Asset Management through Integrated Monitoring & Diagnostics in Protection Relays

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Presenter

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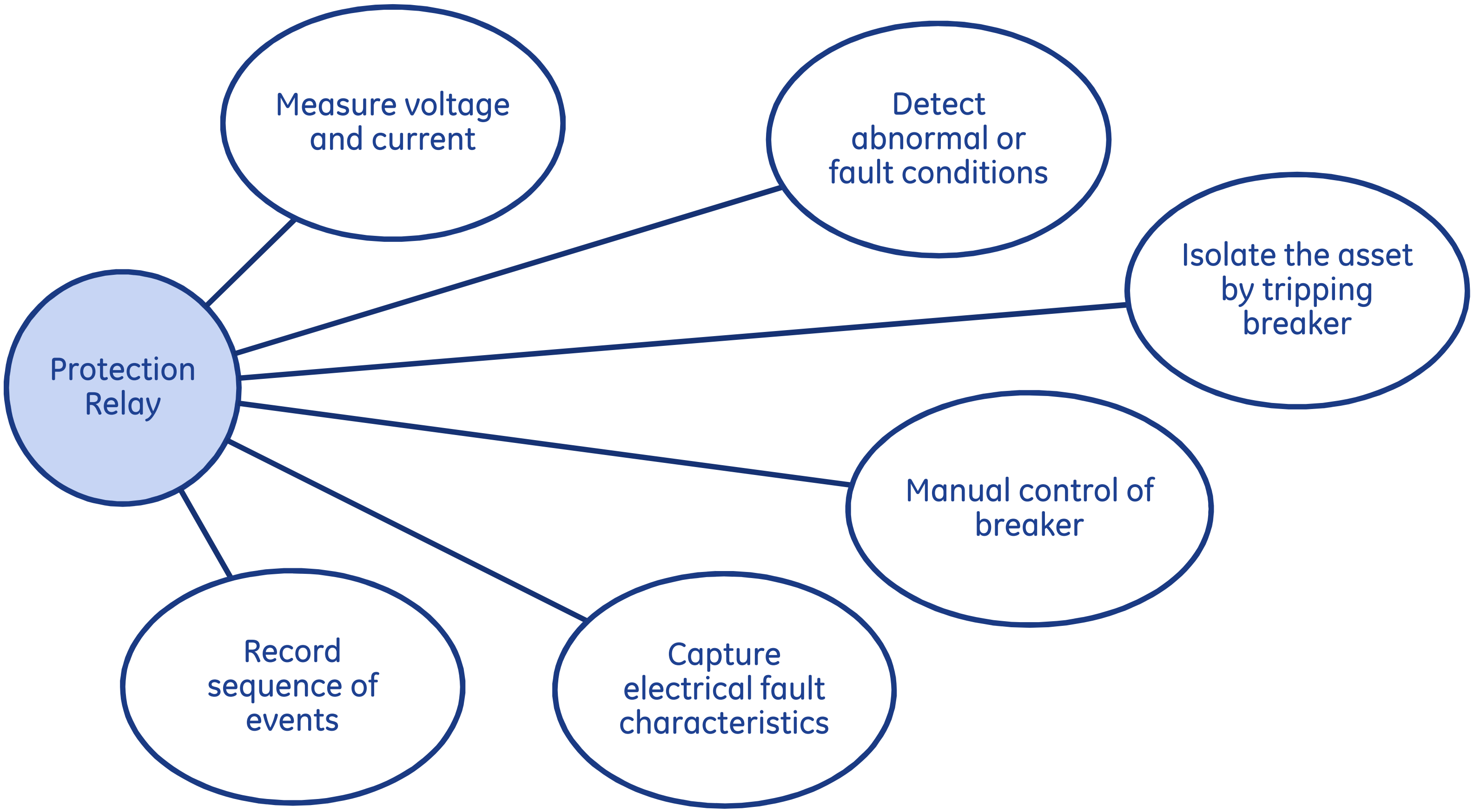
Agenda

- Traditional protection relay approach
- State of the art protection relay capabilities
- Common asset management challenges
- Protection relay to Asset management device
- Integrated Monitoring & Diagnostics for Motors
- Integrated Monitoring & Diagnostics for Transformers
- Integrated Monitoring & Diagnostics for Switchgear/Breakers
- Summary

Traditional Protection Relay Approach

Traditional protection relay approach



State of the Art Protection Relay Capabilities

State of the art protection relay capabilities

Reliability of Hardware

ELECTRONICS DESIGNS WITHOUT E-CAPS

Reliable electronics ensures maximum uptime and offers extended life for the relay

Dependability & Security of Protection

FAST FAULT CLEARANCE, SECURE PROTECTION ALGORITHMS

Faster the operating time, larger the reduction in stress on asset
Preventing mis-operation ensures maximum system availability

Convergence of Applications

DISCRETE DEVICES VS. ONE DEVICE

Eliminate complex protection schemes
Power quality, Metering, Logic & Control applications converging

Ability to communicate securely

SYSTEM WIDE CONNECTIVITY

Reliable network architecture IEC 62439
Interoperable IEC 61850
Cyber security

Advanced Signal Processing

HIGHER SAMPLING RATE, ACCURACY, LEARNING CAPABILITY

Accurate modeling and representation of asset conditions

Ease of Use

TOOL SETS FOR LIFE CYCLE MGMT.

Simplified configurations
Troubleshooting tools
Simulation & testing tools

State of the art protection relay capabilities

- Reliability
- Performance
- Extended Life
- COMMs & Data volume
- Convergence
- Ease-of-Use

In the Era of Industrial Internet – Protection Relays
will not be just tripping devices

Common Asset Management Challenges

Industry Asset Management Challenges

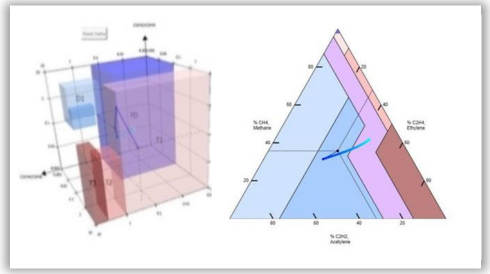
Industry challenge	Industry can benefit from
Aging asset fleets with many assets reaching end of design life in an environment of increased CAPEX constraints	Extension of life for aging assets and prioritize asset replacement projects (defer cost of replacement)
OPEX constraints leaves overwhelmed resources and difficult preventive maintenance programs	Optimize maintenance schedules and shift from schedule based to condition based preventive maintenance
Unexpected failures leading to safety concerns, unplanned outage, and loss of production	Prevent unexpected failures, ensure safety and save cost of unplanned outage or production loss
Expertise reducing due to retiring work force	Migrate analysis and interpretation done by personnel into devices and tools that can provide actionable intelligence

Present and Future of Monitoring Assets

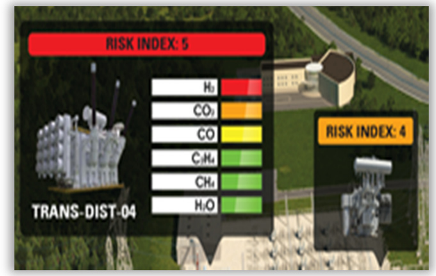
Reactive

Managed

Predictive



Proactive



Today largely practiced

- Offline monitoring of assets & Discrete monitoring devices
- Scheduled based maintenance / monitoring
- Expert based interpretation of voluminous data

Evolving trends – Industrial Internet

- Online monitoring of assets
- Condition based maintenance
- Big data analytics and Remote M&D with actionable intelligence

Protection Relay to Asset Management Device

Why Integrated M&D in Protection Relay

Regulatory device

- Relay is a must, it is always there
- While monitoring is an insurance play

Convergence

- Converging applications such as monitoring, control & logic
- Leverage data available in relay
- Natural evolution is Asset Management

Relay Technology

- Technology advancements in signal processing, processing capability, storage
- Ability to share big data over COMMs

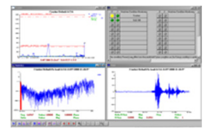
Simplified & Scalable Solutions

- Offers simplified M&D solution
- Cost effective M&D solution within a relay
- Scalable for small to large systems
- Integrate sensors for advanced solution

Facets of Asset Management in Protection Relay

Data Gathering

- Electrical / Thermal characteristics
- Chemical / Mechanical characteristics
- Real time, short term & long term data
- Reduce discrete Hardware devices



Condition Monitoring

- Techniques to detect failure modes
- Enable condition based maintenance
- Reduce dependency on consulting experts

