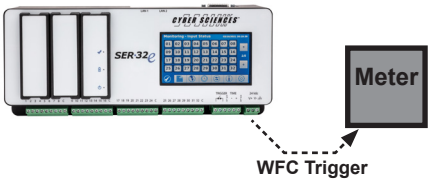
① START EVENT

Event	Date and Time	Channel	Event Type	Status	Time Quality	Delta Time
1204	10/20/2020 14:04:01.468	Fdr FCB3 Trip Contact	Input Status Change	Normal --> TRIPPED	0:Good (< 1ms)	0.094
1203	10/20/2020 14:04:01.374	Fdr FCB3 OC Relay	Input Status Change	Off --> Trip Signal	0:Good (< 1ms)	0.140
1202	10/20/2020 14:04:01.234	Fdr FCB2 Status	Input Status Change	Open --> Closed	0:Good (< 1ms)	0.094
1201	10/20/2020 14:04:01.140	Fdr FCB2 Switch	Input Status Change	Open --> Close	0:Good (< 1ms)	23 days
1200	09/27/2020 06:12:10.172	Fdr FCB3 Status	Input Status Change	Open --> Closed	0:Good (< 1ms)	1.094

$\Delta t = ② - ①$

Events web page with calculated time between events (delta time): trip signal (start event) and tripped status (end event).

BENEFITS OF KNOWING BREAKER OPENING TIMES



SER with Trigger for Waveform Capture

Breaker Opening Times

Low voltage circuit breakers are expected to open in 1 to 3 cycles, whereas medium voltage breakers are rated for 3-cycle or 5-cycle interruption.

Opening times in milliseconds (60 Hz):

- *1 cycle = 17 ms*
- *3 cycles = 50 ms*
- *5 cycles = 83 ms*

Capture Coincident Waveforms for Zero-Crossing Analysis

The SER can be configured to trigger a waveform capture by an advanced power meter coincident with any event. Voltage and current waveforms are used to evaluate breaker opening times under load/overload in the context of what point on the sine wave the interruption occurred.

Verify Arc Flash Calculations

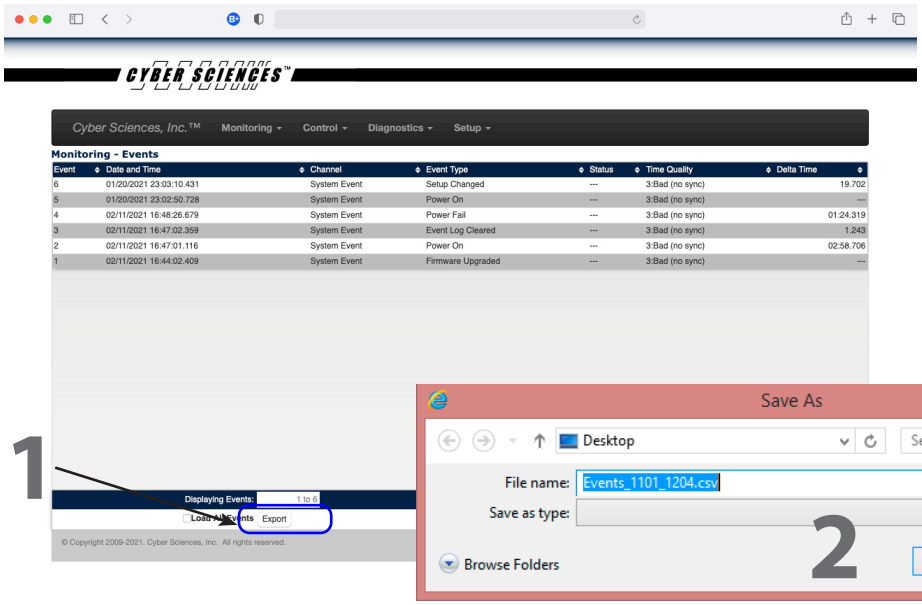
Arc flash calculations are based on expected circuit interruption times at various overcurrent levels. Arc flash energy is directly proportional to time, and so actual breaker opening times that exceed rated values impact the reliability of published arc-flash energy calculations. Advance warning of slowing circuit breakers is crucial.

Check Time-Current Coordination

Time-current coordination studies should ensure optimal selectivity of protective devices. However, changes to power system devices and loads can impact study results. In some cases, the study recommendations are never followed in the first place, and protective devices are left at default settings. When multiple devices open to interrupt a fault, event data from an SER can clarify which breakers opened in what sequence. Fault current data and coincident waveforms from meters augment this event data, either to confirm proper operation or to identify problems.

Export Events to Excel for Further Analysis, Trending

Click the Export button on the SER Events web page to save event data (csv) for custom analysis in Excel or other spreadsheet software. This allows statistical analysis of opening times by breaker or type, graphical analysis to spot trends, etc.



