Assessing the Service Condition of an Electrical Panel Board

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***Abstract*—Electrical panel boards are used to locate controlling, measuring and metering devices which are used in electrical power distribution. It is a customized product which is used for a specific purpose. In order to obtain the proper functioning of an electrical panel board, it should be maintained properly. Normally it will be a routine maintenance which will be performed once a year or half a year. But it is very important to know the service condition of an electrical panel board to avoid failures and perform the maintenance activity where it is necessary. This research presents a method to assess the service condition of an electrical panel board. Initially the importance of the temperature, the humidity and number of operations of a circuit breaker is highlighted. This was proven by various field measurements. Those measurements were statistically analysed and the Service Condition Analyser (SCA) was fabricated and tested under the laboratory conditions.**

Keywords—Predictive Maintenance, Electrical Panel Board, Service Condition Analyser, Predicted Temperature and Humidity Profile

I. Introduction

Maintenance is the process that keeps something in proper condition which has four main strategies called Reactive, Preventive, Predictive and Proactive [1]. According to the statistics, preventive maintenance is the cost effective method which will increase return on investment 10 times, reduce the maintenance cost by 25% to 30%, and reduce down time by 35% to 45% [1].

In the context of electrical distribution system, electrical panel board is the most critical asset which needs to be monitored and maintained properly to avoid hazardous situations. Our scope is to design and fabricate a cost effective predictive maintenance tool called a Service Condition Analyser (SCA) which was tested and verified in laboratory conditions.

II. Theoretical Analysis

A. *Predicted Temperature Profile*

According to the IEC 61439-1[3] standard for low voltage switchgear and controlgear assemblies, the proper operating conditions can be summarized as follows.

- The normal operation conditions are implied as the designed conditions that ensure the proper operation. If these conditions are not met, appropriate steps should be taken to ensure proper operation [4].
- The ambient air temperature for indoor installations shall not exceed +40 °C and its average shall not exceed +35 °C over a period of 24 h. The lower limit of the ambient air temperature shall be –5 °C. Similarly, ambient air temperature for outdoor installations shall not exceed +40 °C and its average shall not exceed +35 °C over a period of 24 h. The lower limit of the ambient air temperature shall be –25 °C [4].

During the operation of panel boards, it is important to consider the temperature rise in the air inside them due to the power losses of the various components in the panel board which is described in IEC TR 60890[6]. Figure 01 explains the calculation process of the temperature rise of air inside the panel board.

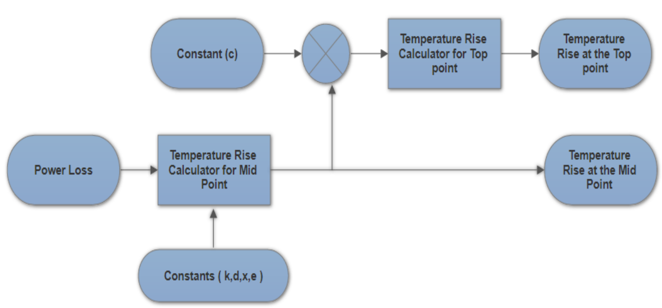

Figure 01 Temperature rise calculation as per IEC TR 60890[6]

Firstly, Enclosure constant (k), Temperature rise factor (d), Temperature distribution factor (c) and Exponent for the effective power loss (x) were found by referring to IEC TR 60890[6]. Then effective power loss was calculated by using following equation with aid of actual current (I), rated current (I_{rated}), current independent power loss (P_1) and current dependent power loss (P_2) which is mentioned in manufacturer catalogs.

Effective Power Loss = $P_1 + (I / I_{rated})^2 * P_2$

By using these values and following equations, the temperature rise at the mid-point ($\Delta t_{0.5}$) and the temperature rise at the top (Δt_1) were calculated [6]. Temperature rise at the bottom is assumed to be zero.

$$\Delta t_{0.5} = k.d.P^x$$

$$\Delta t_1 = c.\ \Delta t_{0.5}$$

According to $\Delta t_{0.5}$ and Δt_1 values, predicted temperature profile was obtained as mentioned in Figure 02 [6].

