Electricity Breakdown Management for Sarawak Energy: Use of Condition-Based Equipment for Detection of Defective Insulator

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Abstract: Managing electricity breakdown is vital since an outage causes economic losses for customers and the utility companies. However, electricity breakdown is unavoidable due to some internal or external factors beyond our control. Electricity breakdown on overhead lines tend occur more frequently because it is prone to external disturbances such as animal, overgrown vegetation and defective pole top accessories. In Sarawak Energy Berhad (SEB), majority of the network are composed of overhead lines and hence, is more prone to failure. Conventional method of equipment inspection and fault finding are not effective to quickly identify the root cause of failure. SEB has engaged the use of corona discharge camera as condition-based monitoring equipment to carry out condition based inspection on the line in order to diagnose the condition of the lines prior to failure. Experimental testing has been carried out to determine the correlation between the corona discharge count and the level of defect on line insulator. The result shall be tabulated and will be used as reference for future scanning and diagnostic on any defect on the lines.

1. Introduction

The world’s requirement for a more reliable electricity supply has been ever increasing, nevertheless electricity supply utilities have not been able to effectively reduce service disruptions due to unplanned outages on lines. The causes of unplanned outages were studied and are categorized as animal, weather, vegetation, human intervention and unknown [1]. Various approaches and initiatives have been undertaken to mitigate and to reduce service downtime due to unplanned outages on lines.

Sarawak Energy Berhad (SEB), a utility company in south east region, is responsible for the generation, transmission and distribution of electricity for the state of Sarawak, Malaysia [2]. While majority of its systems are made up of overhead lines, SEB strives to minimize the occurrences of unintended outage on lines. In order to improve the reliability of the lines and to effectively identify the root cause of the outages, SEB is looking into improving company maintenance philosophy from reactive maintenance and time based maintenance to predictive maintenance. This is mainly due to the fact that it has been found that equipment failed before the next scheduled maintenance date.

This paper discusses the use of corona discharge camera as part of the diagnostic maintenance on overhead lines to detect any abnormalities prior to outages.
2. Proposed Research
The study shall be undertaken via experiments to determine the effectiveness of the corona discharge camera in detecting any abnormalities in the overhead lines.

3. SEB Distribution System
Due to the geographical nature of Sarawak, and the customers are sparsely populated, 75% of the distribution system is made up of overhead lines with a total circuit length of 24,031.49KM [3]. Table 1 shows the breakdown statistic for SEB from year 2014 to 2016 [4] based on circuit category. It is noticed that unplanned interruption due to overhead lines is increasing for the last three years up to 69.27% at year 2016.

| Circuit Category       | 2014   | 2015   | 2016   |
|------------------------|--------|--------|--------|
| Overhead lines         | 62.61% | 62.72% | 69.27% |
| Underground cable      | 9.79%  | 8.40%  | 9.21%  |
| Equipment failure      | 5.45%  | 6.76%  | 5.04%  |
| Others                 | 22.15% | 22.13% | 16.48% |
| Total                  | 100%   | 100%   | 100%   |

*Table 1. Breakdown statistics (in %) by circuit category from 2014 - 2016*

Table 2 shows the contribution of unplanned outage on overhead lines on SAIDI for the year 2014 to 2016 [4]. Breakdown due to overhead lines has contributed to over 50% of the total distribution SAIDI.

| Circuit Category       | 2014 | 2015 | 2016 |
|------------------------|------|------|------|
| Breakdown on overhead lines | 66   | 59   | 58   |
| Distribution SEB       | 123  | 103  | 87   |
| (%)                    | 53.7%| 57.3%| 66.7%|

*Table 2. SAIDI contribution from outages on overhead lines from 2014 – 2016*

Based on the statistics in table 1 and 2, it is clearly shown that the performance of overhead lines circuit has significant impact on the company performance. Further analysis and data gathering were undertaken on SEB breakdown statistics, emphasising on identifying the root cause of the unplanned outage on overhead lines. Table 3 shows the root cause of all outages from the year 2014 to year 2016 [4].

Analysis results in table 3 show that unplanned outage on overhead lines due to transient fault contributed to over 40% of the total outages. In view of the significant impact of unplanned outages
due to transient fault (Cause unknown) on overhead lines, it is necessary to relook into various maintenance methodologies to reduce this figure and to improve the line performance.

| Cause of outages       | 2014   | 2015   | 2016   |
|------------------------|--------|--------|--------|
| Excavation             | 1.09%  | 1.74%  | 2.60%  |
| Public tree clearing   | 1.36%  | 1.19%  | 1.73%  |
| Vehicle                | 1.77%  | 2.43%  | 2.83%  |
| Aerial cable fault     | 3.52%  | 2.61%  | 2.62%  |
| Cable fault            | 3.91%  | 3.53%  | 3.57%  |
| Equipment failure      | 5.45%  | 6.76%  | 5.04%  |
| Lightning              | 15.81% | 16.89% | 17.61% |
| Transient              | 37.41% | 38.18% | 42.41% |
| Vegetation             | 4.29%  | 4.42%  | 2.83%  |
| Protection non-        | 0.02%  | 0.05%  | 0.05%  |
| discrimination         |        |        |        |
| Mis-operation          | 0.09%  | 0.17%  | 0.05%  |
| Animal                 | 7.56%  | 6.61%  | 7.43%  |

Table 3. Cause of outages for SEB from 2014 – 2016

3.1 Diagnostic Maintenance
Diagnostic maintenance was first proposed in 1978 by the Electric Power Research Institute (EPRI), also known as predictive maintenance [5]. This maintenance is done through state monitoring tools, diagnostic equipment and health level to determine the condition of the equipment and the best time to carry out maintenance and repair. There are various types of diagnostic maintenance tools used for determining the condition of the overhead lines as well as to detect the location of fault on the overhead lines. In most European countries, there is also ongoing reform of the maintenance system towards condition-based maintenance.

