Grid Solutions

CB WATCH 3

HV Circuit Breaker Monitoring Solution

With circuit breaker fleets worldwide averaging >30 years of age and operating budgets shrinking yearly, many Asset Managers are exploring ways to move from time-based to condition-based maintenance on their circuit breakers while also providing increased availability and reliability.

The CB Watch 3 is a compact, modular, online monitoring solution, suitable for most high voltage circuit breakers. The monitoring functionalities can be selected to match the varied needs, from the simplest configuration (gas monitoring only for example) to the most complete one for critical breakers.

The CB Watch 3 records information using non-invasive sensors and monitors key diagnostic parameters, some during each breaker operation and other continuously. It looks for significant changes in performance and evaluates the breaker by providing an easy 1 to 5 risk assessment of the various monitored functions.

This emphasizes the urgent requirement for mechanical maintenance or arcing contact replacement, thereby minimizing expensive outages and routine inspections. It facilitates a more cost-effective, proactive "as needed" maintenance strategy.

Given the global focus on SF_6 gas usage, along with increased environmental reporting requirements and the risk of penalties, precise early detection of minor gas leaks is vital. The latest EMC-resistant digital gas sensor, can anticipate refilling needs before reaching critical levels that might disrupt operations.

Key Benefits

- Modern modular solution that fills diverse fleet monitoring needs with the same platform
- Can be factory fitted on new GE Vernova breakers or retrofitted to most types and brands
- Helps reduce costly SF_6 gas releases to the environment
- Seamless communication with control or asset management tools and through web server HMI

Applications

The CB Watch 3 is suitable for most HV circuit breakers: live tank or dead tank, with ganged or independent pole operation.

It is also increasingly used on GCB (Generator Circuit Breakers), on HYpact and on the circuit breaker compartments of GIS (Gas Insulated Switchgear).

Operational Timing

- Verifies that mechanism is opening/ closing and indicates deviation in speed of operation
- Detects performance degradation possibly linked to friction, corrosion or linkage failure
- Timing compensation for cold temperature to avoid spurious alarms

SF_6 Gas Monitoring

- Measures pressure, temperature of SF_6 gas (or gas mixture like g3) and calculates density and pressure at normalized 20 °C
- Detects gas leaks, calculates gas leak rate and gives advance warning before reaching critical threshold levels

Arcing Contact Wear

- Measures the current during each interruption as well as the arcing time
- Calculates the arc energy (I2T) and resulting cumulative electrical contact wear/erosion