Performance Monitoring

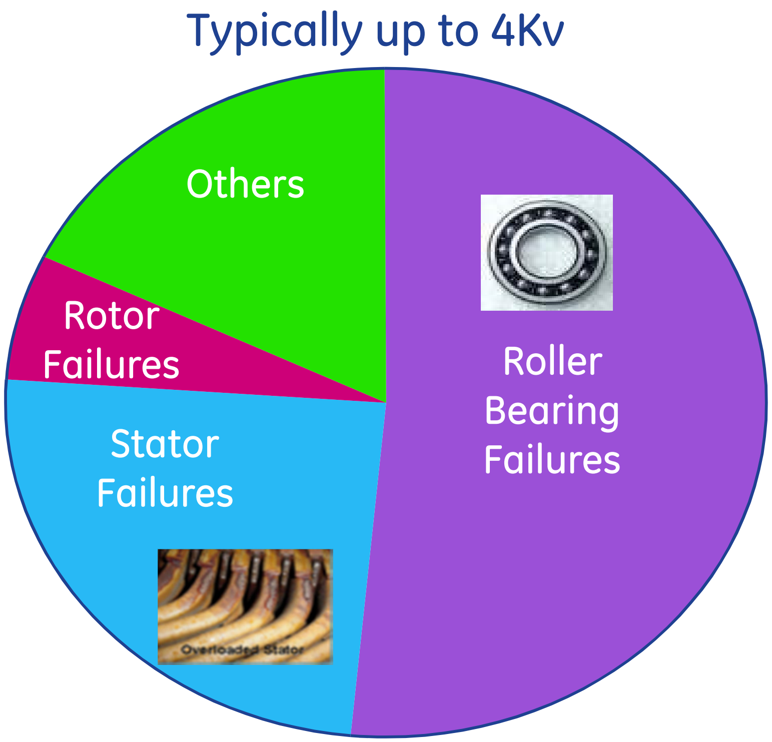
- Operational event capture
- Historic correlation for performance
- Improved situational awareness

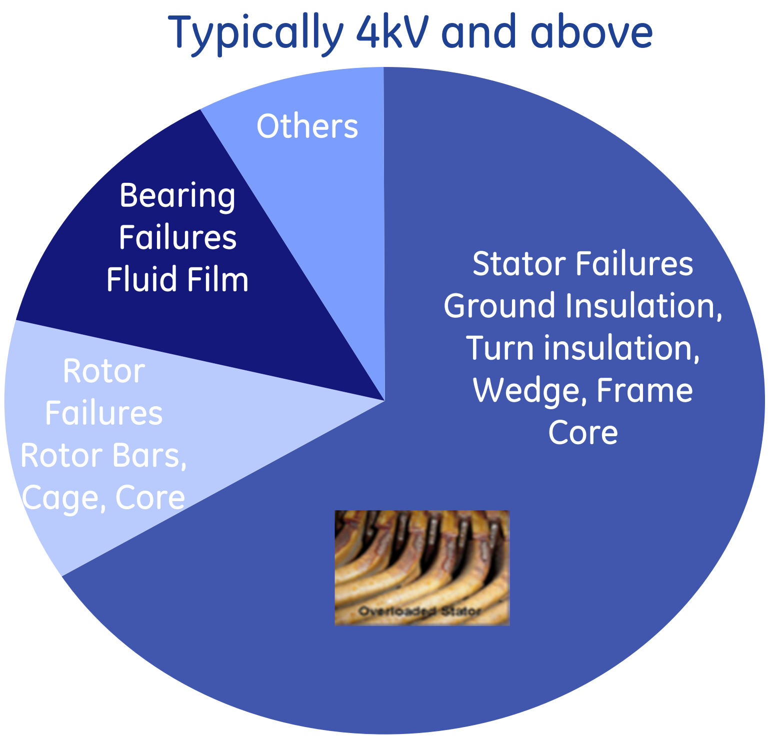
Diagnostics, Reports & Analytics

- Asset health report
- Electrical / Thermal / Chemical models
- Data correlation models
- Less analysis/paralysis – actionable intelligence

Integrated Monitoring & Diagnostics for Motors

Motor Failure Modes



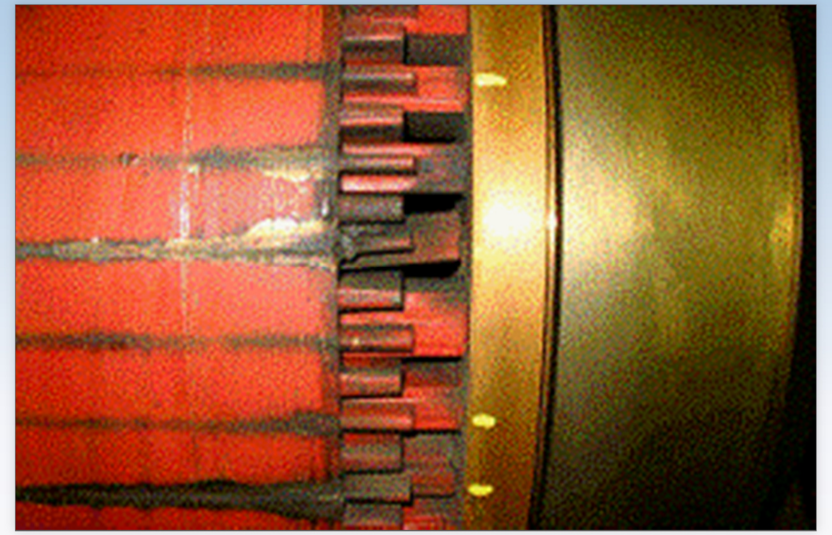


Integrated M&D in Motor Relay

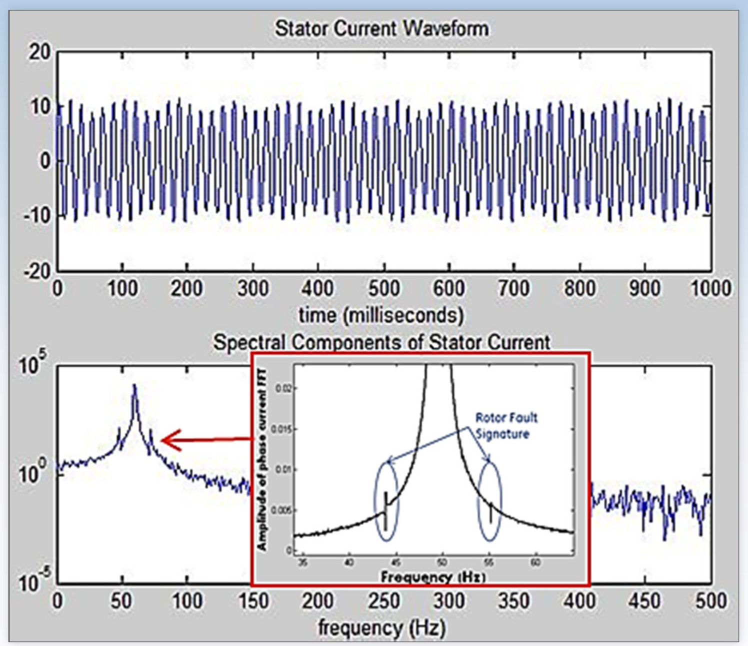
- Bearing vibration monitoring using 4-20mA inputs
- Broken rotor bar detection
- Stator turn-turn fault detection
- Historic data records
- Motor start characteristics
- Stator Insulation online monitoring solution

