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Condition Based Monitoring Approaches of Maintenance in Indian Industry- Some Case Studies

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Abstract – Machines are widely used in industry for automation. Any machine consists of mechanical, electrical and electronics components along with software which are required to work under varied environments for long durations, in some cases continuously. Therefore, the maintenance of machine is very important so that it can work without any breakdown. This paper presents the results of surveys conducted in 5 different industries to study the condition based monitoring (CBM) practices for industrial machines. For this purpose, a questionnaire based survey was conducted in these industries which offer beneficial research results for CBM system providers, consultants and industries alike. The case study of these 5 industries helps in identifying the different types of CBM techniques, instruments used, sensors used, CBM activities, etc. being practiced in a particular industry. The paper also discusses the recent advancements in software based remote monitoring systems being used in the industries for predicting the health of the machines.

Index Terms – Condition based monitoring (CBM), maintenance, questionnaire, survey, case study.

1. INTRODUCTION

Condition Based Monitoring (CBM) is a process of systematic data collection and its analysis in order to assess the condition of a machine. These conditions can be determined by various physical parameters (known as signatures) like vibration, noise, temperature, oil contamination, wear debris, etc. [1]. Rastegari et.al. [2] studied some of the major challenges while implementing CBM in a manufacturing industry, which includes companies' culture, management support, competence within organization to use CBM effectively, etc.

But today maintenance engineers are realizing that successful CBM deployments result in lower maintenance costs with increased reliability, lesser downtime, high asset life, lesser overtime cost and higher worker safety. Rastegeri [3] discussed the implementation of condition based maintenance in industry for vibration analysis of electric motor bearing. In general, the primary steps involved in CBM are [4]:

Figure 1 CBM steps

To understand CBM practices in the work place a questionnaire based survey was conducted in 5 different industries (Appendix-Table 1). The questionnaire mainly targeted the 5 key areas [1] : (a) Type of industry, (b) Type of CBM techniques used, (c) Type of instruments and sensors used (d) Monitoring frequency of machines, and (e) Method of analyzing the CBM data. An online survey with limited general questions related to CBM was conducted in 2004 in order to find the applications of CBM systems within the industry [1]. Laakso [5] conducted survey in 3 different nuclear plants for understanding the applications of CBM. The purpose of this paper is to study various CBM techniques used in the industries and to discuss its various applications for monitoring of the health of machines. used, (c) Type of instruments and sensors used (d) Monitoring frequency of machines, and (e) Method of analyzing the CBM data. An online survey with limited general questions related to CBM was conducted in 2004 in order to find the applications of CBM systems within the industry [1]. Laakso [5] conducted survey in 3 different nuclear plants for understanding the applications of CBM. The purpose of this paper is to study various CBM techniques used in the industries and to discuss its various applications for monitoring of the health of machines.

2. SURVEY TECHNIQUE

The survey was conducted in offline mode, which involved researcher's direct interaction with the working environment and employees of particular industry. The survey was conducted systematically as per following steps:

- The relevant questions related to CBM were selected to be part of questionnaire.

- A questionnaire for collecting data was designed taking into consideration the main objective of the study.
- A pilot survey was conducted to test the questionnaire in order to detect any flaws in questionnaire and to correct them prior to the main survey [6].
- Distribution of final questionnaire to the employees in order to get their responses and its subsequent analysis along with measurement of effectiveness of different CBM techniques was done.

3. RELATED WORK

In order to have wider reach of the study, responses were collected from 5 different types of industries using questionnaire. The list of questions asked is tabulated in Table 2 (Appendix). On subsequent analysis of data collected, following findings were found which mainly focused on various condition assessment techniques and its application in an industry

3.1. Company Information

Table 2 (I) shows the type of industries chosen and equipments available while conducting the survey (Table 1).