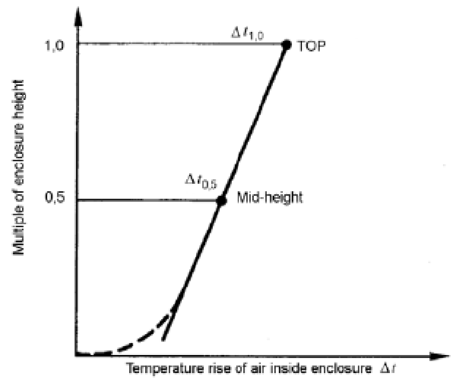

Figure 01 Predicted Temperature Profile [6]

B. *Predicted Humidity Profile*

As per IEC 61439-1, Humidity in an air inside the electrical panel board should be as follows.

"The air must be clean and its relative humidity will not exceed 50% at a maximum temperature of +40 °C. But higher relative humidity may be permitted at lower temperatures, for example 90% at +20 °C [4]."

By considering the above mentioned information, a linear variation of humidity over the temperature inside the panel board was approximated.

III. FIELD DATA ANAYLYSIS

Initially a proper sample space was defined by considering the age and the maintenance status of a particular panel board. Then, by using temperature and humidity measuring devices, field data were obtained and compared with predicted profiles.

A. *Temperature Variation*

Predicted temperature profile and actual temperature profile were compared and observations were made as mentioned in Table 01 for the selected sample space.

Table 01 Observations of Temperature data analysis

Age of the panel board	**Maintenance status**	**Organization**	**Observation**
Below 05 years	Well maintained	KIK Lanka Factory 02	Theoretical values and field data coincide each other
		DCSL - Seeduwa	Field data lay below the theoretical values
		YKK Lanka – Awissawella – Stage 02	Theoretical values and field data coincide each other
	Less maintained	Ocean Lanka – Biyagama – Stage 02	Theoretical values lay below the field data
Between 05 to 10 years	Well maintained	KIK Lanka Factory 01	Theoretical values and field data coincide each other
		Lion Beer – Biyagama	Field data lay below the theoretical values
	Less maintained	Ocean Lanka – Biyagama – Stage 01	Theoretical values lay below the field data
More than 10 years	Well maintained	Shore to Shore Ltd	Theoretical values and field data coincide each other
		YKK Lanka – Awissawella – Stage 01	Theoretical values and field data coincide each other
	Less maintained	Packages Lanka Ltd	Theoretical values lay below the field data

By considering the results, a normalized temperature variations with respected to predicted temperature variation was obtained. Normalized temperature profiles are depicted in Figure 03 for the selected sample space.

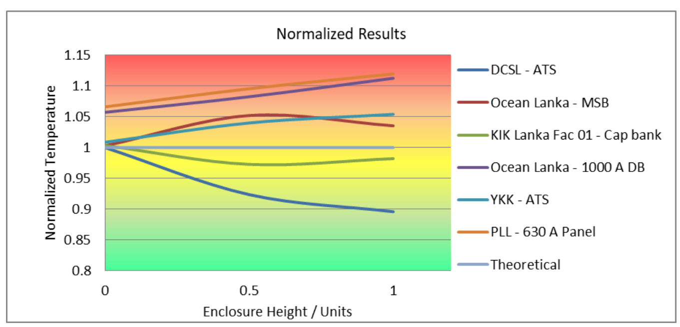

Figure 03 Normalized Temperature Results

According to the above mentioned normalized results, the following conclusions can be outlined.

- ✓ If the condition of the electrical panel board is poor, the temperature variation is deviated upwards with respect to the unit step function (highlighted in RED colour).
- ✓ If the condition of the electrical panel board is better, the temperature variation is deviated downwards with

respect to the unit step function (highlighted in GREEN colour).

- ✓ If the condition of the electrical panel board is good, the temperature variation is deviated around the unit step function (highlighted in YELLOW colour).

B. *Humidity Variation*

For the selected sample space, humidity value at the mid-point of the enclosure was taken and recorded. Then it was compared with the predicted humidity value with respect to the temperature at the mid-point. The difference between the actual and predicted humidity values was calculated as shown in Table 02.

