OPTIMISING THE MAINTENANCE OF 11KV OIL FILLED SWITCHGEAR – AN EXAMPLE OF CONDITION BASED DECISION MAKING

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Over the past 2 - 3 years EA Technology has undertaken a significant programme of work on behalf of a group of UK electricity companies to investigate, understand and qualify degradation and failure processes which affect 11kV oil filled switchgear. The work has included physical examination of many relatively old units of switchgear which have either been recovered from the system or have been accessible at the time of maintenance. This work led to a good understanding of the degradation and failure processes that could affect many types of equipment. The influence of the oil condition was identified as a prime concern. If the oil is kept in good condition, degradation of other components is effectively prevented.

Independent of this research work, several UK RECs have undertaken RCM studies of 11kV oil filled switchgear. In many cases they have concluded that the critical parameter in determining the need for maintenance is the oil condition. Both approaches identified the criticality of oil condition and further work was undertaken on behalf of the UK RECs to study the degradation of oil in switchgear. This involved specific oil tests and data obtained by RECs as part of their routine activities.

The outcome has been a thorough understanding of the degradation processes of oil in switchgear, and identification of a means of determining the onset of critical degradation which therefore warrants maintenance. A generic approach, based on internal examination and oil sampling has been developed, to enable the optimum interval for maintenance to be established. This generic programme, amended to meet the specific circumstances and requirements of each company, is being applied within six UK RECs. The results obtained to date have provided the confirmation of the validity of the conclusions from the earlier work and are enabling major savings to be achieved by RECs.

The approach is therefore providing a structured framework against which individual companies can optimise their future maintenance policies. Not only does this lead to cost savings while maintaining or improving reliability and safety, but it also enables the real limits, in terms of maintenance interval and lifetime of switchgear, to be defined. The work with individual RECs is continuing and the full paper includes a summary of the outcomes and the benefits obtained by UK RECs.
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1. INTRODUCTION

Owners and operators of electricity networks are reviewing policies and procedures to ensure the optimum level of maintenance is carried out on network plant. EA Technology has worked closely with a number of UK RECs to assist with the introduction of maintenance regimes which are based on establishing the condition (and future performance) of assets using carefully designed programmes of sampling and inspection. These programmes are resulting in very significant cost savings while maintaining or improving the level of reliability and safety.

This paper describes the application of a maintenance optimisation scheme related to 11 kV oil filled switchgear within UK electricity companies. It is believed the approach described can not only be applied more widely to 11 kV oil filled switchgear but many of the generic features are applicable, with the potential for very significant savings, to other assets on electricity networks and beyond.

2. BACKGROUND

In order to optimise maintenance regimes and in particular to link maintenance to the results of condition assessment procedures it is vital to understand many aspects of the equipment’s life cycle. Issues related to original specification, design criteria, operating conditions, previous maintenance history, degradation and failure processes together with available condition assessment procedures are all very relevant. In particular understanding the relationship between on-going degradation processes and ultimate failure, within the operating conditions that prevail, is paramount in making the appropriate decisions.

EA Technology has a long history of working with the UK electricity companies and is therefore very familiar with operational procedures and conditions and has derived special knowledge from investigating failures of plant, including 11 kV oil filled switchgear. From this starting point EA Technology has recently undertaken a programme of work for the UK electricity companies (as part of the EA Technology Strategic Technology Programme) to investigate the condition and degradation of relatively old 11 kV oil filled switchgear. This work included the examination of many different types of switchgear which had either been removed from the system or were available for inspection during routine maintenance. This enabled a detailed understanding and qualification of degradation processes within oil filled switchgear to be achieved. This initial programme identified that the condition of the oil is the key factor in determining the internal condition of the switchgear.

Several RECs have independently applied reliability centred maintenance (RCM) procedures to groups of oil filled switchgear. For many types of switchgear it has been concluded that the condition of the oil is the critical factor in determining the need for maintenance. As both approaches identified the significance of oil condition a subsequent study was undertaken by EA Technology designed to achieve a better understanding of oil degradation processes in switchgear. This work identified a schedule of specific tests that can be applied to oil from switchgear to provide critical information on both the oil and the switchgear condition.