Broken Rotor Bar Detection

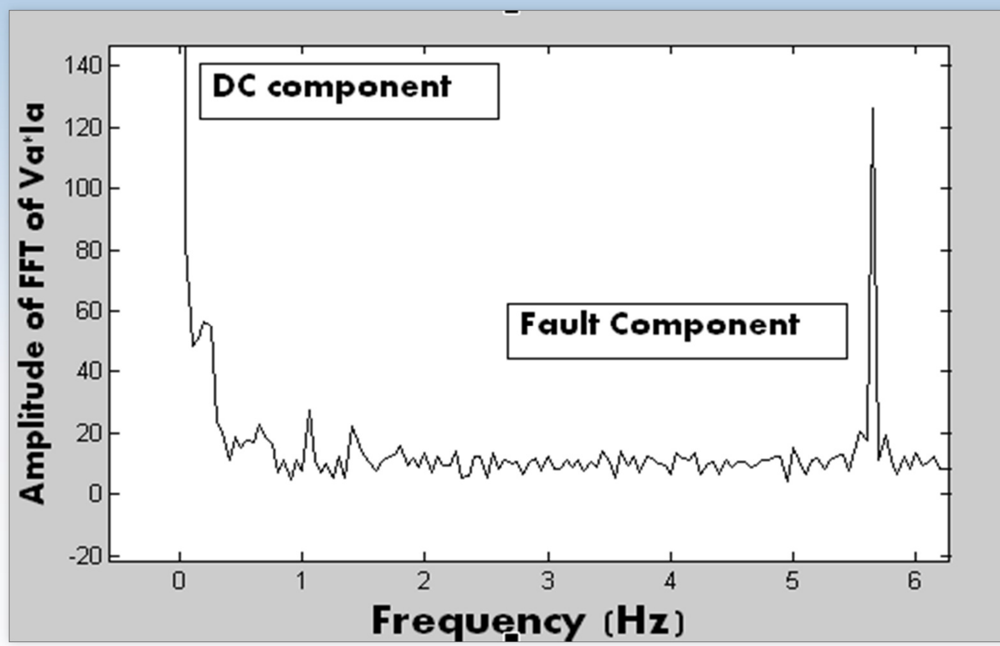
- Uses motor current signature analysis (MCSA) to detect broken rotor bars
- 2 methods:
  - Power based coherent demodulation when voltage available above motor voltage supervision level
  - Conventional current based FFT when voltage not available or under voltage supervision level



Comparison of two BRB detection methods



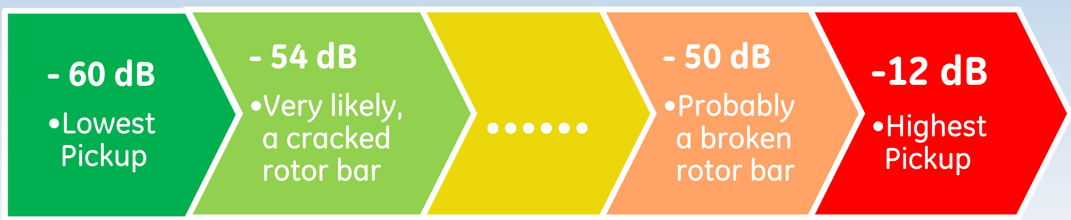
Conventional stator current based FFT



FFT of Power Based Coherent Demodulation

Broken Rotor Bar Detection Example

- Example of spectrum spread:

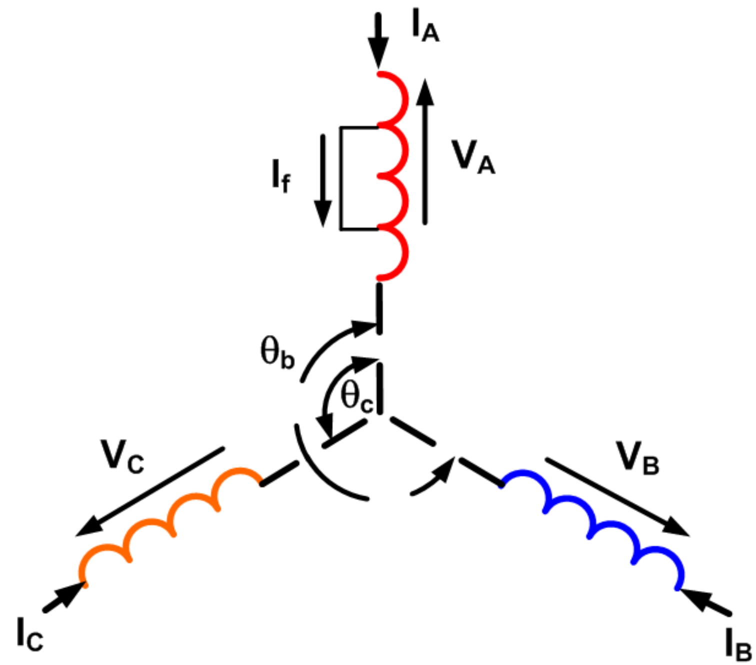


$$Start\ of\ BRB\ Offset = 2sf_1 - \max(0.3, \min(2sf_1 - 0.4, 1))$$
$$End\ of\ BRB\ Offset = 2sf_1 + \max(0.3, \min(2sf_1 - 0.4, 1))$$
$Where$:
$f_1 = system\ frequency$
$s = motor\ slip\ at\ full\ load$

Function	Latched Alarm
Start of BRB Offset	1.00 Hz
End of BRB Offset	3.00 Hz
Start Block Delay	60.00 s
Minimum Motor Load	0.70 x FLA
Maximum Load Deviation	0.10 x FLA
Maximum Current Unbalance	15.0 %
Motor Voltage Supervision	50.0 %
Pickup	-50 dB
Dropout Delay	10.00 s

Turn to Turn Fault Detection

- Technique is based on measuring the cross coupled Impedance of the motor
- Balanced machine has ideally zero cross coupled impedance
- Variance on this parameter used to detect turn-turn fault
- Characteristics
  - Load independence
  - Robustness to system imbalance
  - Machine independence



Historic Data Records in Relay

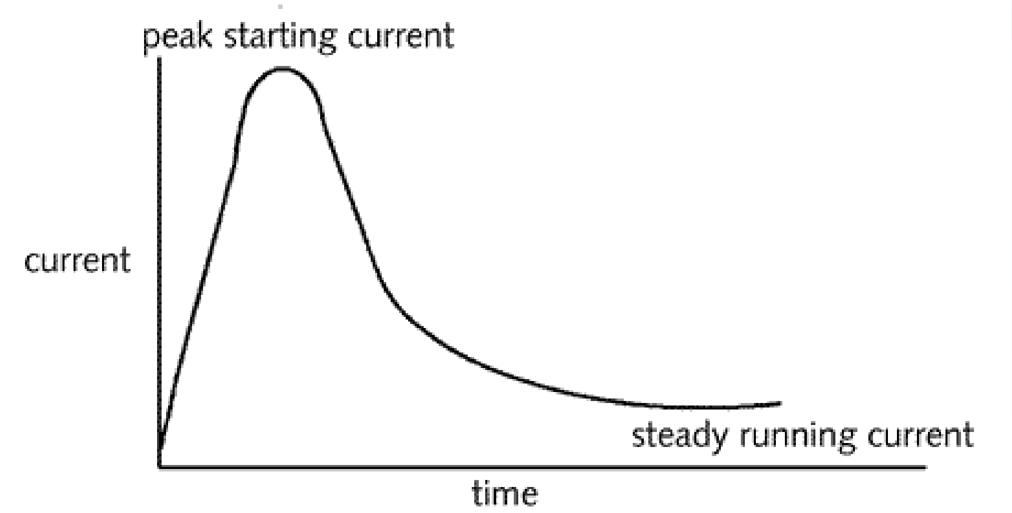
- Critical motor parameters captured for historic operational correlation
- Large number of records to cover lengthy operational cycle
- Thermal, Electrical and Mechanical parameters stored

Record Number	Date
11	Jul 10 2014
10	Jul 10 2014
9	Jul 10 2014
8	Jul 10 2014
7	Jul 10 2014
6	Jul 10 2014
5	Jul 09 2014
4	Jul 09 2014
3	Jul 09 2014
2	Jul 09 2014
1	Jul 09 2014

Item Name	Value	Value
Learned Acceleration Time	0.0 s	0.0 s
Learned Start Current	0.0 xFLA	0.0 xFLA
Learned Start TCU	0 %	0 %
Last Acceleration Time	0.0 s	0.0 s
Last Starting Current	0.0 xFLA	0.0 xFLA
Last Start TCU	0 %	0 %
Learned Average Load	0.90 xFLA	0.90 xFLA
Learned Average KW	22100.00 KW	117.70 KW
Learned Average Kvar	133400.00 Kvar	66.30 Kvar
Learned Average PF	0.16	0.87
Average Run Time (Days)	0 days	0 days
Average Run Time (Hr/Min)	00:26 hr/min	00:00 hr/min
RTD1 Max	0 °C	0 °C
RTD2 Max	0 °C	0 °C
RTD3 Max	0 °C	0 °C
RTD4 Max	0 °C	0 °C
RTD5 Max	0 °C	0 °C
RTD6 Max	0 °C	0 °C
RTD7 Max	91 °C	91 °C
RTD8 Max	0 °C	0 °C
RTD9 Max	0 °C	0 °C
RDT10 Max	0 °C	0 °C