Control Circuits

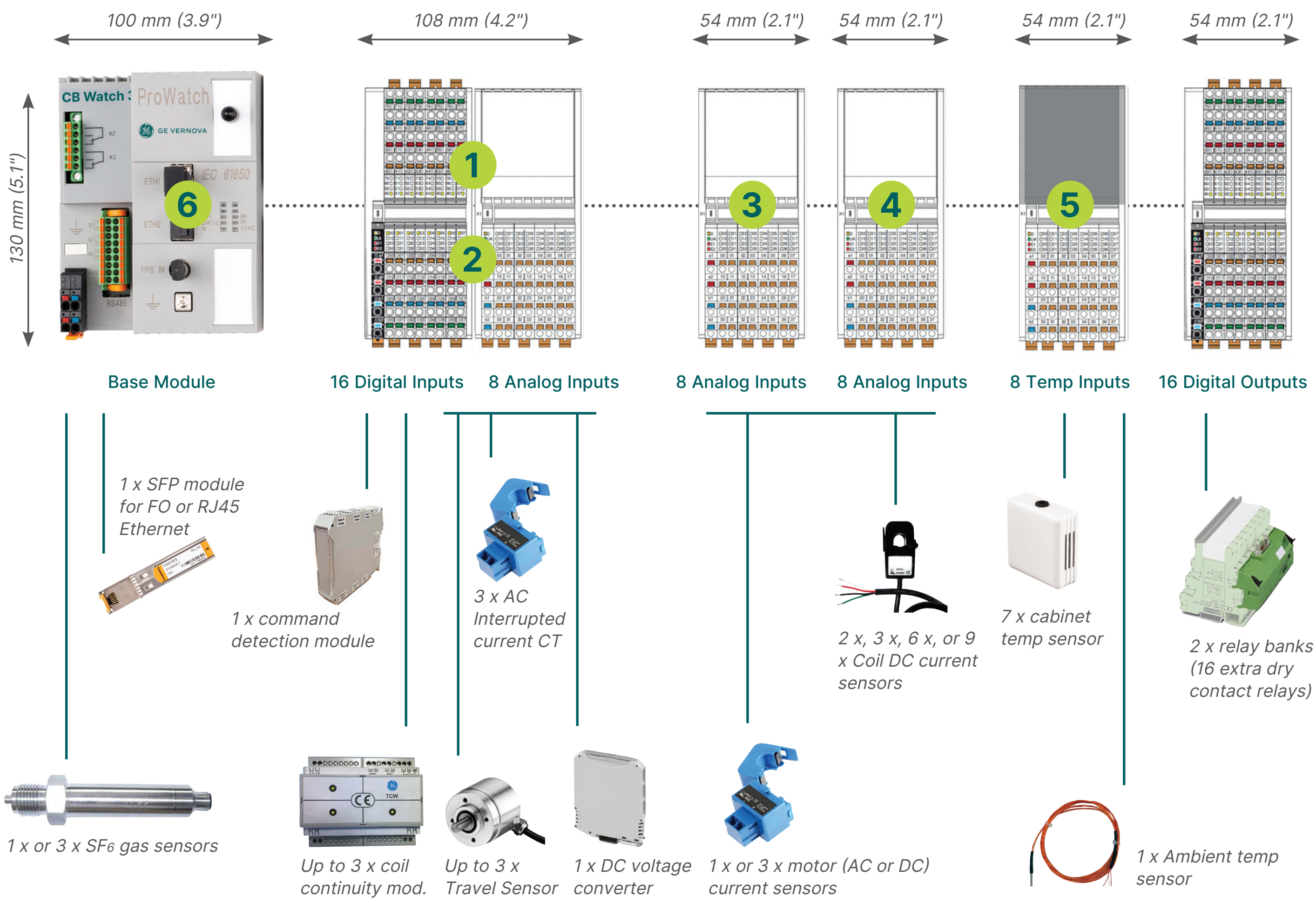
- Measures current flow through open/ close coils to monitor for degradation
- Can check coil continuity and DC supply level
- Uses temperature sensors to check for proper operation of the cabinet heating systems

Stored Energy System

- Looks at the frequency and time taken to rearm the stored energy system
- Monitors the current used by the motor(s) to detect any change in its profile

GE VERNOVA

Modular Design for most Brand/Types of Circuit Breakers



Modern Compact System

The CB Watch 3 is modern both in terms of its design and its performance. It can capture high-speed waveforms thanks to its fast 0.4 ms data sampling rate, enabling it to precisely analyze rapid events.

Interaction is through a Web-page server interface that displays both data tables and graphs for easy understanding of the information. Connection is made using any web browser to the CB Watch 3's IP address using secure https connection with SSL certificate. No software is required and the HMI is available in several languages and in either metric or imperial units.

Modularity

One key advantage lies in its modularity: its ability to add modules as necessary to make the system as small and simple or as complex and powerful as required for each individual breaker in your fleet, yet always using the same platform and HMI.

Each input/output module enables more sensors to be connected, more data to be acquired and more circuit breaker functionalities to be monitored. Small configurations can easily fit inside the circuit breaker's control cabinet but the CB Watch 3 is also available in its optional own cabinet.

