EXAMPLES OF CONDITION BASED MAINTENANCE IN DISTRIBUTION SYSTEMS

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ABSTRACT

Traditionally, electric utilities have always relied on maintenance programs to keep their equipment in good working condition for as long as it is feasible. In the past, maintenance routines consisted mostly of pre-defined activities carried out at fixed time-base intervals. In many recorded cases, the human intervention caused problems with the healthy equipment after such maintenance was done. Recently, many utilities replaced their fixed-interval maintenance schedules with more flexible programs based on an analysis of needs and priorities, or on a study of information obtained through periodic or continuous condition monitoring (predictive maintenance).

On-line condition monitoring is also a tool among many useful tools in the area of asset management. When used as part of a well developed strategy, on-line condition monitoring can be a powerful tool for utilities to use to achieve its intended business benefits. This can have a direct impact on cost reduction of maintenance operations since it becomes based on the condition of equipment, consequently preventing cascaded failures.

Fault Recorders or Disturbance Recorders are used for disturbance analysis as well as other purposes and they can play vital role in the maintenance management of the utility. Data analysis and diagnostics from records obtained from Fault Recorders lead to amazing conclusions that support the predictive maintenance operation in any world-wide electricity utility.

This paper illustrates, in some value event examples, the importance of the use of Recording Devices as an effective tool for predictive and condition-based maintenance. These cases include actual records at Medium Voltage Distribution Network that helped, after analysis, to determine the need for equipment maintenance. Examples of these cases are:

- *Breaker restriking,*
- *Intermittent fault and*
- *Fault location*

1. INTRODUCTION

Maintenance is required for almost all equipment in order to guarantee its performance, prevent failures and to extend the life expectancy. Modern high voltage equipment as well as protection & control equipment requires less maintenance compared to older technology. Unnecessary maintenance can also be a cause of failures by itself. Both failures and traditional maintenance will normally result in a disconnection of a part of the power system and by this reduce the availability.

The unavailability of the component can be simplified as MTTR/MTBF + MTTM/MTBM; where,

- MTBF = Mean Time Between Failure
- MTTR = Mean Time To Repair
- MTBM = Mean Time Between Maintenance
- MTTM = Mean Time To Maintain

The ideal situation with zero unavailability and 100% availability can theoretically be obtained if MTBF and MTBM is extremely high (infinity) which means that there are no faults and no need for maintenance. This is naturally impossible to obtain. The other alternative is that MTTR and MTTM is zero. This is however possible to obtain with a combination of redundancy (up to certain limits) and on-line diagnostics. By using on-line monitoring to discover stresses and ageing before a failure occurs and plan suitable maintenance (or replacement) the interruption of that particular part of the system can be done when other redundant part can maintain the operation. This is called CBM, Condition Based Maintenance and replaces the earlier TBM, Time Based Maintenance or in worst case "NMA" = No Maintenance at All. CBM can be further refined to RCM, Reliability Centered Maintenance which is using RBA, Risk Based Analysis to give the priority to maintenance and replacement activities.

Recent surveys of maintenance management effectiveness indicate that one-third—33 cents out of every dollar—of all maintenance costs is wasted as the result of unnecessary or improperly carried out maintenance [1]. The dominant reason for this ineffective management is the lack of factual data to quantify the actual need for repair or maintenance of plant machinery, equipment, and systems. Maintenance scheduling has been, and in many instances still is, predicated on statistical trend data or on the actual failure of plant equipment.

This vision of interruption free diagnostics of a complete network with substations, lines and cables requires a holistic approach identifying the critical components and possible supervision methods including both existing and new ways of monitoring. Today the data about the condition of different equipment is spread among different persons, organizations and measurement equipment. This includes everything from paper reports from manual inspection to digitally stored disturbance recordings. The main challenge is to convert raw data islands to useful information for Asset Management and Operation. This includes an efficient communication infrastructure and data management where for example high speed LAN/WAN according to IEC 61850 can be utilized. The major task is however still to analyse the data and present useful information for different users. This can be done manually or automatically. Since different organizations or even companies own, operate and maintain the assets, another challenge is to improve the information exchange between these organizations. Some utilities have therefore created a special "Asset monitoring" function to handle short term, midterm and long term analysis and planning [2].