	A	B	C	D	E	F	G	H	I
1		Event	Date and Time	Channel	Event Type	Status	Time Quality	Delta Time	Seq #
2		1204	10/20/2020 14:00:58.468	Fdr FCB3 Trip Contact	Input Status Change	Normal --> TRIPPED	0:Good (< 1ms)	00 00:00:00.094	1204
3	3	1203	10/20/2020 14:00:58.374	Fdr FCB3 OC Relay	Input Status Change	Off --> Trip Signal	0:Good (< 1ms)	00 00:00:00.140	1203
4		1202	10/20/2020 14:00:58.234	Fdr FCB2 Status	Input Status Change	Open --> Closed	0:Good (< 1ms)	00 00:00:00.094	1202
5		1201	10/20/2020 14:00:58.140	Fdr FCB2 Switch	Input Status Change	Open --> Close	0:Good (< 1ms)	23 07:48:47.919	1201
6		1200	09/27/2020 06:12:10.221	Fdr FCB3 Status	Input Status Change	Open --> Closed	0:Good (< 1ms)	00 00:00:00.798	1200
7		1199	09/27/2020 06:12:09.423	Fdr FCB3 Switch	Input Status Change	Open --> Close	0:Good (< 1ms)	00 00:00:24.511	1199
8		1198	09/27/2020 06:11:44.912	Fdr FCB3 Trip Contact	Input Status Change	Normal --> TRIPPED	0:Good (< 1ms)	00 00:00:01.306	1198

Exported event data shown in Excel, formatted for further analysis and trending

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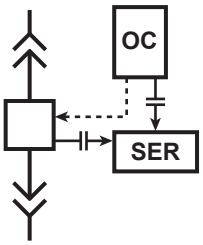
IMPLEMENTATION DETAILS

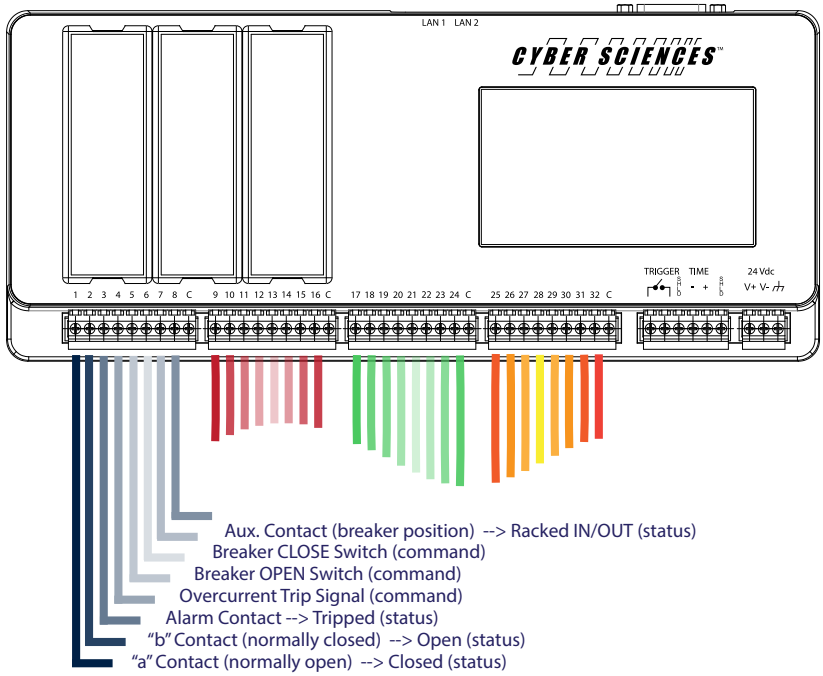


Examples of Action/Status Pairs

Condition	Control Action	Contact: Status
No load	Switch OPEN	a: Open
No load	Switch CLOSE	b: Closed
Normal load	Control OPEN	a: Open
Normal load	Control CLOSE	b: Closed
Overcurrent	Relay TRIP	alarm: Tripped