Only one system (not 3) is required for an IPO (Independent Pole Operation) breaker, just with more analogue input modules. It means only one IP address per circuit breaker and simplified communications.

Data Communication

In addition to being available through the HMI, all measured data points and alarm status after each operation are stored in registers that can be remotely accessed. Information from the last 50 operations is kept in memory for easy future comparison, along with associated graphs.

Data can be downloaded to historians (or to GE Vernova's Perception Fleet software) through Ethernet TCP/IP over either copper or fiber optic cables using either Modbus, DNP3 or IEC 61850 Edition 2 protocols.

Synchronization with the sub-station time is possible using either SNTP or IEC 1588 (PTP) and all graph data points are also stored in COMTRADE format files for easy comparison with relay information.

While the system does have 2 x dry contact relays (1 x system watchdog and 1 x user assignable), it does support an option for

16 x additional assignable relays for more traditional connections to a SCADA system.

The CB Watch 3 can also easily be interfaced with GE Vernova's Orbit wireless communication systems to avoid digging trenches for cables within the substation or to replace any missing network connection from the sub-station.

Complete Coverage Made Easy

The CB Watch 3 covers all the main monitoring requirements outlined in IEEE C37.10.1 "Guide for the selection of monitoring for circuit breakers". It measures and checks key parameters every time the circuit breaker operates but also continuously monitors other items in between operations.

Risk Indexes

With over 100 parameters being measured and 70 alarms that can be set, we wanted to facilitate the understanding of the data obtained and make it actionable, especially to non-CB specialists.

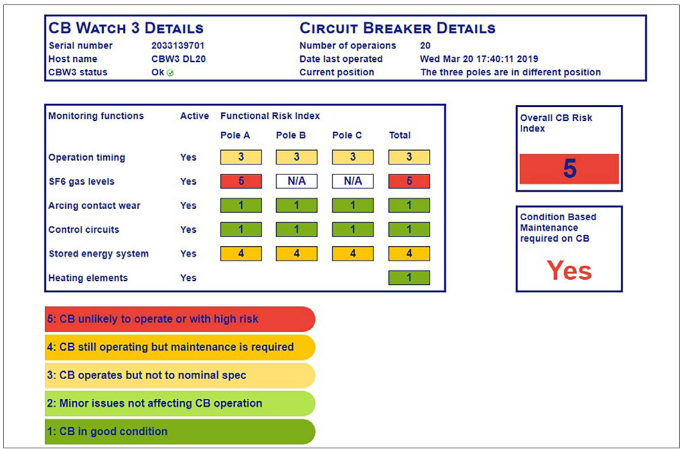
The CB Watch 3 continuously and automatically analyses the results obtained for each monitored function and uses algorithms to calculate an associated color-coded Risk Index (RI). An overall RI for the CB is then derived, measuring from 1 to 5 the risk to the CB successfully operating when next requested.

The functional RIs enable to pin-point what monitored function is causing the problem, down to the pole level for IPO CB. A log explains what triggered the change in RI, provides a recommendation of what to do next and sets a flag if maintenance is deemed required for that CB.

Integration with Perception

When used in conjunction with GE Vernova's Perception Fleet software, the data from each CB can be polled and archived centrally. Further analysis, trending and comparisons can then be made from the data accumulated over time.

A fleet of CB can be ranked based on their Risk Index, in order to easily focus action on the CBs with the highest RI or with recently worsening RIs.