3.2. CBM Technique

Table 2 (II) helps in finding various CBM techniques used for mechanical and electrical equipments. Bhavsar [7] presented different CBM techniques for three phase induction motor. Adigo [8] developed CBM model by using shaft vibration analysis technique for marine gas turbine. On analyzing the responses received, it was observed that the most widely used techniques for mechanical equipments involves vibration, temperature and pressure monitoring, and for electrical equipments it involves temperature monitoring, winding resistance measurement, transformer oil testing, dissolved gas analysis, magnetic balance test, etc. But temperature monitoring was found to be common to both types of equipments.

3.3. Method of Monitoring

Table 2 (III) shows the way of monitoring the machines which can be either Localized CBM (periodic) or Remote CBM (online) or both [10]. Localized CBM is based on portable handy instruments or test kits whereas remote monitoring involved using of sensors. Due to its lesser cost, periodic monitoring is used mainly whereas online monitoring is mainly preferred for critical machine(s) and is costlier also.

3.4 Types of Instruments Used

Table 2 (IV) shows the type of various instruments used for a particular CBM technique. The infra red camera & thermocouple, sound level meter & shock pulse meter and pressure gauges are mainly used for temperature, vibration and pressure monitoring respectively. For transformer monitoring, suitable test kit(s) is used for a particular CBM technique in order to assess the condition of its various protections and oil.

3.5 Types of Sensors Used

Table 2 (V) shows the various types of sensors used for continuous assessment of equipments. It involves recording of data into the software and its subsequent analysis. The main sensors used includes LVDTs for axial displacement measurement, resistance temperature detectors (RTDs) for temperature monitoring, vibration transmitters for vibration monitoring, piezo-electric sensors for pressure monitoring, turbine meter for fluid flow and differential pressure sensors for fluid level monitoring. Cargol [9] discussed the sensor based online monitoring techniques for transformer oil and grouped them into three categories: combustible gas monitors, complete multi-gas monitors and oil quality monitors. All 3 of them helps in gathering data related to amount of gases present in the oil.

3.6 Monitoring Frequency

Table 2 (VI) shows the frequency of monitoring the health of the equipment which mainly depends upon the pre-decided schedule considering the criticality of the equipments. The most common schedule followed by all the industries is on hourly basis monitoring of the equipment. However, monthly, quarterly, half yearly and annual schedules are also there for electrical equipments.

3.7 Mode of Implementing CBM

Table 2 (VII) shows the way of implementing the CBM in an industry. The responses revealed that combination of both internal maintenance team as well as external CBM consultant is used for assessing the condition of machine. However, the major response was for internal maintenance team because of lesser cost involved.

3.8 Reasons of Vibrations

Table 2 (VIII) shows major reasons for vibrations in equipment. The major reasons include bearing defect, gear noise and misalignment of components in mechanical equipments and, core vibration (magnetostriction) in electrical equipments like transformers. Thrust pad bearings worn out also came out as the major reason of vibrations in turbines. Trendafilova et.al. [11] proposed a method for defect detection in robot joints from their measured vibration values by using pattern recognition principle with nonlinear autoregressive modeling. Sarvanan et.al. [12] successfully implemented the vibration monitoring for diagnosing faulty bearing in a lathe. Gracia et.al. [17] made a vibration model to detect the winding deformation for power transformer condition monitoring.

3.9 Oil Analysis or Testing

Table 2 (IX) shows the different type of oil testing techniques used for transformers. The responses clearly indicated the various parameters for which the oil is tested and these involves breakdown voltage (Kv), water content (ppm), resistivity (Ω-cm), tan delta, interfacial tension, total acidity (mg KOH/g) and flash point (°C). Roy et.al. [13] performed oil testing of distribution transformer of 100 kVA capacity for its dielectric strength with the help of breakdown voltage test.

3.10 Thermography

According to Elanien et.al. [18] thermal analysis of the transformers can be helpful in the assessment of its condition and in detecting any hidden or uncovered fault inside it like, degradation due to direct thermal effects, increased oil temperatures, etc. Table 2 (X) shows main equipments for which thermography is done. The responses indicated for bearing, oil tanks, windings, pumps, cooling fans, compressor, boilers, etc. for which temperature is being monitored. Bittencourt et al. [14] developed a friction model to show the effects of temperature as a wear estimator for an industrial robot joint of ABB IRB 6620.