There are various diagnostic maintenance tools currently in use. The first and the most common one used by many utilities is the overhead lines infrared thermography scanning camera. It is put into use since 2010 through which a number of major defects were detected easily [6]. On the other hand, corona discharge scanning has also been widely used for detection of fault and to determine the condition of the equipment on the line.

Comparing to corona discharge scanning, infrared thermography scanning has been used in a wide variety of fields such as medical, military and electrical equipment diagnostic. Well-established Delta-T acceptance criteria from the International Testing Association Maintenance Testing Specifications, 1997 (NETA MTS-1997) has also been set up to ease on evaluation of site findings before any action (repair maintenance works) needs to be taken [7]. However, no similar acceptance criteria on corona discharge count that has been set up.
Sarawak Energy Berhad has purchased one (1) set of CoroCAM 504, a corona discharge camera developed by South Africa’s Eskom Transmission. This CoroCAM is able to detect corona discharges released from an equipment and to quantify the number of photons reaching the camera into a value called photon count.

Scanning was carried out on frequently tripped feeders and lots of data were gathered. All the pin insulator detected with counts were shut down for inspection but no abnormality was found. It is thus necessary to find out any correlation between the photo count and the severity of insulation failure within an equipment in order to carry out “just-in-time” maintenance. The findings will be able to provide a better understanding and be able to interpret the scanning result accurately and effectively.

4. Experimental Methods
A preliminary study through field data collection and laboratory experiments shall be carried out to determine the corona count acceptance criteria to ease the field crews when evaluating their findings.

4.1 Laboratory Set Up
The testing shall be carried out at Sarawak Energy Berhad high voltage laboratory located at Jalan Belian, Kuching, Sarawak.

4.2 Equipment
Throughout the laboratory testing, CoroCAM 504 shall be used as the tools for carrying out the scanning work. The high voltage equipment used is Hipotronics high voltage test set.

4.3 Test Sample
For this study, the pin insulators of the same brand rated at 36KV shall be used for the testing. The total number of pin insulators required are as follow:

- **New pin insulators**: One (1) number (The new pin insulator shall be used as the control specimen) and shall be numbered **0001**.

- **Old/crack/used pin insulators**: ten (10) numbers with flash over sign but without visible crack on the pin insulator skirt and shall be numbered **0002 to 0011**.

### 4.4 Test Method

All the pin insulators shall be installed based on SEB Overhead Lines Construction Standards. This is mainly to simulate the actual condition on site. It shall be tested under dry condition. All tests are carried out

*Test 1:
Sample: New pin insulator 0001
Test voltage: **19KV and up 36KV or when the test set trips

*Test 2:
Sample: Used pin insulator 0002 – 0011
Test voltage: **19KV and up to 36KV or when the test set trips

*Test 3:
Sample: Used pin insulator 0002 – 0011*
Test voltage: **19KV and up to 36KV or when the test set trips

*The first layer of all the used pin insulators were intentionally broken

**19KV is normal phase to ground system operating voltage

All the tests started with injection voltage of 6.5KV and the voltage was raised at 0.5KV every one (1) minute. Shall the test equipment trips within the one (1) minute, the test will stop.

### 5. Experimental Results and Discussion

The results of the tests were tabulated as in table 4:

| Test                | Injected voltage (KV) | Photon Count |
|---------------------|-----------------------|--------------|
| Test 1: 0001        | 19KV                  | Nil          |
| Test 1: 0001        | 36KV                  | Nil          |
| Test 2: 0002 – 0010 | 19KV                  | Nil          |
| Test 2: 0002 – 0010 | 36KV                  | 30 – 47      |
| Test 3: 0002 – 0010 | 19KV                  | 35 – 60      |
| Test 3: 0002 – 0010 | *31KV to 33.5KV       | 475 – 533    |

*the high voltage test set tripped at the max voltage of 31 to 33.5KV

**Table 4. Experimental Test Results of various scenarios.**
6. Discussion and Conclusion

Based on the findings of the above result, it is found that:

- Corona discharges are hardly visible for system voltage below 19KV for normal pin insulator and those pin insulators that have flash over sign.
- With all the normal conditions remained unchanged, any photon count above 30 may indicate insulation failure on pin insulator such as hair line crack or broken skirts and should be replaced immediately before it gets worse, as this may cause outages.

Preliminary results found from this study triggered for a more detailed study with the intention to set up a table of corona count acceptance table for ease of troubleshooting. Some of the possible work that can be carried are:

- To conduct the test with more specimens with various defects
- To conduct the test by simulating different weather condition (Raining, lightning days)
- To conduct the test with lower voltage level pin insulator (11KV)

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