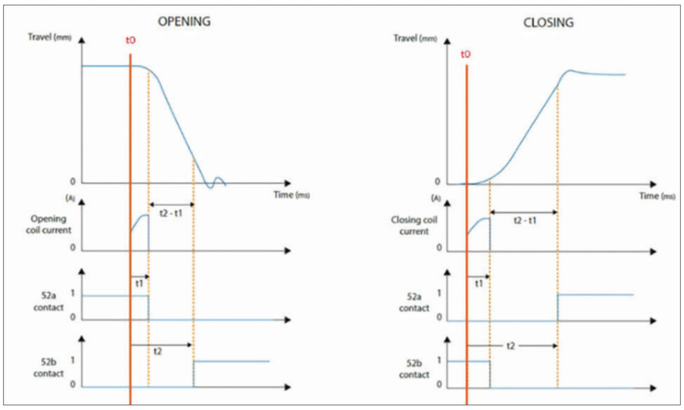


Overview page with Risk Indexes

Measured During Each Operation

1 Operational Timing

Ensuring that the Circuit Breaker (CB) continues to operate quickly and within specs is key to preventing fault currents from damaging transformers (and also from burning the CB coils out).



Operation timing point charts

Timings

For each opening/closing operation and for each pole, a recording is made of:

- The date and time of the appearance of the command to open/close
- The reaction time (t1) between the command and the CB starting to move. Any increase of this portion is linked to the coil or latch
- The operation time (t2) between the command and the CB finishing its movement. This is the overall time taken by the CB
- The travel time (t2-t1) is also calculated as well as the contact separation/touching speed. Any increase is linked to the physical motion

The above values can be compared to nominal values (from Factory Acceptance Test) and an alarm raised for any significant deviation.

Last opening operation data

	Pole A	Pole B	Pole C
Last operation date and time	Mon Jun 15 11:39:08 2020		
Opening operation counter	801	801	801
52a contact switching time	17.2 ms	18.4 ms	19.6 ms
Opening reaction time (t1)	17.2 ms	18.4 ms	19.6 ms
Opening contact separation time (ts)	18.2 ms	19.4 ms	20.6 ms
52b contact switching time	29.6 ms	30.4 ms	31.2 ms
Opening operation time (t2)	29.6 ms	30.4 ms	31.2 ms
Opening travel time (t2-t1)	12.4 ms	12.0 ms	11.6 ms
Contact separation speed	8.5 m/s	8.8 m/s	9.1 m/s
Coil circuit DC voltage source 1	121.0 V		
Coil circuit DC voltage source 2	121.0 V		
Outside ambient temperature	20.1 °C		

Time Discordance Between Poles

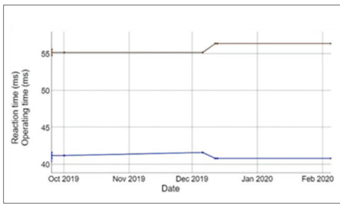
	|A-B|	|A-C|	|C-B|
Opening reaction time (t1) discordance	1.2 ms	2.4 ms	1.2 ms
Maximum reaction time discordance	2.4 ms		
Opening operation time (t2) discordance	0.8 ms	1.6 ms	0.8 ms
Maximum operation time discordance	1.6 ms		
Opening travel time (t2-t1) discordance	0.4 ms	0.8 ms	0.4 ms
Maximum travel time discordance	0.8 ms		

Operation timing values recorded

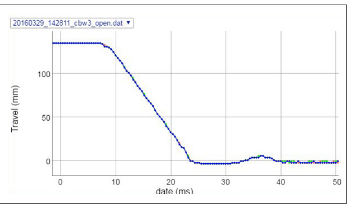
Additional features

As the CB operating times can vary due to increased friction at low temperature or lower DC voltage to energize the coil, these known timing variations (not attributable to the CB) can be compensated for in order to avoid false alarms.

As we only need one system for an IPO CB, we can measure any pole to pole discordance, when one pole exhibits a delay compared to the others.



Time trending graph



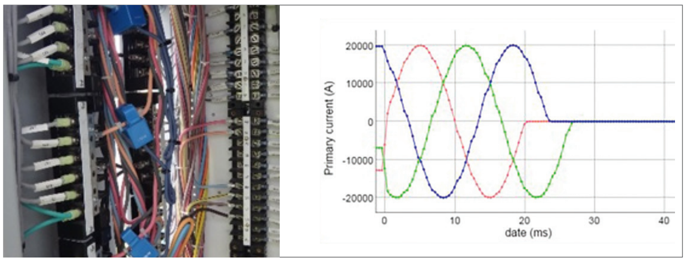
Travel curve graph

In addition to the alarms, historical graphs are available so that you can trend the various timing values, from operation to operation, and spot any slowing.