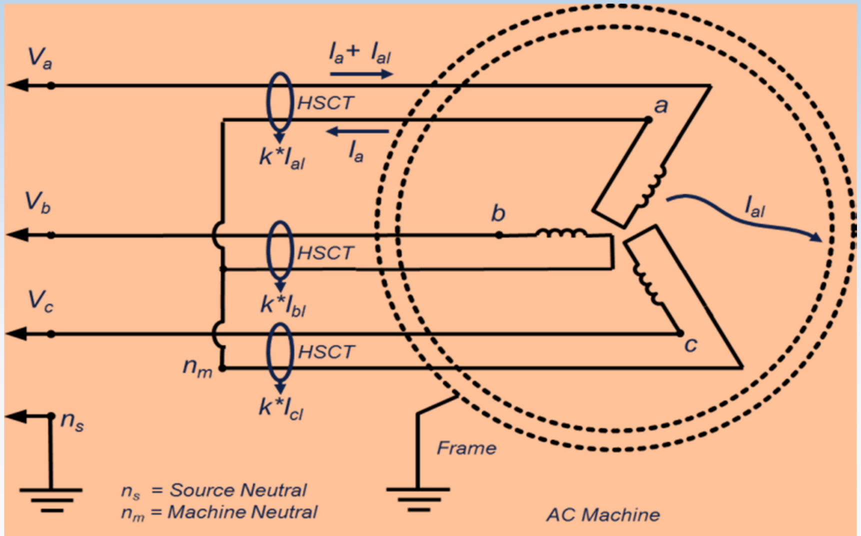
Motor Start Characteristics in Relay

- Every motor start, motor parameters can be recorded at frequent sampling interval
- Baseline a healthy motor start
- Study variance in motor start characteristics
    - RMS I_a, I_b, I_c, I_{avg}
    - RMS V_{an}, V_{bn}, V_{cn} (Wye)
    - RMS V_{ab}, V_{bc}, V_{ca} (Delta)
    - Current Unbalance (%)
    - 3ϕ Real Power
    - 3ϕ Reactive Power
    - 3ϕ Power Factor
    - Thermal Capacity Used (%)
    - Frequency
    - Motor Status

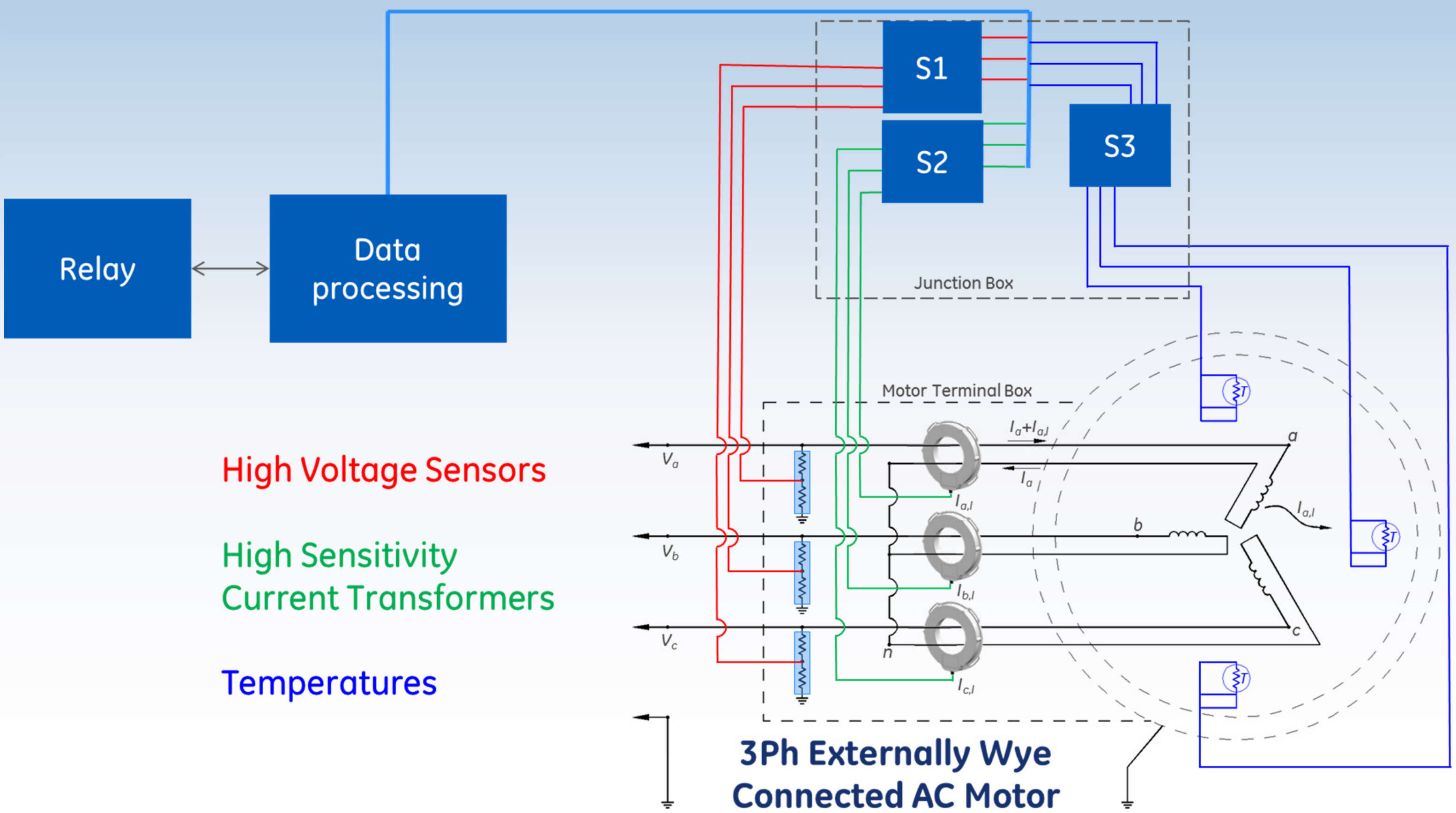


Motor Online Insulation Monitoring Technology

- Purpose: Early detection of insulation degradation or failure to ground
- Traditional approach:
  - Offline Megger test
  - Offline PD measurement
  - Online PD measurement
- Evolving trend
  - High Sensitive Current Transformer
  - Directly measures resistive and capacitive leakage current
  - Provides capacitance and Dissipation Factor (DF)
  - Allows trending of insulation degradation



High Sensitive Current Transformer Technology

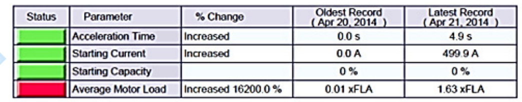


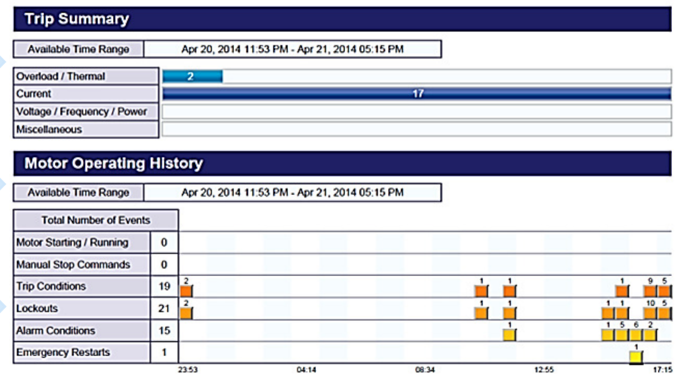
HSCT Technology Benefits

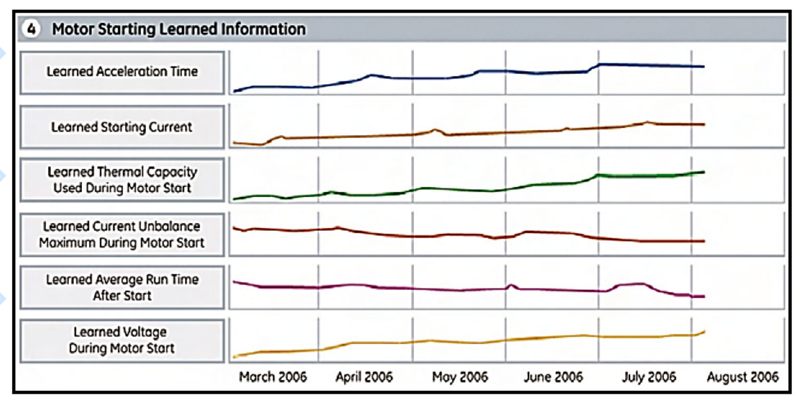
- Continuous, online insulation integrity measurement
- No need to take the motor offline or shut down the process
- Avoids or reduces the economic impact of motor replacement and repair
- Intensive monitoring while running until the process can be shut down in a controlled way
- Provides insights to avoid secondary damage to the process that occurs in an emergency trip
- Simplified interpretation – set thresholds or trend. No need for expert analysis or interpretation