Table 02 Observations of Humidity data analysis

No	Panel Name	Actual Humidity %	Predicted Humidity %	Difference
1	KIK Fac 2 - Cap Bank	67	65.4	1.6
2	KIK Fac 2 - ATS	67	66	1
3	DCSL - ATS	77	75.2	1.8
4	YKK - Cap1	57	57.8	-0.8
5	YKK - Cap2	58	56.6	1.4
6	Ocean Lanka - Distribution Panel	64	54.8	9.2
7	Ocean Lanka - Incoming Panel	70	60	10
8	Ocean Lanka - MSB	66	52.8	13.2
9	KIK Fac 1 - Cap Bank	60	61.8	-1.8
10	Lion Beer ATS1	67	68	-1
11	Lion Beer ATS2	69	70.4	-1.4
12	Ocean Lanka - 1000 A DB1	60	51	9
13	Ocean Lanka - 1000 A DB2	65	53.8	11.2
14	Shore to Shore - CO panel	60	62.4	-2.4
15	YKK - ATS 1	53	55.4	-2.4
16	PLL - 630A Panel	74	66.8	7.2

By considering the above table, the following observations have been made.

- ✓ When the service condition is poor, the difference between the actual and predicted humidity values is more than 5%.
- ✓ When the service condition is good, the difference between the actual and predicted humidity values is less than 5%.

IV. Implementation of Service Condition Analyser

By considering the theoretical and practical concerns, Service Condition Analyser (SCA) was designed and fabricated. A programmable logic controller (PLC), temperature sensors with 4-20 mA converters and humidity sensors were used to arrange the complete setup for analysing the service condition. Service status on temperature, humidity and wear tear condition were given as the output of SCA.

A. *Service Status on Temperature*

In order to compare the deviation between normalized temperature variations with unit function, D_{rms} value was calculated by using following equation.

$$D_{rms} = \sqrt{\frac{(T_{0n} - 1)^2 + (T_{0.5n} - 1)^2 + (T_{1n} - 1)^2}{3}}$$

where T_{0n}, $T_{0.5n}$ and T_{1n} are normalized temperature values at the bottom, the mid-point and the top respectively**.** By considering the observation from the field data collection, the following method stipulated in Table 03 was used as the decision making logic**.**

Table 03 PLC Logic for Service Condition on Temperature

Logic in PLC	Condition of The Panel Board	Service Percentage on Temperature %
If $(T_{1n} - 1) > 0$ & $D_{rms} > 0.5$	WORST	100
If $(T_{1n} - 1) > 0$ & $0.5 > D_{rms} > 0.25$	POOR	75 + ((Drms – 0.25)*100)
If $(T_{1n} - 1) > 0$ & $0 < D_{rms} < 0.25$	GOOD	50 + Drms*100
If $(T_{1n} - 1) < 0$ & $0 < D_{rms} < 0.25$	GOOD	25 + ((0.25 – Drms)*100)
If $(T_{1n} - 1) < 0$ & $0.5 > D_{rms} > 0.25$	BETTER	(0.5 – Drms)*100
If $(T_{1n} - 1) < 0$ & $D_{rms} > 0.5$	BEST	0

B. *Service Status on Humidity*

By considering the humidity difference percentage with respect to the predicted humidity value, the condition of the electrical panel board was estimated with the aid of the conditions stipulated in Table 04.

Table 04 PLC Logic for Service Condition on Humidity

Logic in PLC	Condition of The Panel Board	Service Percentage on Temperature %
If the | difference | < 5 %	GOOD	$\frac{The\ Humidity\ Difference}{5} * 50$
If the 5 < | difference | < 10 %	POOR	$50 + \frac{The\ Humidity\ Difference - 5}{5} * 50$
If the | difference | > 10 %	WORST	100

C. *Wear and Tear Status*

As per the manufacturer's specification there is rated number of operations for a switchgear or control-gear. By using the auxiliary contact of the switchgear or control-gear, the number of operations was counted and compared with the rated number of operation as percentage which implies the life time of the switchgear or control-gear. According to the number of operations, the condition of the switchgear or control-gear was estimated by using the following equation.

$$\text{Tear Wear Condition} = \frac{Number\ of\ Operations\ of\ the\ Circuit\ Breaker}{Electrical\ Life\ of\ the\ Circuit\ Breaker} * 100\ \%$$

V. METHOD VERIFICATION

In order to validate the proposed Service Condition Analyzer (SCA), a test setup was established and results were obtained. A sample test panel, a panel with SCA, current injector and test bench were main parts of the test setup.