When a travel sensor is present, its information can be used to provide more precise data, check the auxiliary contacts and measure over-travel, but in most retrofit cases, travel sensors are not present but are also not required.

2 Arcing Contact Wear

Circuit breakers use special arcing contacts specifically designed to withstand the high electrical energy that occurs during opening. These contacts have a finite life and need to be replaced, especially in high fault current subjected environments. As inspecting and/or replacing them requires removing the SF_6 gas, breaking the gas seals and opening the breaker, this should only be done when absolutely necessary. Not only does it increase the likelihood of gas leaks but there are EHS risks associated with opening a CB, just for inspecting the state of the contacts.



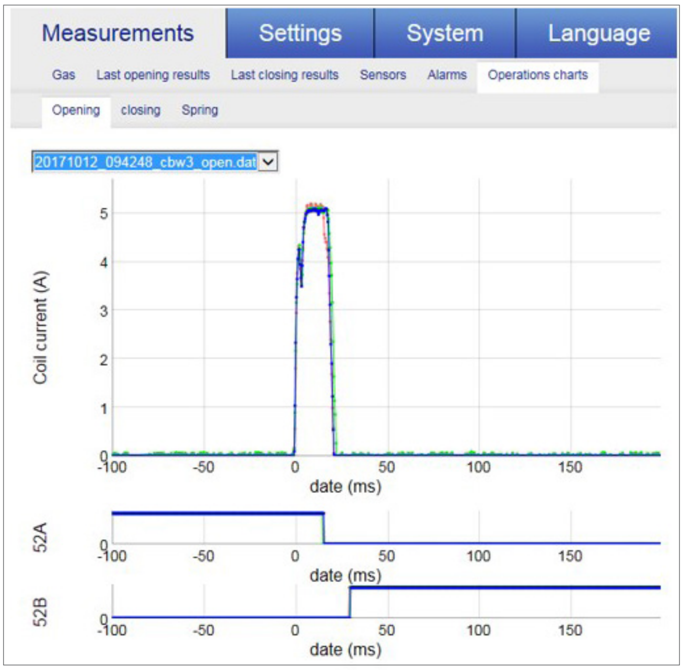
Acquiring interrupted current from primary CTs

By measuring when the current stops flowing through the CB, we can calculate the arcing time and monitor it for any increase.

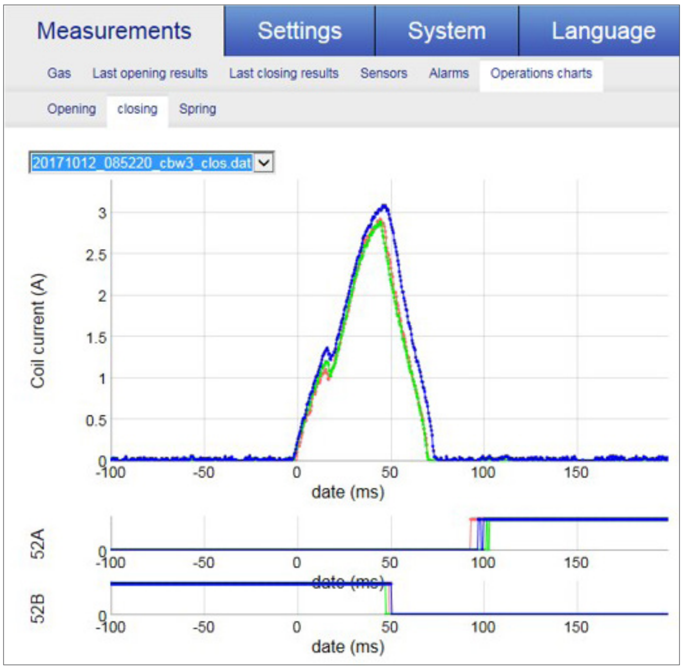
Since the current is much larger than normal during fault conditions (and this is what wears out the contacts more quickly), it is essential to measure the actual current involved in the arc. Some breakers can only do a few openings under fault condition before the contacts need replacement.