Motor Health Report Analytics in Relay

Device Overview	General information on the motor
Status Overview	Summarizes historical data and status of the motor
Trip Summary	Summary of events that resulted in the motor trip
Motor History	Events associated with operating conditions
Motor Starting	Collects and displays the learned data from starting
Motor Start	Displays the start data, including presents the detailed start data
Motor Stop/Trip	Provides events that are specifically related to the stopping and tripping of the motor







Integrated Monitoring & Diagnostics for Transformers

Transformer Monitoring & Diagnostics Today…

Relay

Transformer electrical characteristics

- Continuous monitoring of electrical parameters
- Internal or external fault detection and electrical data collection
- Pre and post fault analysis of electrical data - transient record and fault report

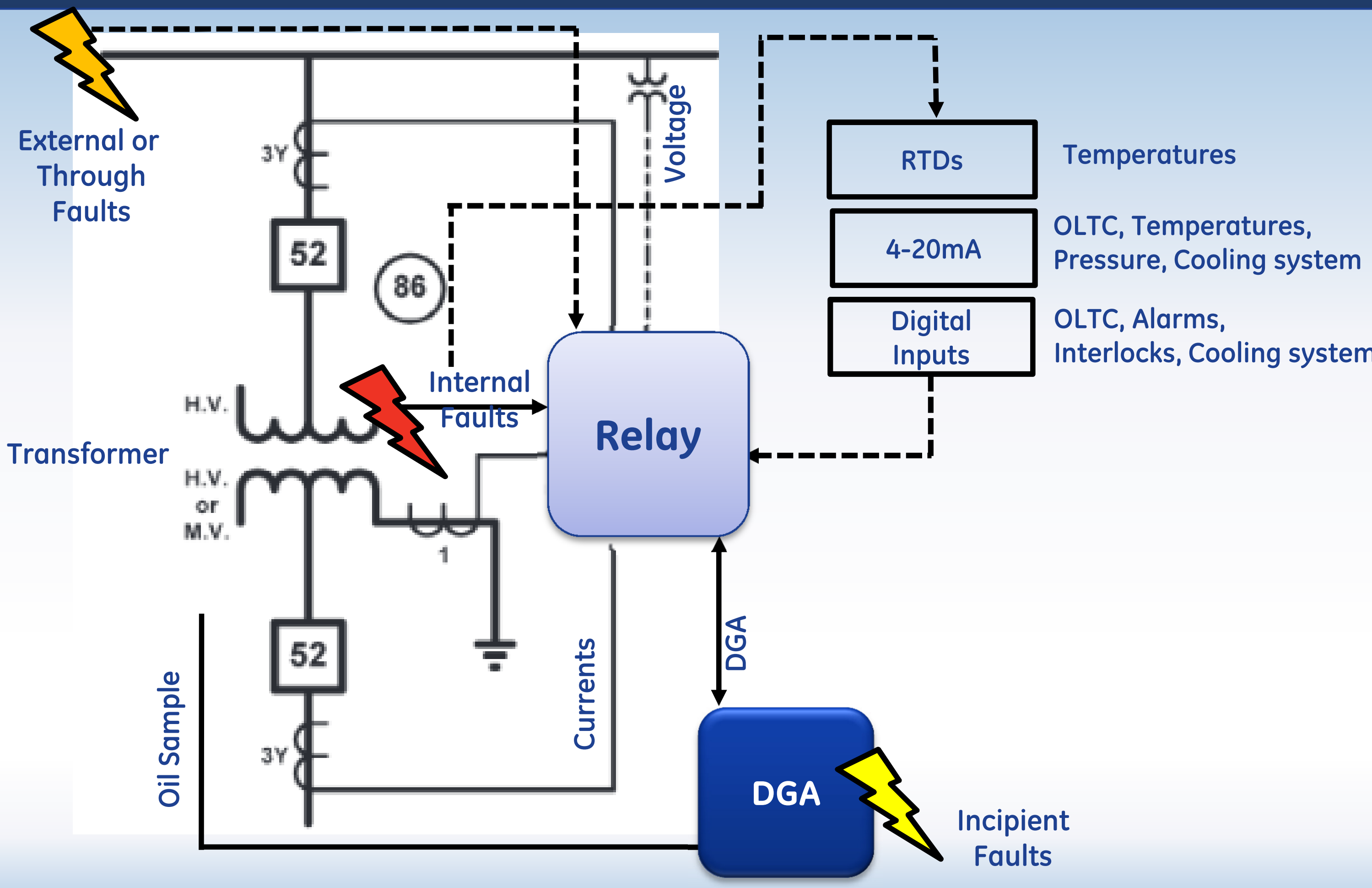
Dissolved Gas Analyzer

Transformer dissolved gas characteristics

- Continuous monitoring of single or multiple gas parameters
- Transformer incipient fault detection using DGA data and models

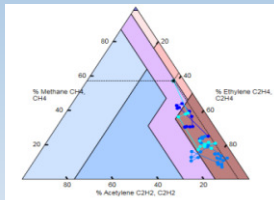
No Convergence of Physics & Chemistry

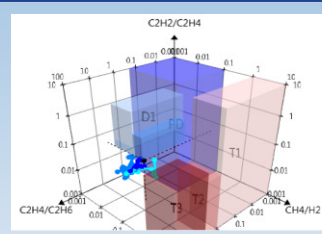
Transformer M&D in Protection Relay



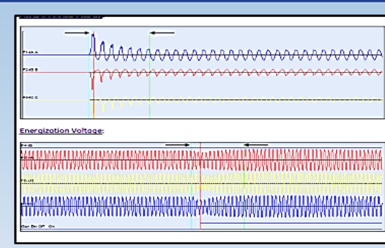
Integration of DGA into Protection Relay

