The Future of Predictive Technologies is Here Now

Claude Kane, Electrical Diagnostic Innovations, LLC.

INTRODUCTION

In today's competitive environment, it is imperative to capitalize on advances in technology that allow new approaches to the maintenance of a facility's physical assets. These include reliability-centered maintenance, predictive diagnostics, condition monitoring and expert systems. These approaches have had a significant factor in reducing unscheduled downtime and realizing gains in lost profit opportunities.

Studies have shown that 80% of equipment failures occur on a random basis and only 20% are age related. This indicates that whatever our current maintenance practices are, they are not overly effective. Reasons for this phenomenon include:

- Many defects develop quickly (weeks, days or hours) that are not caught during normal periodic maintenance. Time intervals between outages have increased over time, therefore less maintenance is being performed.
- Some components of equipment are rarely, if ever, inspected or tested such as the main bus structure of medium voltage switchgear and bus duct.
- Outages are shorter and more compact, therefore less effective maintenance is provided due to budget and time constraints.
- Equipment has been "Valued Engineered", which means all of the tolerances in clearances, etc, are at the absolute minimum to reduce cost and yet pass standards. The old adage of a built in "safety margin" is now a misnomer.
- Many new insulating systems are being utilized and are not time tested and are being thermally, mechanically and electrically stressed to their limits.
- Many past periodic online maintenance activities have been severely limited due to new Arc Flash and Safety requirements.

Many times money is spent when not necessary. Many repair/replace decisions are made due to limited qualitative and quantitative information. Also, many times "Ultra Safe" decisions are made due to not having enough valid and reliable information or made due to internal corporate politics (what the boss wants to hear).

RELIABILTY AND FAILURE STATISTICS

The IEEE Standard 493-1997, IEEE Recommended Practice for Design of Reliable Industrial and Commercial Power Systems – Gold Book completed end-user surveys over two time periods. This data is relatively old, but at the same time it does represent the majority of existing medium voltage electrical equipment in service today. Table 1 and Figure 1 show the comparable hours of downtime per year of a variety of medium and high voltage industrial equipment.

Table 1
Failure Rates and Average Downtime per Year for Common medium Voltage Industrial Electrical Equipment

IEEE Standard 493-1997 All Industry Equipment Type	Failure Rate/Year	Avg. Hours/Outage	Avg. Downtime Hours/Year
Switchgear - Bus Only 7 Sections	0.0119	261	21.7413
Large Power Transformers	0.013	1076	13.988
MV Synchronous Motors	0.0318	175	5.565
MV Induction Motors	0.0404	76	3.0704
Underground Cables 3000 feet	0.00613	53	0.97467
Cable Terminations	0.000814	284	0.693528
Small Power Transformers	0.0025	217	0.5425
MV Circuit Breakers	0.0064	89.3	0.57152
Bus Duct - 30 feet	0.0038	128	0.4864

Note: Average downtime hours per year is calculated by multiplying the Failure Rate per Year times the Average Hours per Outage.

The cost of an unplanned outage can be calculated by multiplying the Average Downtime Hours per year by your hourly plant cost of an outage. Even with a low hourly outage cost, a rapid ROI can be realized. It must be noted that switchgear and large power transformers are identified as two of the highest critical assets, mainly due to the high number of hours per outage. We know from experience that we already perform extensive maintenance on transformers such as visual inspections, power factor testing and dissolve gas analysis, yet the failure rate is in the top four. We also know we perform limited maintenance on the main bus compartments of switchgear and bus ducts, mainly due to outage constraints.