By taking the measured RMS interrupted current, squared and multiplied by the measured arcing time, we get the "I^2T" energy value (or wear) that each contact has been subjected to. By keeping a cumulative I^2T energy total and comparing it with the manufacturer's stated life for the contacts, we can trigger a timely contact replacement warning.

Measured During Each Operation



Coil Current - Opening



Coil Current - Closing

3 Control Circuit

The control circuits, comprising the DC sources (1 or 2) and the individual opening and closing coils (up to 9 for an IPO CB), are crucial to the execution of the opening or closing commands from the protection relays.

Coil Current

Any deterioration in the number of turns in a coil will decrease the coil resistance and will increase the DC current flowing through each coil. By measuring this current during each operation, we can detect any increase and thus any sign of deterioration prior to the coil becoming open circuit.

The current curve is displayed and stored. Alarms can be set on the mean current value and the coil charge (current x time). If the DC Voltage is also measured, then the actual coil resistance can be calculated and displayed.

Coil Continuity

This is more of a legacy requirement from when systems did not measure coil current. While most modern relays already do this, coil "continuity" can also be monitored. This is done by injecting a small current (below the level needed to actuate the coil) and continuously checking for electrical continuity. But it is invasive to retrofit (compared to clip-on CTs), and it does not provide any deterioration warning.

4 Stored Energy Motors

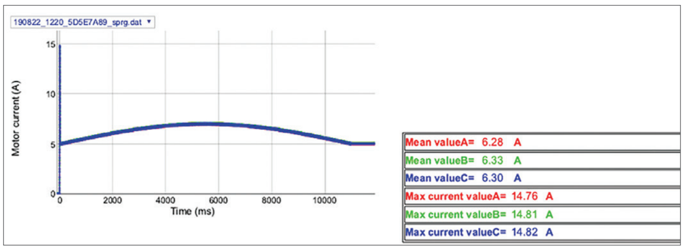
A spring is often used as the source of energy to move the CB contacts. It is normally rewound by a motor at the end of each closing operation. In other types of CB, a pump is used to maintain hydraulic or pneumatic pressure inside a tank, independently of CB operation. Either mechanism can be monitored:

Motor/Pump Run Times

By connecting to the motor on/off contacts or by using a relay, the time taken by the motor/pump can be acquired. Alarms can be set. Any shortening of the spring rewind time may indicate a partially broken spring.

Any lengthening may point to additional friction or a problem with the motor/compressor.

The cumulative run time and number of operations is also maintained for any motor/compressor maintenance requirement.



Motor current graph

Daily Pump Activity

By measuring the number of pump starts without CB operation every 24hr period, we can detect if the pump is running regularly to compensate for a pneumatic/hydraulic leak. The more the pump runs, the bigger the leak and the higher the likelihood that the pump will over-work and eventually fail.

Continuously Measured

6 Gas Leakage

Most new HV CB today use SF_6 gas (or a mixture) to extinguish the arc and insufficient gas pressure can prevent their operation (lockout).

Our fully digital, EMC-resistant, gas sensor can detect a leak in either one common gas tank or three (one gas tank per pole). It has a male BSPP G1/2" straight parallel thread to connect to existing tank valves (adapters or T-pieces will be required depending on brand/type of CB).

SF_6 Gas Sensor with digital output

Gas Density / Pressure

Gas pressure varies with temperature so comparisons are often made using the "gas density" as analogue gas sensors could only provide one value.