Predictive Maintenance has so many advantages; increasing component operational life/availability, allowing for on-time corrective actions, decrease in equipment or process downtime, decreasing costs for parts and labor, improving worker and environmental safety, improving worker morale, substantial savings over preventive maintenance programs, eliminating most unexpected down events, providing information to perform a root cause analysis and decreasing of spare parts inventory.

2. DISTURBANCE MONITORING SYSTEMS AS A TOOL FOR CONDITION-BASED MAINTENANCE MANAGEMENT

Fault Recorders and Power Quality Analyzers as disturbance monitoring systems are used for disturbance analysis as well as other purposes and they can play vital role in the maintenance management of the Distribution Companies. This can have a direct impact on cost reduction of maintenance operations since it becomes based on the condition of equipment, consequently preventing cascaded failures. Data analysis and diagnostics from records obtained from Fault Recorders lead to amazing conclusions that support the predictive maintenance operation in any world-wide electricity utility.

Disturbance Recorders can play vital role in the maintenance management of any utility. They are scattered and permanently connected throughout the power system. Some goales of using these recorders was traditionally as follows [3]:

- Determining the performance of system components
- Analysis of the nature and cause of a disturbance.
- Identifying equipment misoperations
- Analysis and correction of protection system and control deficiencies
- Reducing the risk of recurring misoperations

The recorded values of voltages and currents can identify the behavior of the system components. Consequently their operative status and performance can be fully analyzed. Two main requirements have to be fulfilled in order to fully run the required analysis:

1. Additional Software capable of handling the captured data for the purpose of identifying the incorrect performance of the specified equipment.
2. Accumulated expertise capable of reading the hidden information given by these data and analysis software outcomes.

In the following sections, we will give some actual recorded examples that prove the importance of these devices as a predictive and corrective maintenance management tool.

Example 1: Circuit Breaker Restriking

Circuit breaker is designed to interrupt the fault current by mechanical opening of its contacts inside sufficient isolating medium. For some reasons, this insulation may become weak and insufficient resulting in restriking of the electric arc of the short circuit current. Although the breaker is mechanically totally open, it does no longer achieve the interruption of the fault current.

During the testing of one feeder cable, it was noticed that the fault records contain unusual situation. At the moment of switching of the breaker, phases R and S are successfully opened and interrupted the load currents, but the current in phase T still flowing and restriked after interruption as shown inside the highlighted circle. As soon as this was discovered, necessary actions were taken for replacing the breaker of the bay with another one. When opening the breaker after the testing, it was found that the moving and the fixed contacts of both chambers are seriously damaged.

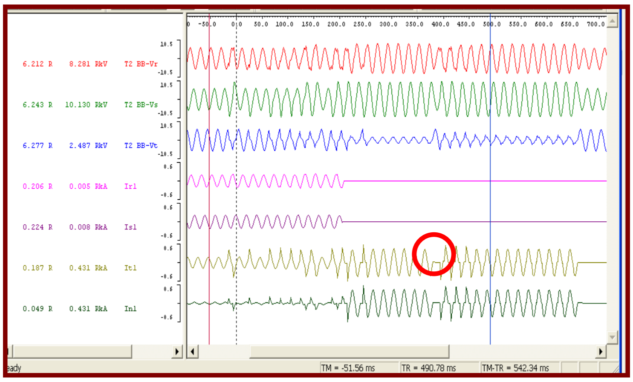

Fig.1: The recorded voltage and current channels – CB Restrike –

From the fault described above, it can clearly be seen that an in-depth fault analysis, making use of records coming from DFR's, can be used as a basic input for maintenance and so improve the overall reliability of the network.