These investigations concluded that within the UK Electricity Industry switchgear and oil were generally in very good condition and not exhibiting evidence of significant deterioration at the end of existing maintenance intervals. In many cases it was concluded that maintenance was not necessary on the frequency that was being employed.

3. OIL TESTING - MAXIMISING THE INFORMATION OBTAINED

If oil tests are to be used to determine the need for maintenance it is clearly important to derive the maximum relevant information from each sample. As part of the detailed studies of oil condition in switchgear EA Technology has developed a specific package of 5 procedures. These include the standard measurement of moisture, acidity and breakdown strength together with 2 additional procedures.

The first additional test is the use of HPLC (High Performance Liquid Chromatography) to separate and quantify the levels of early oxidation products. These are products which form in the oil prior to the formation of acidity. This procedure therefore enables a more sensitive assessment of the early stages of the oxidation processes.
The second additional test, which is proving to be the most revealing of all the tests, involves filtering the oil and examining and analysing the solid residue. This provides information on both the oil condition AND the condition of internal components within the switch. Any interaction between the oil and solid components, which ultimately will lead to serious degradation, is very clearly identified by this method. Our experience with this test is indicating that this is a very sensitive procedure which enables identification of significant deterioration before it is clearly indicated by the other tests.

Having carried out these oil tests on hundreds of individual samples, many of which have been directly linked to the physical condition of the equipment by internal examinations, we are in a position to classify the overall condition of individual units or larger groups from oil sample results.

This is proving to be a very powerful tool for practical application, enabling the optimisation of maintenance and/or replacement programmes based on actual condition. Some aspects of utilising this approach are described in the following sections.

4. GENERIC PROGRAMME OF OIL SAMPLING AND INTERNAL INSPECTION TO OPTIMISE MAINTENANCE

Based on the outcome of the earlier programme it was recognised that in many instances it would be appropriate to extend maintenance intervals. It had been determined that for many types of switchgear the condition of the oil was the critical factor in determining the need for maintenance and at the end of the current intervals the oil was in good condition, not showing any evidence of significant deterioration.

The knowledge gained during the initial investigations also indicated that carrying out appropriate internal examinations and oil tests on a relatively small sample of equipment at the end of its current maintenance interval, would enable an assessment of the need for maintenance based on actual condition.

It had been established that the factors which significantly affect the rate of degradation (and therefore the ultimate safe life) of oil in switchgear include the equipment type (due to different material content), original oil quality, and previous maintenance regimes (including oil handling procedures). Therefore when designing a programme of sampling to establish the condition of oil and switchgear as a function of time in service it is important to treat different types of switchgear in different organisations as separate populations.

Consequently a generic programme has been drawn up for each type of switchgear within each company taking particular account of the specific issues related to that population. The generic programme is described in three stages below.

Stage 1 - Planning

A number of significant factors must be taken into account when determining the most appropriate sampling regime. These include the types of plant involved, the history of the plant, the previous maintenance regimes employed and the objectives of the owner and operator. In most cases it is possible to identify relatively large groups of switchgear, which are known to contain similar components, that can be treated as a single population within one company. Prior to implementing the programme it is also necessary to carry out a formal review of failure modes for that switchgear type in order to ensure that the degradation of the oil is the critical factor. In many cases this has been achieved by application of RCM methodology.

With this information it is possible to design a cost effective programme of inspections and oil sampling specifically tailored to the requirements of individual populations of switchgear.

Stage 2 - Initial Programme of Oil sampling and Internal Examinations

Having established the appropriate programme this then needs to be implemented. The purpose of the initial programme is to establish the condition of switchgear and oil at the end of the existing maintenance interval. If maintenance intervals are to be extended it is necessary to demonstrate that this condition is satisfactory i.e. there is no evidence of significant deterioration and therefore maintenance is not required. From the previous work, described in the earlier sections, EA Technology has developed a standard procedure for internal examination of switchgear (at the time of maintenance) which enables the critical information on internal condition to be obtained. In order to implement this examination programme EA Technology has worked with the maintenance teams in a number of RECs to ensure consistent and accurate recording of condition information. Oil samples are also taken at the time of the maintenance and these are subject to the range of tests specifically designed to establish both the condition of the oil and any evidence of component deterioration within the switch.

