Maintenance Strategies & Condition Monitoring Techniques for Power System Equipment: A Literature Survey

* Engr. Enemuoh F.O. / presenter
** Mr. Omidiora M. A / co-authors
Contents

1. Definitions
2. Overview of Maintenance Approaches
3. Need for Condition Monitoring
4. Power Equipment and their Insulation Problems
5. Inside a Monitor: Sensors, Data acquisition, Fault detection and Diagnostic Techniques
6. Current Research on PM & CM of UHV line
7. Conclusion
1. Definitions

- **Maintenance**: is a process of extending the lifetime of equipment or at least mean time to the next failure whose repair may be costly.

- **Replacement**: Restoration wherein a device is removed and one in better condition is put in its place; if the device is failed, it is replaced by a working one.

- **Predictive Maintenance**: A maintenance carried out when it is deemed necessary, based on periodic inspections, diagnostic tests or other means of condition monitoring.

- **Overhaul**: Maintenance or repair requiring major effort and resulting in a significant improvement of the device’s condition.

- **Repair**: Restoration wherein a failed device is returned to operable condition.
What are Condition Monitoring and Preventive Maintenance?

- **CM:** The collection, storage, comparison, and evaluation of data taken from a machine to establish the running condition of that machine.

  *Data parameters:* Looseness of mechanical parts, Vibration, temperature, Pressure, Wind speed, current, voltage e.t.c

- **PM:** The practice of identifying production equipment needing maintenance attention before its performance gets to the point that product quality is reduced or an unplanned shutdown occurs.

  *Information about the condition of equipment is a key to PM for timely correction*
2. Overview of Maintenance Approaches

System identification, Critical equipment listing and their functions

failure mode and effects analysis. Determination of failure history and calculation of meantime between failures

Categorization of failure effect with flowchart and determination of possible maintenance task

Maintenance task assignment

Program evaluation including cost analysis

Figure 2.: RCM procedures used for equipment maintenance at Consolidate Edison Company of New York [8]

Figure 1. Overview of maintenance approaches.

West African Power Industry Convention 2007, Abuja, NIGERIA
3. Need for Monitoring

Monitoring can be applied for a number of reasons:

- Equipment Status
- Primary Voltage, Current etc.
- Predict Maintenance
- Prevent Failure
- Operation/Maintenance Support
- Active Control
- Life Assessment

All of these must be taken into consideration
Potential Benefits of Condition Monitoring

- Reduced commissioning time
- Reduced preventive maintenance
- Reduced failures rate & time between failures
- Reduced breakdown maintenance
- Reduced spares usage
- Increased equipment availability
- Increased equipment life
- Increased functionality

All resulting in lower Life Cycle Costs

Each of these can generate a “Need for Monitoring”
4. Power Equipment and their Insulation Problems

Equipment
- Generators
- Transformer (Power, CT & VT)
- Power line
- Circuit Breakers,
- Earth Switches,
- Switch Disconnectors
- Isolators

Insulators & coolants
SF6 gas, Air, Air Blast, Oil, cellulose (paper/oil)
Gas & oil: self-restoring
Cellulose: not self-restoring

Summary of the key gases produced by different types of fault
Table II: Source of “key gases” from decomposition of cellulose and oil [13]

<table>
<thead>
<tr>
<th>Material</th>
<th>Condition and Temperature</th>
<th>Key gas</th>
<th>Chemical Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose</td>
<td>Overheated &gt; 150°C</td>
<td>Carbon monoxide, carbon dioxide</td>
<td>CO, CO₂</td>
</tr>
<tr>
<td>Cellulose</td>
<td>Excessive heat &gt; 1000°C</td>
<td>Carbon monoxide, Carbon dioxide</td>
<td>CO, CO₂</td>
</tr>
<tr>
<td>Oil</td>
<td>Overheated &gt; 150°C</td>
<td>Methane, Ethane, Ethylene (organic acid)</td>
<td>CH₄, C₂H₆, C₂H₄</td>
</tr>
<tr>
<td>Oil</td>
<td>Electrical stress (partial discharges and arcing to 1000°C)</td>
<td>Hydrogen gas, Acetylene (wax and water)</td>
<td>H₂, C₂H₂</td>
</tr>
</tbody>
</table>