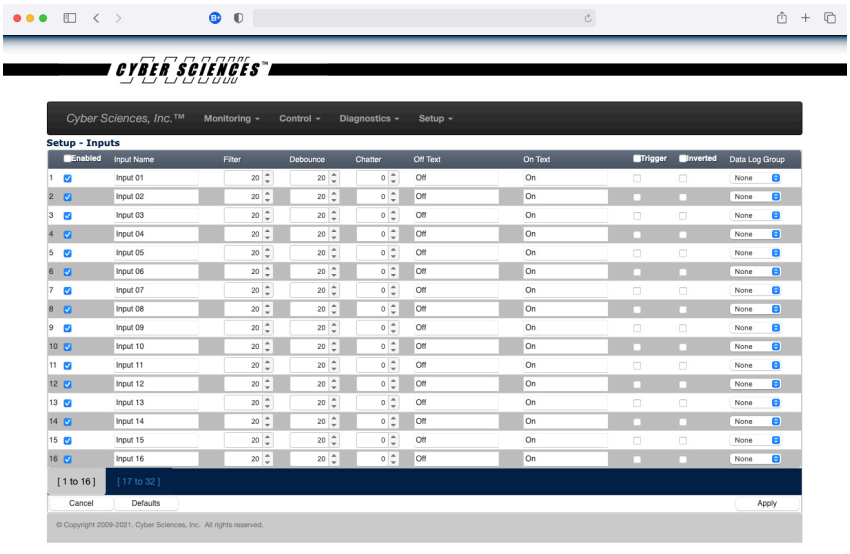
Monitor Start/End Pairs via Digital Inputs

The drawing below illustrates typical connections to SER high-speed digital inputs. For each type of breaker operation, inputs are used to record both the starting and ending events to 1 ms, necessary for calculation of breaker opening times.



Web Setup for Complete Customization

The SER web server makes setup easy. Customize descriptive text for each input, including input name, off-text and on-text descriptions (e.g., use "Open" and "Closed" instead of Off/On).



Use Setup-Inputs page to customize descriptive text for input names and off/on states

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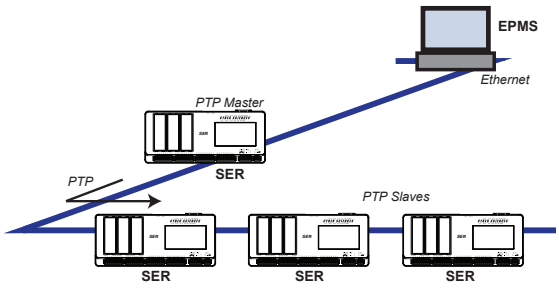
PART OF A COMPLETE SOLUTION



SERs use PTP (IEEE 1588) for hi-res time-sync over Ethernet with each other and with relays/meters

Correlating Events with other Devices

In large systems, it may be desirable to monitor the initiating action (e.g., trip signal) in one device and correlate with the resulting status (e.g., breaker tripped) recorded by the SER. This is accomplished using "hi-res" time synchronization of both devices, typically via PTP (IEEE 1588).

Integrate with Complete EPMS

Event Recorders integrate into a complete EPMS over Ethernet, using Modbus TCP. See CyTime SER Reference Guide (IB-SER-02) for details.

Extend with Custom Pages

The SER functionality can be further enhanced with custom pages developed by Cyber Sciences to meet unique project requirements. An example of a custom page is show below, providing detailed analysis of breaker opening times.

	#	Channel Name	Off-On	State	Date and Time	Time (sec)	Count
1	1	Main MCB1 OC Relay	0 1	Trip Signal	10/14/2015 09:07:44.296	0.089	1
	2	Main MCB1 Trip Contact	0 1	TRIPPED	10/14/2015 09:07:44.385		1
2	3	Main MCB1 Switch	0 1	E.O. Close	10/14/2015 09:07:44.296	0.089	1
	4	Main MCB1 Status	0 1	Closed	10/14/2015 09:07:44.385		1
3	5	Main MCB2 OC Relay	0 1	Trip Signal	10/14/2015 09:07:44.296	0.089	1
	6	Main MCB2 Trip Contact	0 1	TRIPPED	10/14/2015 09:07:44.385		1
4	7	Main MCB2 Switch	0 1	E.O. Close	10/14/2015 09:07:44.296	0.089	1
	8	Main MCB2 Status	0 1	Closed	10/14/2015 09:07:44.385		1
5	13	Fdr FCB1 OC Relay	0 1	Trip Signal	10/14/2015 09:07:44.296	0.089	1
	14	Fdr FCB1 Trip Contact	0 1	TRIPPED	10/14/2015 09:07:44.385		1
6	15	Fdr FCB1 Switch	0 1	Close	10/14/2015 09:07:44.296	0.089	3
	16	Fdr FCB1 Status	0 1	Closed	10/14/2015 09:07:44.385		3

Save Config | Load Config | Export | Update

Conclusion

Modern industrial/commercial EPMS already monitor real-time status of circuit breakers throughout the electrical network. By recording the exact time of both the starting event (control action) and ending event (status), the CyTime SER records state changes of up to 32 digital inputs and accurately measures breaker opening times—to 1 ms. Compare results under different load conditions, combine with data logging and waveforms captured by advanced power meters. Accurate measurements of breaker operating times contribute to the reliability, efficiency and safety of the electrical power system.

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