Electrical Models

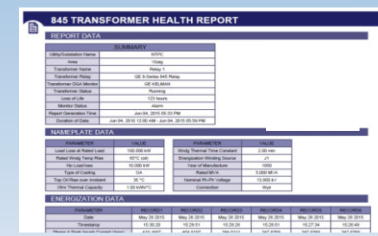




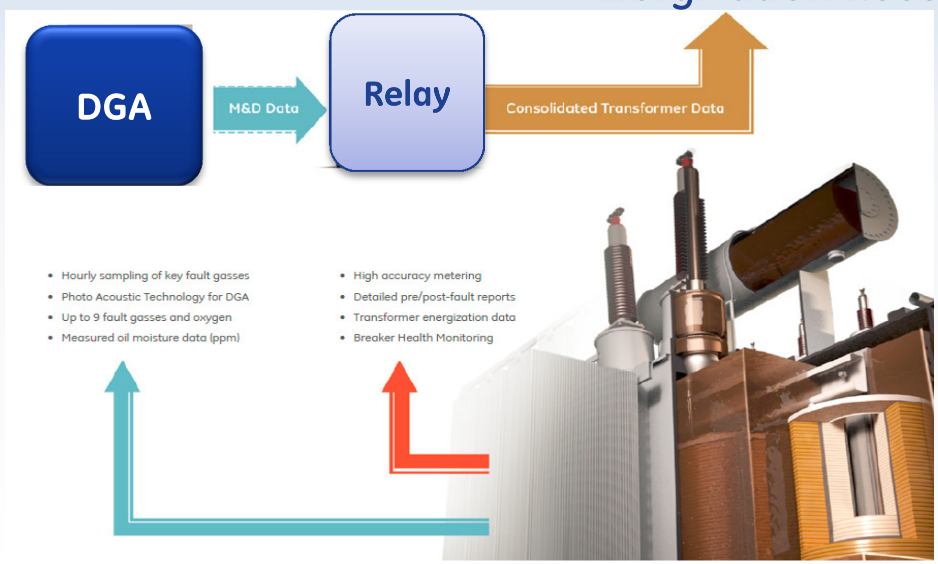
DGA Models



Energization Record



Health Report



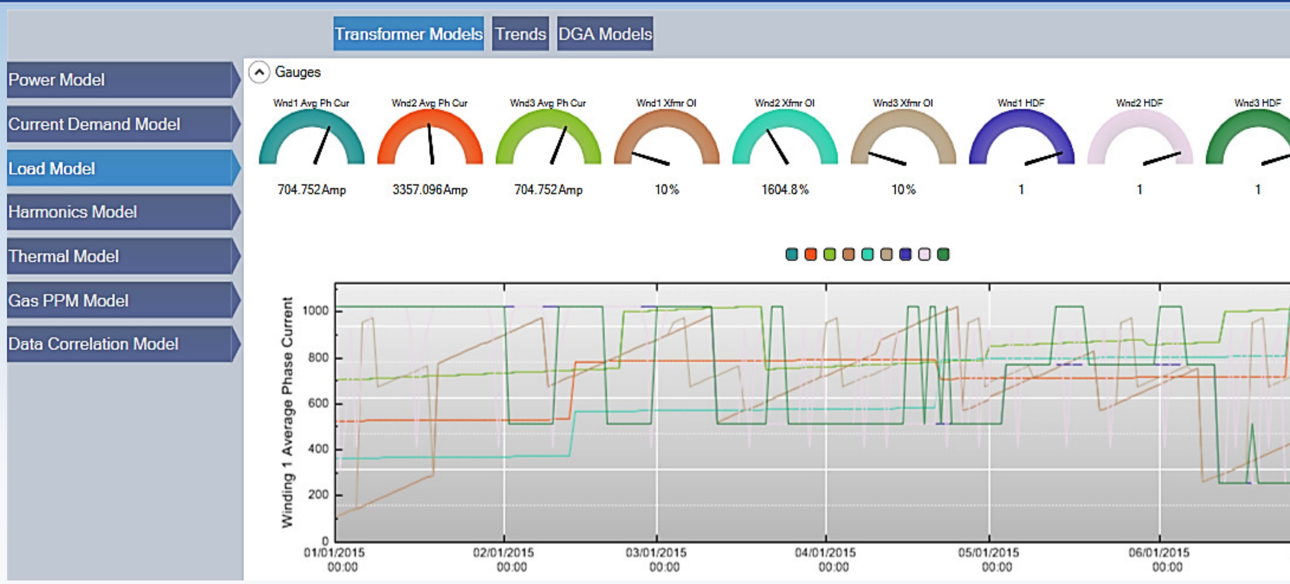
Transformer Monitoring & Diagnostics in Relay

Basic Monitoring
Dry type Distribution Transformer (<2 MVA)
- Breaker monitoring
- Harmonics & THD
- RTD

Advanced Monitoring
Mid Range & High End Power Transformers (>10 MVA)
- Standard monitoring +
- Learning, History
- Energization characteristics
- Transformer health report
- Transformer models
- Integrated DGA analysis

Standard Monitoring
Low End Oil Filled Transformer (<10MVA)
- Basic monitoring +
- Hottest spot
- Aging factor
- Loss of life

Electrical Models



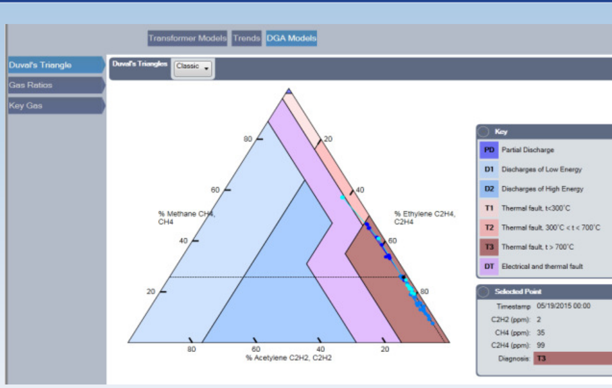
What is it?

- Numerous critical electrical parameters computation/monitoring
- Max operational data log & trending

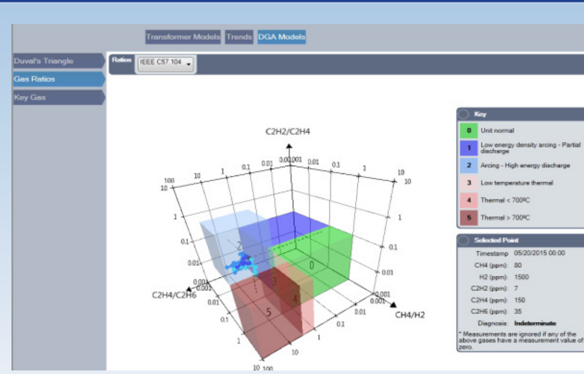
How to use?

- Simplified data analytics from ready to read monitoring data
- Powerful data correlation (e.g. load vs temperature)

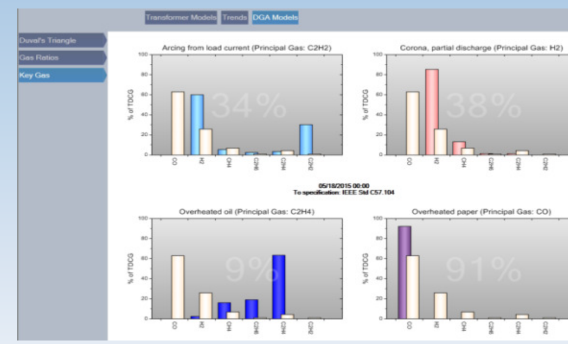
DGA Models



Duval triangle



Gas ratios



Key gas

What is it?

- Dissolved Gas Data brought into relay
- DGA history in the relay
- DGA models as per IEC and IEEE standards

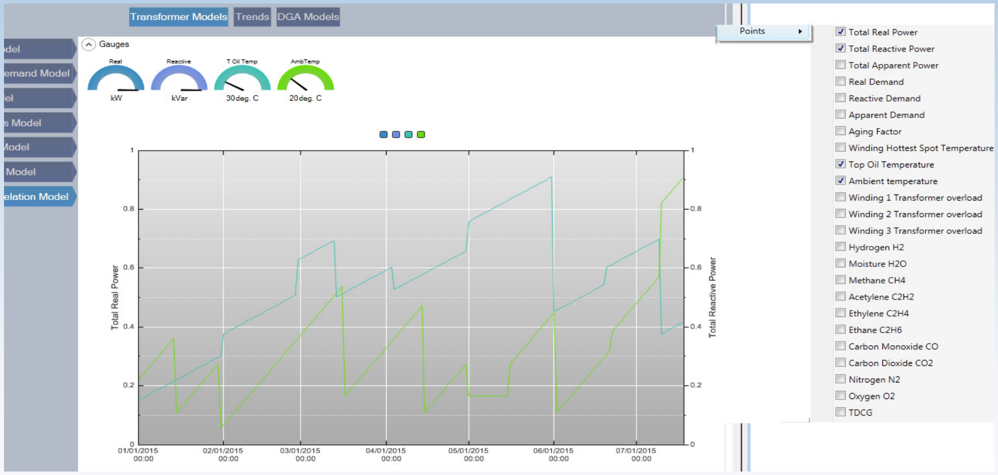
How to use it?

- Evolving incipient fault conditions detection & monitoring
- Eliminates offline DGA assessment and need for DGA analysis consulting
- Simple and direct analytics

Data Correlation Models

What is it?

- Correlation between electrical and DGA data – overload, over heat, corona, PD etc.
- Max operational data available for correlation



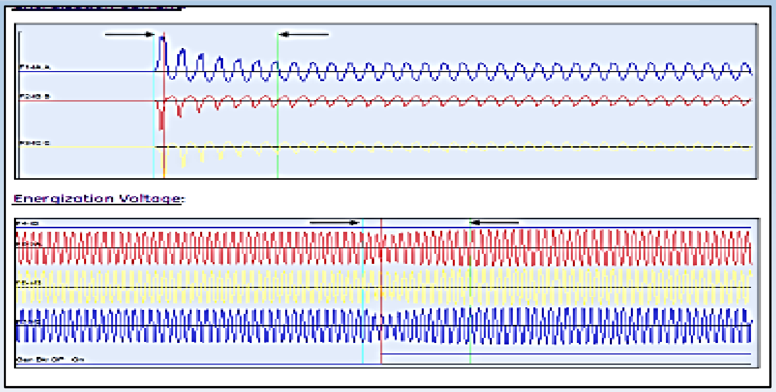
How to use it?

- Electrical and DGA data correlation e.g., load vs. H2, WHST/aging vs. CO/CO2
- Take preventive actions upon detection of incipient fault conditions
- Correlating electrical and DGA historical data during transformer fault analysis

Transformer Energization Record

What is it?

