Use of diagnostic and condition assessment techniques for asset risk management

Colin Gardner
Head of Asset Management
EDF Energy Networks
Contents

• Use of diagnostic techniques/condition monitoring for asset risk management

• Examples of techniques in use
  – Transformers
  – Switchgear
  – Overhead Lines
  – Underground Cables

• Summary

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14.6 GW peak demand
7.9 million homes and businesses
14.6 GW peak demand
7.9 million homes and businesses
Condition monitoring and diagnostic testing context

- **Measure**
  - Sense
  - Observe
  - Sample
  - On/off site
  - On/off line
  - Continuous/test
  - All/sample

- **Process**
  - Models
  - Algorithms

- **Interpret**
  - Assess capacity
  - Remnant life
  - Reliability
  - Policies etc.

- **Act**
  - Maintain
  - Replace
  - Develop
  - Repair
  - Operate

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Condition based risk management

Condition

Combined Health Index
Existing

Degradation
Failure mech.
Environment Duty

Combined Health Index
Future – no intervention

Investment plan

Intervention
Repair
Refurbish
Replace

Combined Health Index
Future – with intervention

Probability of failure

Consequences
network performance, safety, cost, environment

Criticality

Existing Risk

Future Risk
no intervention

Future Risk
with intervention

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ASSET CONDITION CATEGORIES

- 4 point condition scoring: 1 as new, 4 end of life
- Multiple condition points for each asset
- Condition 3 triggers refurbishment if economic
- Condition 4 triggers high volume asset replacement
- Individual detailed assessment for high value assets
- Type defects trigger additional condition monitoring
Health Index

**Year 0 Health Index Profile**

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**Year 10 Health Index Profile**

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**% Replacement Intervention HI Profile at Year 10**

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**Health index shift**

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Asset Risk

Total Condition and Non-Condition Risk

- Year 0 Risk Profile
- Year 10 Risk Profile
- Year 10, % replacement
- Year 10, Targeted Intervention
- Risk of New Assets

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TRANSFORMERS

- Routine oil tests
- On-line oil monitoring
- Winding temperature sensing
- Thermal imaging
- Tap changer operations and motor current
- Partial discharge
- Bushing tests
- External condition
- Management systems
MEASURES TO MINIMISE MAINTENANCE AND EXTEND LIFE

Conservator air bag

Automatic breathers

On line gas and moisture monitor
Good coatings
Temperature sensing
On line management systems

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ROUTINE OIL SAMPLING:

Indicates the condition of core, winding and insulation

The routine tests comprise:
• Dissolved gas analysis
• Moisture content
• Acidity
• Breakdown voltage
• Furan content
• PCB content

![Condition based on oil results chart](chart-image)
Prague, 8-11 June 2009

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SCADA OPERATIONAL DISPLAY

**ATM MO150 STATUS (ACTIVE/FAIL)**

**Duke Street T1 132/11/11kV**

132kV Winding

11kV Winding

11kV Winding 1

11kV Winding 2

**THERMAL INDICATIONS**

**MAIN TANK**

- Top Tank Oil Temp. °C
- Winding Bubbling Temp. Margin °C
- Highest Winding Hot-Spot Temp. °C
- 132kV Winding Hot-Spot Temp. °C
- 11kV Winding 1 Hot-Spot Temp. °C
- 11kV Winding 2 Hot-Spot Temp. °C

**TAP CHANGER TANK**

- Tank Temp. °C

**DERIVED TRANSFORMER CONDITION**

- Cooling Efficiency Index

**GAS & MOISTURE MEASUREMENTS**

- Hydran Level, Main tank (ppm)
- Hydran Level, COOLING CIRCUIT (ppm)
- %RH Level
- Winding Paper Moisture Content (ppm)
- Insulating Barrier Moisture Content (ppm)
- Hydran Level, Tap Changer Tank (ppm)
## Trend Analysis