Example 2:Insulation Maintenance-Intermittent Fault

The phenomenon of intermittent faults, indicate insulation deterioration. It causes high current spikes as shown in Fig. 2. This record was captured at one of the Egyptian 66/22kV substation. The duration of these current spikes and the pause between their occurrences do not permit the appropriate protection to operate, or even to sense them. However, disturbance recorders can capture these types of faults as shown.

Once this phenomenon has discovered, the maintenance crew can make some investigations and/or tests to find the place where the insulation is deteriorated and take the appropriate corrective maintenance action before a short circuit occurs causing insulation or equipment damage.

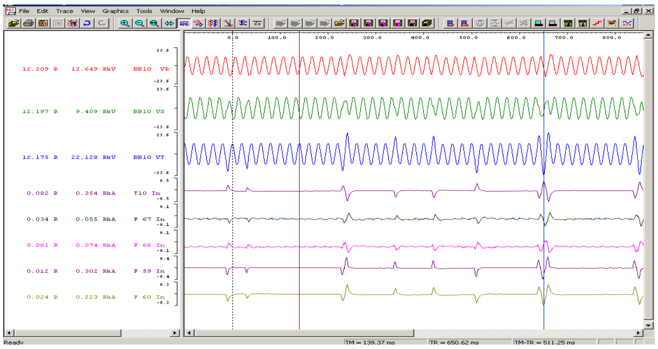

Fig.2: Intermittent fault on a 22kV feeder – Phase B

This case study proves the capabilities of Disturbance Recorders as a maintenance tool since it gives early detection before serious consequences occur due to insulation deterioration.

Example 3: Fault Location

Fault location has two issues. The first is an operating issue, in which the system should be isolated to prevent further occurrences of faults. The other is a maintenance issue, as to what equipment needs checking or repaired in order to return it to service as soon as possible.
Modern Disturbance Recorders have an integral fault locator that uses information from the high scanned voltage and current inputs to provide a distance to fault calculation at the cursor location. Figure 3 shows an actual record that used for calculating the fault location on a high voltage transmission line with high accuracy (an error of only one span).

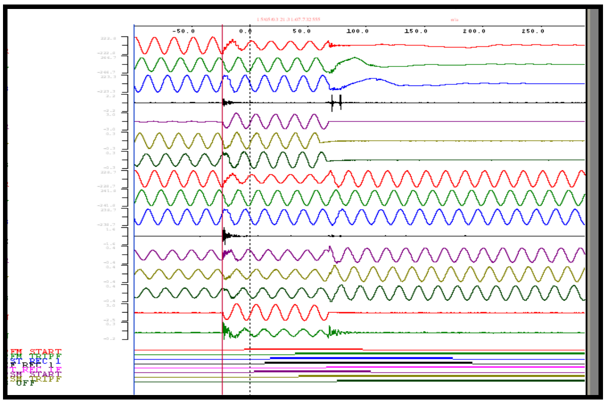

Fig.3: Fault Record that used in calculation of fault location

Such accuracy in fault location saves maintenance time and money since the crew arrived at the specified location to take the corrective maintenance actions which lead to improve the reliability of the system by reducing the outage time.

3. OTHER FIELDS OF APPLICATIONS

A wide horizon for the applications using Disturbance Monitoring Devices exists. Electric Utilities make efforts to be proactive, rather than reactive, and, Predictive Maintenance is considered as the best medicine trying to prevent cascading and/or catastrophic failure of equipment.

There are some other fields of applications that DMS can add a value in the predictive maintenance operation of the transformer:

- Monitoring of the transformer on-load tap changer's motor current
- Correlate Dissolved Gas Analysis (DGA) with fault information (fault energy) can avoid transformer failure by scheduling proper predictive maintenance.
- ……. And much more

4. PROTECTION IED'S VERSUS DISTURBANCE RECORDERS FROM PREDICTIVE MAINTENANCE POINT OF VIEW

For Protection IED, the primary function is to detect Electrical Power System conditions which can cause damage to equipment, danger to personnel and to the operation of the system. The relay then isolates the problem and/or eliminates the conditions as quickly as possible. Secondarily, the digital relay records the conditions which are monitored for a period of time, beginning with a prefault period and continuing until after the fault is cleared. A relay may also obtain fault data and equipment performance on devices such as circuit breakers. Relays are usually installed for a single line or a piece of equipment such as transformer. The capacity or total number of faults stored is limited by the available memory. Most relays do not record and store data if no fault is detected. Usually, the settings for starting the relay are much higher than the level of DR's triggering.