West African Power Industry Convention 2007, Abuja, NIGERIA
5. Units Inside a Monitor

Sensors, Data acquisition, Fault detection and Diagnosis units

- **Sensors**: convert physical quantities to electrical signal
  - Anemometers, Ambient thermometer, Infra Red, Accelerometers, Fibre optic sensors e.t.c
  - **Features**: Online, Sensitivity, Cheapness, compact, Non-invasion

- **Data acquisition**: Realization of amplification and pre-processing of output signal from sensors
  - Analogue to Digital signal conversation & sensor failure correction
  - **Data communication device, microcomputers e.t.c**
Fault Detection: Fault recognition and Alarming for Preventive maintenance

- Methods Use: Model-reference (frequency & time domain analysis) & Feature extraction (comparison of result with its model prediction)
  - Artificial Intelligence (Neural network, Fuzzy logic & Expert system)

Diagnosis: Postprocessing of abnormal signal for decision on required maintenance

Outcome this section prescribed to user; name and location of each fault, defect, status of the machine advice for maintenance.

- Computer techniques, Digital analysis, Artificial Intelligence (neural network & fuzzy logic) & Expert system
Artificial Intelligence in Modern CM and PM

- Ability of a human-made machine (automation) to emulate or simulate human method for the deductive & inductive acquisition and application of knowledge and reasoning

  e.g: Neural Network, Fuzzy Logic, expert system (EPS), evolutionary algorithm (EA) e.t.c.

Its objective in CM & PM
- Enhancement & support for decision making
- Ease and reduction in Manual work done with skillful tasks
Basic Functions to be Monitored

- Insulation
- Current Carrying
- **Switching**
- Mechanical Drive
- Control/Auxiliary
- Equipment

### Example – Switching

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>Auxiliary Switch, Proximity Switch</td>
</tr>
<tr>
<td>Operating Time</td>
<td>Auxiliary Switch, Main Contact</td>
</tr>
<tr>
<td></td>
<td>Coil Current, Proximity Switches</td>
</tr>
<tr>
<td>Operating Speed</td>
<td>Travel (Electronic, Optical), Position</td>
</tr>
<tr>
<td></td>
<td>Switch</td>
</tr>
<tr>
<td>Contact Wear</td>
<td>Wear Indicator, I²t Monitor</td>
</tr>
<tr>
<td>Stored Energy</td>
<td>Pressure Gauge/Transducer</td>
</tr>
</tbody>
</table>
6. Current Research on Power Line CM and PM
Application of OPGW to Japanese Nishi-Gunma 1000KV UHV Transmission line

- West African Power Industry Convention 2007, Abuja, NIGERIA
Application of OPGW to Japanese Nisi-Gunma 1000KV UHV Transmission line

Objective of this Technology

(1) Effective Monitoring meteorological data, such as wind, and icing and snow accretion (due to increased conductor tension and tower structure strain e.t.c)

(2) Industrial TV (ITV) monitoring for visually observing weather, surrounding conditions and site facilities.

(3) Fast fault location and determining the maintenance office responsible by estimating the fault section based on boundaries established for maintenance territories

Installation time: 1993
Line Configuration:
- 2- circuit UHV line.
- Altitude = 1951m
- Line length = 250km
- ambient Temp = -30 degree
- Wind speed = 57 m/sec

Benefit of this OPGW system
CM & PM, Fault detection, Meterological data source Immune to Lighting stroke & Noise Capital cost is 0.3% of total tower line installation

West African Power Industry Convention 2007, Abuja, NIGERIA.
Network Layout
Central Processing Station, Interconnecting Network and Processing Station and Six Maintenance Office

Weather sensors used are anemometer, ambient thermometers, rain gages, snow-accretion samplers, load cell, ground wire and insulators inclinometers

Figure 8: System Configuration [14]

- West African Power Industry Convention 2007, Abuja, NIGERIA
7. Conclusion

Justification for Maintenance?

- Extensive CM & PM ensure reliability, prolong equipment’s life, as well as improving overall power quality of Electrical Power network.

What about the cost of maintenance?

- The savings made by avoiding—or delaying—forced outages and the resulting refurbishment or replacement could be substantial.
Thank you