Since we use digital sensors that can transmit multiple values over Modbus, we can get the gas pressure and the gas temperature. Using algorithms and tables for SF_6 (or the gas mixture used), the gas "density" is calculated and, more importantly, the "gas pressure normalized at 20 °C" (in bar or psig). This makes it easier as all nameplate threshold pressure values are indicated at 20 °C. Alarms can be set for the following threshold levels:

- L1 "Additional filling required": The CB is still capable of fulfilling its function, but a gas refill is required to prevent reaching level L2
- L2 "Interlocking": The CB is no longer capable of fulfilling its function and is either locked closed or automatically opened and then locked
- L3 "Overfilling": When the amount of gas after refill is too high, there is a risk of overpressure at elevated temperature
- "Liquefaction": when at very low temperature (below freezing), a low gas pressure could cause the gas to liquefy (turn liquid)

Gas

	Pole A
Gas pressure measured	1.01 bar
Gas temperature measured	22.3 °C
Gas density	6.06 g/l
Gas pressure at 20°C	1.00 bar

Gas values displayed per tank

Gas Leakage Rate

Nowadays, in addition to making sure that the CB operates, detecting a gas leak early has become key (before the gas is released to the atmosphere): whether it is to be a good environmental citizen, to meet corporate / government leak targets or just to avoid the extra gas cost and even any associated fines.

Any drop in density/pressure is measured, recorded, trended over time and the gas leak rate is then precisely calculated. It is displayed in terms of pressure loss, mass loss and % loss. Two % leak rate alarms can be set.

By extrapolating the leak rate, an estimate can be made of the future pressure value after a user-specified time horizon in days. An alarm can be raised if threshold level L1 is going to be reached within this long-term time horizon, providing an advance warning that a refill will be needed. Similarly, another extrapolation warns you about how quickly L2 will be reached once the L1 alarm has been received.

Future Proof

The use of digital sensors not only enables to transmit more values/features (like the gas moisture level) but also makes it easy to accommodate gas mixtures (rather than pure SF_6) with the same sensor. This is handy when N2 or CF4 is added for better cold climates performance or when using the newest environment friendly gases like g3 (g cube).

2 DC Voltage Sources

The voltage delivered by one or two separate battery backed-up substation DC supplies can be continuously monitored. A low voltage during operation, means a longer time to energize the coils, leading to slower overall operating times.

If the voltage drops too low (for example when on sub-station batteries), then the coil will be unable to generate enough EMF to trip the latch. An alarm can be raised indicating that the batteries need checking.

3 Spare Analogue Channels

Depending on the overall system configuration, up to 4 spare analogue channels can be used to measure and monitor other values as per customer requirements. For example, the pneumatic pressure maintained by a pump or the AC supply voltage could be monitored and displayed.

Any analogue sensor with voltage or current output can be used. The description and the units of the measured value can be specified, and min/ max alarms can be set.

5 Cabinet Temperatures

When operating circuit breakers in harsh winter conditions or when trying to avoid condensation forming in hot humid weather, one wants to make sure that the heaters in the various drive and control cabinets are operating correctly.

While older systems relied on monitoring the heater current for continuity (to check that the heating resistance was not open circuit), this no longer works for thermostatically controlled heaters. By monitoring the end result instead, the actual temperature in the various cabinets, one can ensure that the correct temperature is being achieved and therefore that the heaters are working.

Alarms can be triggered if either the absolute temperature measured or the calculated delta to outside temperature is starting to drift both low or high.

Since 8 temperature sensors can be connected (7 + outside ambient), any tank heaters can also be monitored in addition to the cabinets. Each sensor gets its own user defined name for easier understanding in the HMI display.