The primary function of Disturbance Recorder is to gather as much data as possible to allow detection and analysis of normal and/or abnormal conditions, to verify system modeling, and confirmation of system planning information. Secondarily, the recorder will obtain information on performance of all monitored equipment such as circuit breakers, relays, generator systems, etc. Recorders allow time and system correlated date. They receive data from all available sources including external inputs from relays, other recorders and transducers. A recorder will obtain the desired data by proper selection of quantities monitored for different equipment.

Triggers are necessary to initiate recording for both Protection IED and Disturbance Recorder. Protection IEDs have limited triggering capabilities compared with recording IEDs since DRs have in addition to H/W binary contacts, another software triggering channels in which the user can formulate a specific function to trigger the recorder. For continuous recording, DRs triggers provide markers into the key pieces of data during an event. The ability to "share" triggers between multiple sites is also available in order to capture a wide-area view of an event. The analog channels in a relay are fixed as current or voltage channels. This limits the ability of the relay to record and trigger on the measurements actually available in a substation. Relay triggers are based on specific protection function events, and are generally high or low magnitude triggers. There is little flexibility to apply different types of triggers for a specific measurement. Relays may supply some pre-configured calculated, particularly zero-sequence current, but have no capability to provide user-defined calculated triggering signals, or triggers on user-defined channels.

Figure 2 above shows an example how the sensitivity of the triggering value may capture valuable information. This record is for intermittent faults occured as a result of arcing at certain points in the electrical system where insulation is weakened due to pollution. The duration of these current spicks and the pause between their occurrences do not permit the appropriate protection to operate, or even to sense them. However, disturbance recorders can capture these types of faults as shown. A deep analysis for the comparison between Protection IED's and Disturbance recorders are found in [3, 4].

7. CONCLUSIONS

Today, the electric power industry's long-term vision comes to end the traditional periodic maintenance, and three things are contributing to breakup:

- The expansion of condition monitoring
- The need to cut costs, and
- The desire to get the most out of existing equipment

This paper introduces value event examples that prove the capabilities of Disturbance Monitoring Systems as a tool for improving the overall performance of the power grid by using them as an essential tool for maintenance management operations. The advanced monitoring, recording and analysis give the user, electric utility, valuable tools for improving the efficiency, reliability, and reducing the cost of maintenance in electric power system. Another important factor for improving the reliability and reducing the cost is the predictive capability of such equipment, which gives early alarming for a problem to be solved correctively before serious consequences.

All the above illustrations have been introduced through actual examples, which prove the capabilities of DR as a maintenance management tool from all its directions: predictive and emergency. Also, prove how these devices increase the reliability by helping to take corrective actions (corrective maintenance).

REFERENCES

[1] R. Keith Mobley," An Introduction to Predictive Maintenance" Second Edition, 2002.

[2] A Report of the IEEE/PES Task Force on Impact of Maintenance Strategy on Reliability of the Reliability, Risk and Probability Applications Subcommittee," The Present Status of Maintenance Strategies and the Impact of Maintenance on Reliability," IEEE Transactions on Power Systems, Vol. 16, No. 4, November, 2001.

[3] Mohamed A. El-Hadidy, Dalal H. Helmi, Maha S. Abdelhady," Disturbance Recording Systems within the Environment of IEC 61850: Built-in or Stand alone?," CIGRE 2010 Session, Paris, France.

[4] IEEE final report on "Considerations for Use of Disturbance Recorders", Dec. 2006.