### Derived Transformer Condition
- Cooling Efficiency Index
- Cumulative Aging (days)
- Cumulative Age (days)

### Thermal Indications

#### Main Tank
- Top Tank Oil Temp. °C
- Winding Bubbling Temp. Margin °C
- Highest Winding Hot-Spot Temp. °C
- 132kV Winding Hot-Spot Temp. °C
- 11kV Winding 1 Hot-Spot Temp. °C
- 11kV Winding 2 Hot-Spot Temp. °C

#### Tap Changer Tank
- TC Tank Temp. °C
- Short Term Average Differential °C
- Long Term Average Differential °C

### Gas & Moisture Measurements
- Hydran Level, Main tank (ppm)
- Hydran Level Hourly Trend, Main tank (ppm)
- Hydran Level, COOLING CIRCUIT RETURN (ppm)
- Hydran Level, OLTC Selector (ppm)
- %RH Level
- Winding Paper Moisture Content (ppm)
- Insulating Barrier Moisture Content (ppm)
- Actual Tap Position

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**Long Term Asset Management**

TREND DISPLAYS...

Make use of comprehensive PI data analysis in PI ProcessBook

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SWITCHGEAR

- Partial Discharge
  - TEV, ultrasound, UHF
- Circuit breaker timing
  - Test
  - SCADA timing
- Fluid pressure and density
- Fluid tests
- Contact wear
- Thermal imaging
- Protection and control supervision
PARTIAL DISCHARGE DETECTION (Handheld)

- Detects Transient Earth Voltage using a contact probe and by monitoring airborne ultrasonic signals
- Simple to use: Red, Amber and Green indications
- Used during routine substation inspection

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PARTIAL DISCHARGE DETECTION (Monitoring)

- Continuous monitoring of switchgear where discharge has been detected by some other measure
- Remotely monitored plus local alarm
- Software enables point of discharge to be located

PDM03: TEV Monitor

ASM: TEV & Ultrasonic Monitor

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OVERHEAD LINES

- Helicopter and foot patrols
- High definition photography
- Thermal imaging
- Conductor corrosion
- Foundation corrosion
- Residual strength
  - Ultrasonic, wood poles
  - Sample mechanical tests
HIGH RESOLUTION PHOTOGRAPHS

20 to 40 photographs taken of each tower from a helicopter

Used for investment planning and procurement

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Overhead Line Health Indices

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Health indices show the condition of individual components.

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UNDERGROUND CABLES

- Partial discharge mapping (on/off line)
- Fluid pressure
- PFT fluid leak detection
- Distributed Temperature Sensing
- Cable and joint sample assessments
PARTIAL DISCHARGE MONITORING EQUIPMENT – MV Cables

ON-LINE CONDITION MONITORING

ANALYSIS: WEB INTERFACE

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AVOIDANCE OF AN MV CABLE FAULT

INCREASING PD ACTIVITY

STAGE 1: On-line monitoring

ON-LINE MAPPING

OFF-LINE MAPPING

CABLE ANALYSIS

NO DISCHARGES FOLLOWING RE-ENERGISATION

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FLUID FILLED CABLES (FFC)

- Approximately 2,500km of fluid-filled cable, containing approximately 27 million litres of fluid
- Over 50% of the London HV network is FFC
- Most cables installed in the 1960s, some date back to 1930s
- Risk based repair and replacement based on
  - Environmental sensitivity
  - Condition and criticality
  - Leak detection techniques
FFC ENVIRONMENTAL RISK ASSESSMENT

Legend

- Purple – Very High Risk
- Red – High Risk
- Orange – Medium Risk
- Yellow – Low & Risk
FFC CIRCUIT CLASSIFICATION

Environmental sensitivity vs. Condition/accessibility/Fluid loss
FLUID FILLED CABLES: CABLE PRESSURE MONITORING

LOSS OF PRESSURE DUE TO OIL LEAK

SUMMER

WINTER

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Reduced leakage, repairs and replacement

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Summary

- A range of techniques developed – some on line some stand alone
- New equipment specified to enable diagnostic testing/condition monitoring
- Essential support for asset risk management
- Need to develop fully integrated approach
- Key component of Smart Grids