The results from these internal examinations and oil tests are then compared with the large volume of data from similar equipment gathered by EA Technology as part of the earlier programme and other ongoing studies with similar populations of switchgear.

Stage 3 – On-going Oil sampling

If the results achieved in Stage 2 confirm that there has
been no significant deterioration in the switchgear or the oil, a decision can be made to increase the maintenance interval. The results achieved in Stage 2 provide a good indication of whether it is likely that a significant increase can be recommended. Nevertheless, how ever positive the results are in Stage 1 it is recommended that in subsequent years further oil sampling is undertaken on units of switchgear with oil progressively older on each occasion so that the comparison of the results can be made with the original values. This therefore enables the effects of increased maintenance interval to be monitored on a year-by-year basis. In due course this process will identify evidence of significant deterioration which will define the limit for maintenance.

5. APPLICATION WITHIN UK RECs

Currently six of the UK RECs are undertaking programmes of oil sampling and internal inspections, based on this generic programme, in order to optimise their maintenance activities for large groups of oil filled switchgear. In four cases the initial programme of work has been completed and has demonstrated the validity of increasing the maintenance interval for most of the populations considered. In these cases the companies are planning continued oil sampling to monitor the condition of the oil and switchgear to enable the optimum maintenance interval to be established.

In a few cases the sampling regime has identified evidence of some degradation which indicates the need for maintenance within the next 2-3 years.

The remaining two companies are still to complete Stage 2 but initial results indicate that for most of the populations being considered a positive outcome will also be achieved.

Within these six companies there are several different ranges of switchgear being considered and the validity of the approach, based on identifying significant deterioration of switchgear from oil samples, is being confirmed. Overall the programmes have proved very manageable on a practical level with the quality of information being obtained from the RECs generally very good. The volume of oil test results is also rapidly increasing to provide greater confidence in the interpretation of the results.

Linking this process to the independent (reliability centred maintenance) assessments of maintenance needs by individual RECs is providing a very high level of acceptance and confidence of the validity of increasing maintenance intervals within the companies involved. The programmes have been fully described, discussed and analysed with all members of the maintenance and operational teams and have been very positively received. The results are being used to provide a complete technical case for adopting particular maintenance strategies, which in some cases have been linked to formal risk assessment procedures which demonstrate an improved level of safety based on this approach. In addition the cost savings are very substantial. In one recent example, the REC involved estimates that the application of this approach to one group of switchgear will result in savings of more than £500K over a five year period. Clearly within the current regulatory and financial climate these savings are most welcome.

6. CONCLUSIONS

EA Technology has developed a programme of oil sampling and internal examination of units which enables the optimum interval for maintenance, based on actual condition, to be established for groups of switchgear. This approach is currently being applied with six UK RECs leading to substantial costs savings while maintaining or improving safety and reliability.

The process:-

• is based on a practical understanding of the degradation and failure modes of oil and switchgear
• underwrites a complete technical case for adopting a particular maintenance strategy, linked to a large volume of condition information from similar equipment.
• provides a benchmark to monitor the effect of increasing maintenance intervals.
• enables the ultimate limit for the maintenance interval, necessary to ensure an acceptable level of safety and reliability, to be defined.
• demonstrates the much wider potential of using knowledge of degradation and failure modes to define the critical condition information necessary in order to optimise maintenance, refurbishment or replacement programmes.

EA Technology is currently applying a similar approach to many other areas within the Electricity Industry, examples include; refurbishment of 11 kV wood pole overhead lines, maintenance of tap changers, optimisation of maintenance/inspection of 132 kV overhead lines. In each case specific knowledge and understanding of design, degradation and failure processes is linked to knowledge and information available within the parent organisations in order to derive and apply cost effective and technically sound processes. In all these areas very significant cost savings are being generated for the owners of the plant thus enabling real benefits to be derived from this application of a practical asset management process.