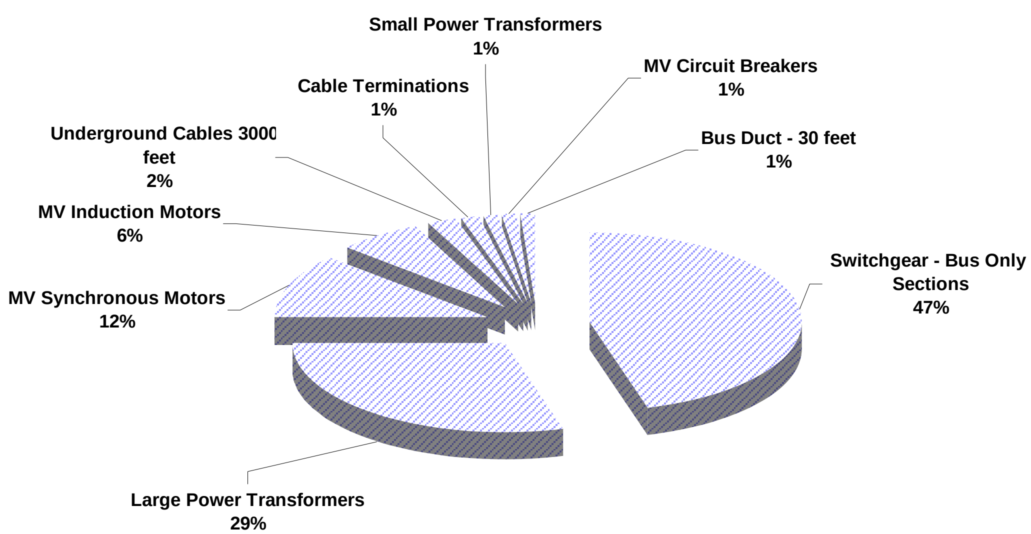

Figure 1 – Percentage of Downtime Hours per Year by Equipment Type

On-Line Monitoring

Use of On-line monitoring and predictive technologies can alleviate the shortcomings inherent in many of our current maintenance practices. If you think these capabilities are beyond your budget constraints, it is time to rethink. The same advances that allow us put a powerful computer on our desk for a relatively low price has put these new monitors and technologies in the reach of most budgets. Many of these technologies have become more intelligent and thus require less expertise in interpreting the results. This is not always the case and it is difficult for companies to employ enough qualified personnel at each site to understand the large variety in data from various types of equipment. Many monitors provide more information than the typical end user can understand but are available to the expert for additional diagnostics and prognostics. A new acronym has emerged for these Intelligent Electronic Devices (IED).

Unfortunately there is no one technology that is the "Holy Grail" for electrical equipment condition assessment. In many cases, multiple technologies need to be employed in order to perform a complete diagnosis. Most monitoring systems are designed to alert the user of a problem or unusual condition and provide additional diagnostic data.

Most of these technologies have built in communication capabilities that allow for remote Predictive Monitoring via Ethernet, Serial communications such as ModBus, DNP 3.0 or customized data streams and wireless and analog modems. Remote predictive monitoring allows companies to streamline expertise at centralized locations or outsource to the appropriate experts. This can be done on a continuous or periodic basis or be event driven. Event driven systems send out an alert via a phone, pager, email or fax to the appropriate person, who then communicates back to the monitor for further analysis and recommendations.

What New On-Line Predictive Technologies are Available Today?

Infrared Monitoring

Performance of infrared surveys is probably the most common predictive technology used today. It is utilized on all types of equipment found in the electrical power distribution systems. It is somewhat limited on medium voltage equipment such as switchgear since it is difficult to "scan" certain areas due to limited access. Also, more problems are found in low voltage equipment due to the higher current levels. Today, there are wireless infrared sensors available that can be placed at connections such as bolted connections and finger clusters that will communicate back to a central source. The US Navy has also utilized specialized infrared sensors in low voltage switchboards for years that connect back to a central location.

Dissolved Gas Analysis (DGA)

DGA on transformer oil use been utilized longer than any other predictive technology for electrical equipment. Improvements over time on the analysis of the results have led to better diagnostics. DGA used to be limited to just the oil in the main tank but have now been validated for us in load tap changers and Oil Circuit Breakers. There are several on-line continuous gas monitors available in the market today. These include Key Gas and Seven Gas monitors. Also, portable instruments are available to provide on-site DGA rather than sending the samples to a lab and having to wait for results.

Motor Current Signature Analysis

By analyzing the signatures of currents on three phase motors, one can diagnosis many problems, such as broken rotor bars, air gap problems, misalignment, improper mounting, eccentricity and problems with gear boxes and loads. Most of this technology is based on making periodic on-line measurements, but strides are currently being made to build this intelligence in to the motor starter protective devices.

Electrical Partial Discharge

A partial discharge (PD) is a small spark that occurs in an insulation system that does not go completely from phase to phase or phase to ground. Therefore, measurement and analysis of this discharge can provide an early warning of insulation failures in equipment rated 4,000 volts and higher. Measurement of PD can be done on a periodic or a continuous basis. In either case, specialized sensors must be installed to detect these pulses created by the small spark. Proven applications of this technology include cables, bus duct, switchgear, motors, generators and transformers. Use of PD monitoring on MV switchgear is an excellent use of this technology and can compensate for the lack of traditional maintenance on main bus structures.

Large Power Transformer Monitoring Systems

Most industrial facilities do very little monitoring of their Large Power Transformers. Modern day systems now control and monitor all aspects of a transformer including temperatures, loads, cooling systems, pressures, bushings and windings. Four great examples include:

- The monitoring of the loads on the cooling fans and pump circuits to indicate abnormal conditions such as locked rotor or loss of cooling capacity.
- Monitoring the temperature differential across the connection board between the main tank and the load tap changer compartment
- Continuous monitoring of the power factor and capacitance of High Voltage Bushing
- Central data concentrator and communication RTU for all third party monitors such as PD and DGA.

SUMMARY

Experience has taught us that half the battle in ensuring electrical equipment reliability is to keep it Clean, Dry, Cool and Exercised. If these four items are accomplished, then currently available on-line predictive technologies can take care of the rest. With depleting technical expertise in electrical equipment and the pressures of running facilities 24 x 7 x 365, these new technologies offer the ability to fill the maintenance gap while reducing costs and increasing power system reliability. Due to the decreasing cost of these IED's and the high cost of unplanned outages, a rapid ROI is achieved.

Bio

Claude Kane has over 30 years of experience in the installation, preventive and predictive maintenance practices on a large variety of power distribution and generation equipment. He graduated from the Milwaukee School of Engineering in February 1973. He started with Westinghouse as a field service engineer and has held a number of technical and management positions. He has presented numerous technical papers on the subject of partial discharge at many IEEE, NETA and other Technical conferences. He also was on the committee for the development of the IEEE Guidelines for the Measurement and Analysis of Partial Discharge on Rotating Equipment (P-1434). Claude is currently the President of Electrical Diagnostic Innovations, LLC and is located in Minneapolis, MN.