Technical Specifications

OPERATIONS MEASUREMENTS		
Feature		**Value**
Time Horizon	Operation	0.3 seconds
	Motor current	12 seconds
Refresh Frequency		Every 400 micro seconds (0.4 ms)
Analogue Measurements	Accuracy	0.1 % of measuring range
	A/D Conversion	16 bit
Time	Accuracy	+/- 1 ms
Temperature	Accuracy	+/- 0.1 °C (PT100 3-wire)
Data Storage	Operation Data	Last 50 operations
	Pump Data	Last 15 pump starts

CONTINUOUS MEASUREMENTS		
Feature		**Value**
Refresh Frequency		Approx. every 1 second
Gas Measurements	Pressure Accuracy	± 20mBar over most of range
	Temperature Accuracy	± 2 °C
Analogue Measurements	Accuracy	0.1 % of measuring range
	A/D Conversion	16 bit
Temperature	Accuracy	+/- 0.1 °C (PT100 3-wire)
Time	Accuracy	+/- 1 second
Data Storage	Short Term Gas Data	Last 3,000 values @ 1 per minute
	Long Term Gas Data	Last 500 values @ 1 per day

POWER REQUIREMENTS		
Feature		**Value**
Power Supply Input Range	DC Source	100-250 V DC
	AC Source	100-240 V AC, 50/60 Hz
Rating System Only	125 V dc 1A	
	100 Vac 1A	
	240 Vac 1A	
Rating in Enclosure with AC Heater	125 V dc 1A	
	100 Vac 4A	
	240 Vac 2A	

CBW3	-	Sxx	Tx	Gx	Wx	Cx	Mxxx	Hx	Rx	Nx	Px	Vx	Exx	Selection Description
System		S11												Ganged CB, 1x open, 1x close circuits
		S12												Ganged CB, 2x open, 1x close circuits
		S31												Independent Pole Operation CB, 3x open, 3x close circuits
		S32												Independent Pole Operation CB, 6x open, 3x close circuits
Timing			T0											No CB operation timing
			T1											CB operation timing
			T2											CB timing and DC voltage monitoring
			T3											CB operation timing, using travel sensor
			T4											CB timing using travel sensor and DC voltage
SF6 Gas				G0										No SF6 gas monitoring
				G1										1x SF6 tank monitoring
				G3										3x SF6 tank monitoring
Contact Wear					W0									No arcing contact wear monitoring
					W1									Wear monitoring, from CTs <50m
Coils						C0								No coil integrity monitoring
						C1								Coil current monitoring (all open & close coils)
						C2								Coil current and continuity monitoring
						C3								Coil continuity monitoring only
Motors							M000							No drive motor monitoring
							MSD1							Spring rewind, DC motor, 1x
							MSD3							Spring rewind, DC motor, 3x
							MSA1							Spring rewind, AC motor, 1x
							MSA3							Spring rewind, AC motor, 3x
							MPD1							Pump, DC motor, 1x
							MPD3							Pump, DC motor, 3x
							MPA1							Pump, AC motor, 1x
							MPA3							Pump, AC motor, 3x
Temperature								H0						No temperature monitoring
								H1						Cabinet heaters temperature monitoring
								H2						Cabinet and tank heaters monitoring
Relays									R0					No extra dry contact alarm relays (2x)
									R1					16x extra dry contact alarm relays (18x)
Ethernet										N1				TCP/IP over MM fibre optic (1x LC connector)
										N2				TCP/IP over copper wire (1x RJ45 connector)
										N3				TCP/IP over MM fibre optic with 1588 (2x LC connectors)
										N4				TCP/IP over copper wire with 1588 (2x RJ45 connectors)
Protocol											P1			Modbus
											P2			DNP3
											P3			IEC 61850 Ed2
												V1		Power supply 85-264V AC / 90-350V DC to 24V DC
Enclosure													E00	No Enclosure; Din Rail Mounted for retrofit
													E2A	In enclosure CBW3, AC powered
													E2D	In enclosure CBW3, DC powered

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