- Transformer energization characteristics captured
- Current & voltage samples for initial cycles
- Inrush parameters: peak inrush current, max voltage dip, volts/hertz, 2nd and 5th harmonics
- Operational data post energization



Measured & Computed parameters

ENERGIZATION DATA

PARAMETER	RECORD1	RECORD2	RECORD3	RECORD4	RECORD5	RECORD6
Date	May 28 2015	May 28 2015	May 28 2015	May 28 2015	May 28 2015	May 28 2015
Timestamp	15:30:20	15:29:51	15:29:26	15:28:51	15:27:34	15:26:49
Phase A Peak Inrush Current (Amp)	419.1687	404.5197	384.0111	347.8769	347.8769	347.8769
Phase B Peak Inrush Current (Amp)	418.1921	404.5197	383.0345	347.8769	347.8769	347.8769
Phase C Peak Inrush Current (Amp)	418.1921	404.5197	383.0345	347.8769	347.8769	347.8769
Phase A 2nd harmonic inrush current (Amp)	291.992	291.992	288.574	288.574	215.332	215.332
Phase B 2nd harmonic inrush current (Amp)	312.012	298.828	298.828	285.645	285.645	285.645
Phase C 2nd harmonic inrush current (Amp)	317.383	316.895	303.711	290.039	290.039	290.039
Phase A 2nd harmonic inrush current (%)	100.0	100.0	100.0	100.0	100.0	100.0
Phase B 2nd harmonic inrush current (%)	100.0	100.0	100.0	100.0	100.0	100.0
Phase B 2nd harmonic inrush current (%)	100.0	100.0	100.0	100.0	100.0	100.0
Phase A 5th harmonic inrush current (Amp)	95.703	95.703	95.703	95.703	41.504	41.504
Phase B 5th harmonic inrush current (Amp)	102.051	97.656	97.656	93.262	93.262	93.262
Phase C 5th harmonic inrush current (Amp)	104.980	104.980	91.309	86.914	86.914	86.914
Phase A 5th harmonic inrush current (%)	15.7	15.7	1.1	1.1	1.1	1.1
Phase B 5th harmonic inrush current (%)	15.7	15.7	1.1	1.1	1.1	1.1
Phase B 5th harmonic inrush current (%)	15.7	15.7	1.1	1.1	1.1	1.1
Frequency (Hz)	60.00	60.00	60.00	60.00	60.00	60.00
Phase A Voltage Dip (p.u.)	0.00	0.00	0.00	0.00	0.00	0.00
Phase B Voltage Dip (p.u.)	0.00	0.00	0.00	0.00	0.00	0.00
Phase C Voltage Dip (p.u.)	0.00	0.00	0.00	0.00	0.00	0.00
Volts per Hertz 1 (V/Hz)	0.00	0.00	0.00	0.00	0.00	0.00
Volts per Hertz 2 (V/Hz)	0.00	0.00	0.00	0.00	0.00	0.00

How to use it?

- Accurate capture of energization event
- Baseline energization behavior in a transformer and compare through the operational life of transformer
- Profile stress induced in transformer during energization
- Can be a simplified commissioning tool

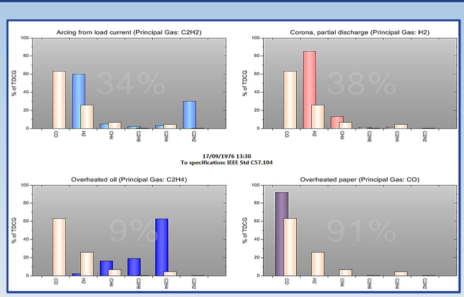
Integrated Transformer Fault Report in Relay

What is it?

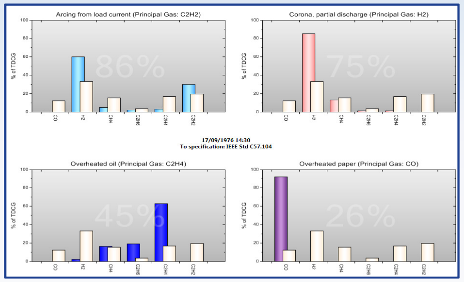
- Detects internal or through fault
- Triggers post fault DGA measurements
- Combined pre/post fault electrical and DGA data for analysis
- Comtrade, fault report and DGA models

How to use it?

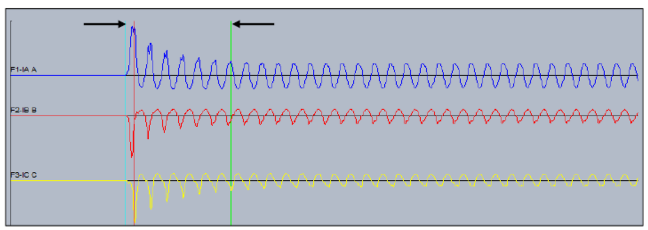
- Comprehensive view of condition post through / internal fault
- Avoid expensive offline DGA or DGA analysis consulting
- Detect incipient fault evolution post external faults and take preventive action



Pre-fault
Principal gas: CO
Over heated paper



Post-fault
Principal gas: C2H2
Arcing fault



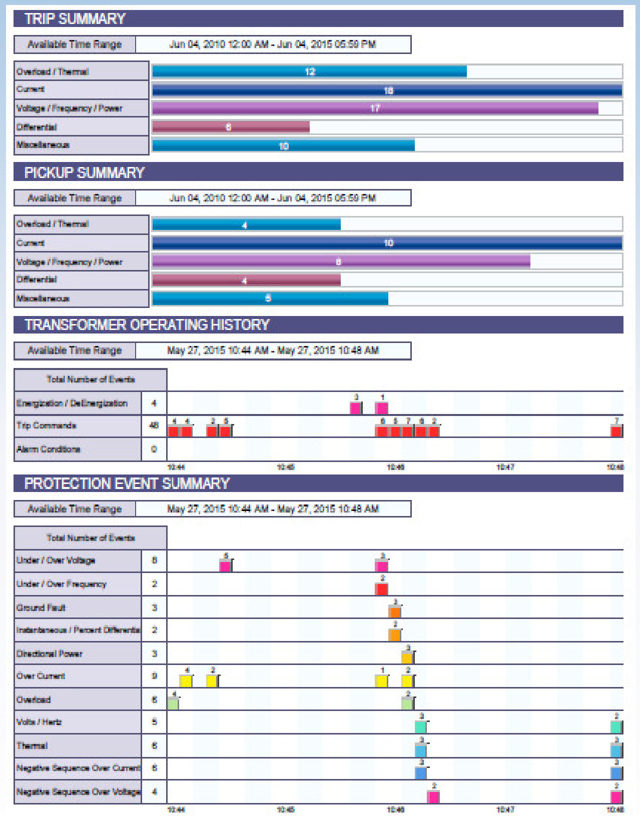
Transformer Health Report in Relay

What is it?

- Compilation of operational and fault data in one place
- Name plate data, trend in energization behaviors, 1 year learned data, historic maximums, DGA models, alarm/trip history

How to use it?

- Eliminate multi layered monitoring and recording devices
- One stop operational, monitoring and fault analytics
- Simple and intuitive analytics



Transformer M&D in Protection Relay Summary

- **Convergence of Electrical, Thermal and Chemical analysis**
- **Simplified correlation between electrical, thermal and chemical characteristics variations**
  - Overloading and Gassing
  - Over voltage and bushing problems
  - Hotspots and DGA
  - Tap changer & Cooling system monitoring
- **Through fault and Internal fault analytics**
  - Trigger new DGA measurement upon fault
  - Integrated fault report summarizing electrical, thermal and chemical analysis laying out impact of a through fault or internal fault
  - Expedite decision making to place the transformer back in service or take it out of service
- Migrate simple conventions and knowledge based rules into **flexible logic and comparator based applications in relay**

Integrated Monitoring & Diagnostics for Switchgear / Breakers

Switchgear Temperature Monitoring

Monitor temperature using data from sensors

- Breaker compartment
- Bus compartment
- Cable compartment etc.