A. *Test Procedure*

Following procedure was followed to obtain the test results.

Step 01: Initially the test set-up was established and test bench and the current injector were powered up.
Step 02: Current injector output was gradually increased with an interval value of 25A from 0 to 300A. For a particular current value, the test was performed for 15 minutes.
Step 03: Then the service status was recorded by using the test report format which is attached in Annexure E.
Step 04: Finally the observations were plotted and analysed.

B. *Results*

Initially, Service status on temperature were recorded and plotted with respect to the applied current value as depicted in Figure 05.

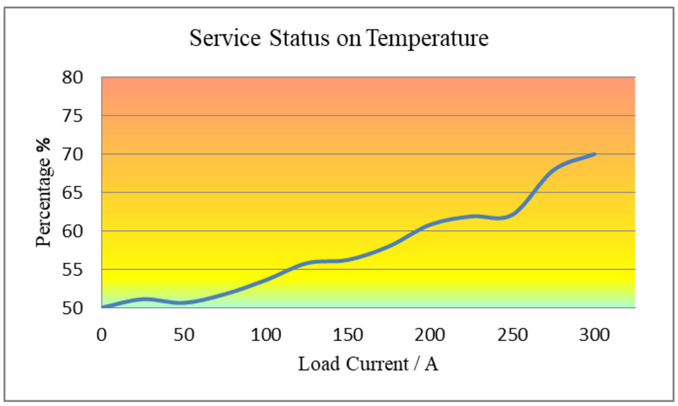

Figure 05 Service status on temperature with respect to the current applied

According to the graph, it was clearly shown if the electrical panel board is operated in a stressed condition, the service percentage will increase which shows the correct trend that gives an indication to the operator to check the operational condition of the panel board. So by considering the above mentioned factors, it was shown that the SCA is showing the correct trend for over temperature conditions.

Then service percentage on humidity were recorded and plotted with respect to the load current as depicted in Figure 06.

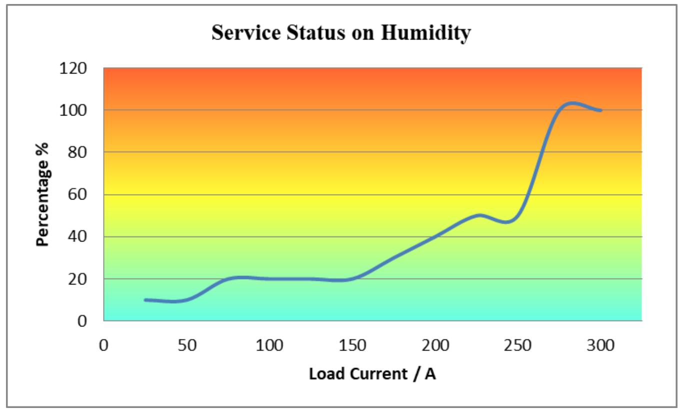

Figure 06 Service status on humidity with respect to the current applied

According to the graph, it was clearly shown if the electrical panel board is operated in a stressed condition the service percentage will increase which shows the correct trend that gives an indication to the operator to check the operational condition of the panel board. So by considering the above mentioned factors, it was shown that the SCA is showing the correct trend for improper humidity conditions.

CONCLUSIONS

Considering all facts and results, it can be concluded that the proposed SCA can be used to indicate the service level of an electrical panel board. This SCA can be used to analyze the condition of Main Distribution Boards (MDB). When compared against the cost of a MDB, the additional cost needed for the SCA is very small and it enhances the life time of the MDB. Also it can be used to prevent hazardous situations in an electrical panel board.

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