Increase operational lifespan

- Real time monitoring of SWGR temperature

Quick and easy analysis

- Correlation models for temperature vs load etc.
- Custom alarm and correlation schemes using logic
- Map data into SCADA / HMI using Modbus or IEC 61850

Advanced Breaker Monitoring

Monitor overall breaker health

- Open and Close times
- Trip circuit monitoring
- Contact wear
  - Per phase arcing current
- Spring charge time
- Trip counters

Preemptively plan maintenance schedules

- Review breaker health information
- Plan maintenance based on actual data
- Move from schedule to condition based maintenance

Item Name	Value	Unit
Total Breaker Trips	12	
Trips Since Last Reset	9	
Alarm Counter	4	
Last Trip Time	2512	ms
Avg. of 5 Trip Time	1842	ms
Avg. of Trip Time	1856	ms
Last Close Time	725	ms
Avg. of 5 Close Time	948	ms
Avg. of Close Time	1217	ms
Last PH A Arc Time	0	ms
Avg. of 5 PH A Arc Time	0	ms

Integrated Environmental Monitor in Relay

Monitor installation environmental conditions

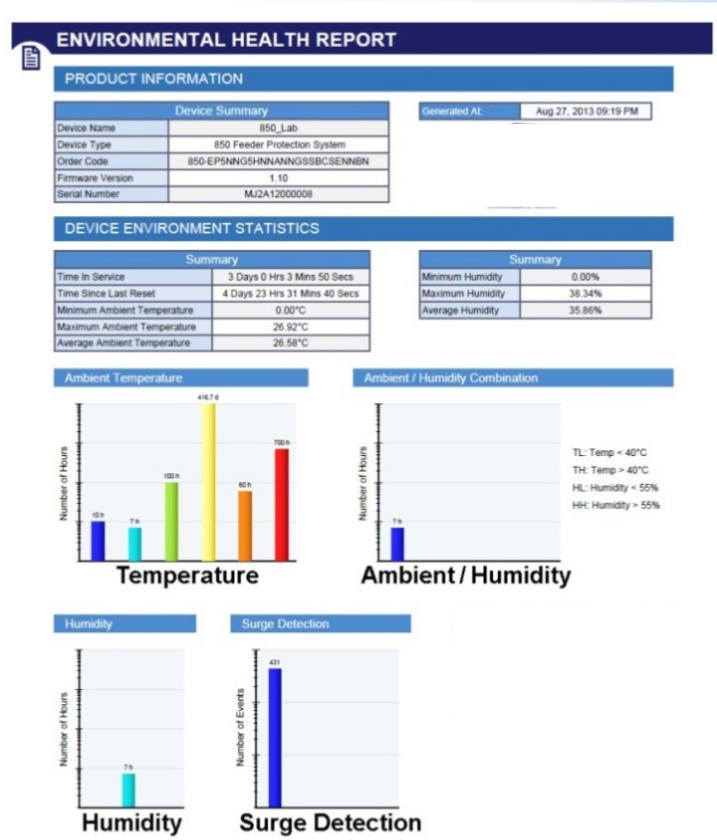
- Monitor installation conditions including
  - Temperature
  - Humidity
  - Surges

Increase operational lifespan

- Quickly correct operating conditions to increase system life

Quick and easy analysis

- Identify system issues
- Increase system uptime



ENVIRONMENTAL HEALTH REPORT

PRODUCT INFORMATION

Device Summary	
Device Name	850_Lab
Device Type	850 Feeder Protection System
Order Code	850-EP5NNG5HNNANNGSSBCSENNBN
Firmware Version	1.10
Serial Number	MJ2A12000008

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DEVICE ENVIRONMENT STATISTICS

Summary	
Time In Service	3 Days 0 Hrs 3 Mins 50 Secs
Time Since Last Reset	4 Days 23 Hrs 31 Mins 40 Secs
Minimum Ambient Temperature	0.00°C
Maximum Ambient Temperature	26.92°C
Average Ambient Temperature	26.58°C

Summary	
Minimum Humidity	0.00%
Maximum Humidity	38.34%
Average Humidity	35.86%

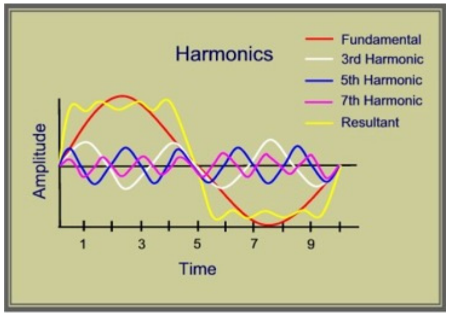
Ambient Temperature

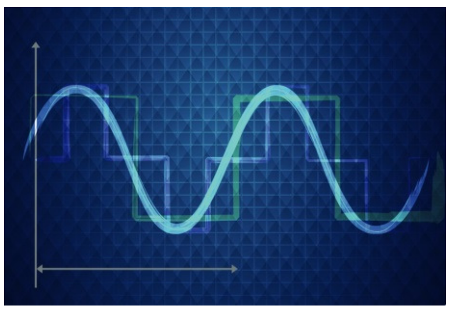
Ambient / Humidity Combination

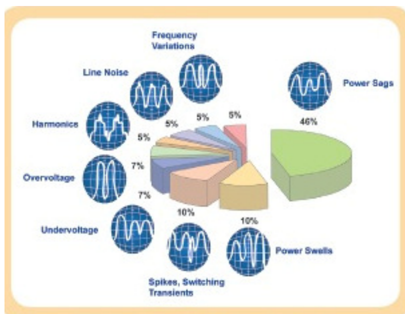
Humidity

Surge Detection

Harmonic Level Detection







- Harmonics up to 25th and THD can be available
- Monitoring of significant harmonics such as 2nd, 3rd, 4th, 5th harmonics and THD
- Power quality monitoring applications

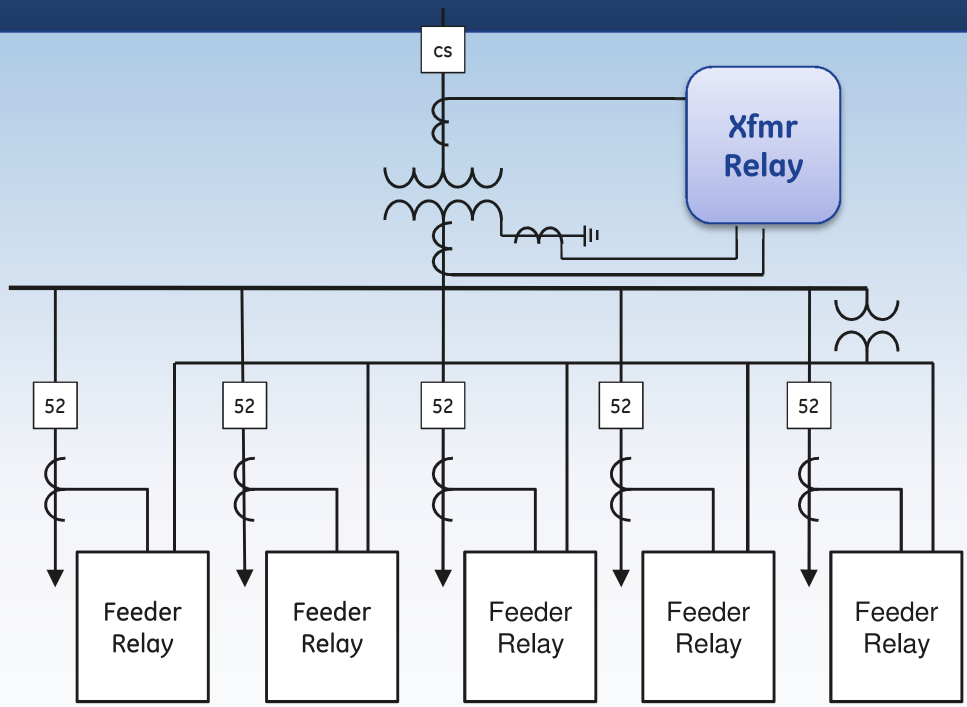
Data Logging Capabilities in Protection Relay

Data Logger

- Multiple measured and computed parameters
- Synchronized data logging
- Short term, mid term and long term storage
- Seasonal storage
- Capture minimum, maximum and mean over a period of time

Data Logger applications

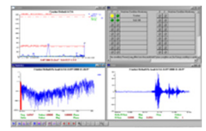
- Coordinated data capture for enhanced analysis of protection coordination
- Long term trending for operational analysis such as Motor stator temperature vs load current profile



Facets of Asset Management in Protection Relay

Data Gathering

- Electrical / Thermal characteristics
- Chemical / Mechanical characteristics
- Real time, short term & long term data
- Reduce discrete Hardware devices



Condition Monitoring

- Techniques to detect failure modes
- Enable condition based maintenance
- Reduce dependency on consulting experts

Performance Monitoring

- Operational event capture
- Historic correlation for performance
- Improved situational awareness

Diagnostics, Reports & Analytics

- Asset health report
- Electrical / Thermal / Chemical models
- Data correlation models
- Less analysis/paralysis – actionable intelligence

THANK YOU!

imagination at work