3.11 Method of Analyzing CBM Data

Table 2 (XI) shows the method of analyzing the CBM data collected. Three options were given whether by manually, by software or by external agency. In case of manually, schedule based data recording on hourly basis and its comparison with prescribed standards is done. NFL uses SYSTEM 1 software by GE India Industrial Pvt. Ltd**.** for its critical equipments. PSPCL is recording the data manually in check sheets and during survey SCADA system was under installation which will be helpful in centralize monitoring of its equipments. JIL uses software by Yokogawa India Ltd. for continuous monitoring, data recording and its subsequent analysis for its turbine unit. PGCIL uses SCADA system by Areva India Pvt. Ltd. for monitoring the condition of its various equipments located remotely in different sub-stations. RSD maintains its data remotely on hourly basis with the help of various sensors and gauges located on turbine. Jaber [15] made use of discrete wavelet transform (DWT) in order to get information related faults and based on this information fault classification was done using artificial neural network (ANN). Verma et al. [16] used genetic algorithms for optimizing the reliability, cost and predictability of the equipment.

3.12 Expectations from CBM

Table 2 (XII) explains the company's expectations from CBM. It basically revealed the real intentions of the member of CBM team while performing CBM activities. The responses showed the CBM exercise as an operating conditions based maintenance activity. While few of them in addition to above, replied CBM as time table based fixed interval maintenance activity.

3.13 Understanding CBM Signatures

Table 2 (XIII) shows the understanding and intellect of the respondent about output signals or signatures of machine in context of CBM. The responses helped in knowing the basic mindset of respondent while observing such signatures by them. All the respondents opted for CBM helps in deciding whether to do maintenance or not. No respondent selected options that mentioned CBM helps in telling machine's time left to fail and percentage failure of machine.

4. RESULTS AND DISCUSSIONS

In order to measure the effectiveness, each monitoring method is classified in two different groups which are: Fault Detection and System Selection Parameters (Table 3). Fault detection is further categorized as Mechanical Electrical and Structural faults (how well the CBM method can detect these faults). System Selection Parameters are categorized as Price (price of equipment), Reliability (how reliable measurement results are in general), Post-Processing (whether there is need of human expertise or not after for further processing and analysis of data) and Reaction Time (indicates how sensitive the CBM method is for changes in equipment health). For analysis these parameters are ranked from 1 to 5 where 5 is extremely good and rank 1 being poor in detecting the faults. 3 is neutral or neither poor nor good. The trend graphs for overall average values (Table 4 to 8) of above 2 classifications are plotted below for comparison of CBM techniques for each industry:

The bar graph for different CBM techniques being practiced in NFL Bathinda is shown below in Fig. 2:

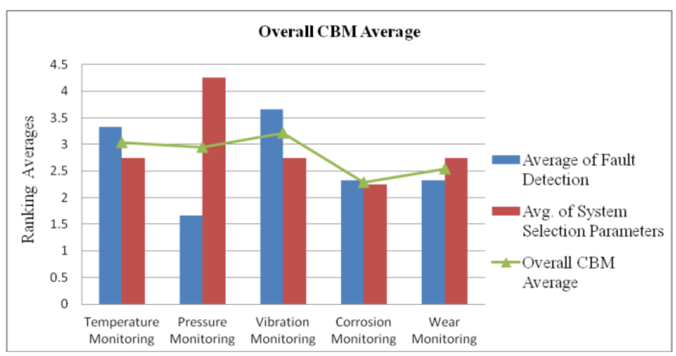

Figure 2: CBM Trend graph for NFL (Table 4)

From fig. 2, it is observed that temperature, vibration and corrosion monitoring are good in detecting the faults, if any, in the system. Pressure monitoring outperforms system selection parameters in their category owing to its less post-processing efforts, lesser cost and lesser reaction time. Corrosion and wear monitoring performs equally well in both detecting faults as well as in its overall performance. The bar graph for different CBM techniques being practiced in PSPCL Jalandhar is shown below in Fig. 3:

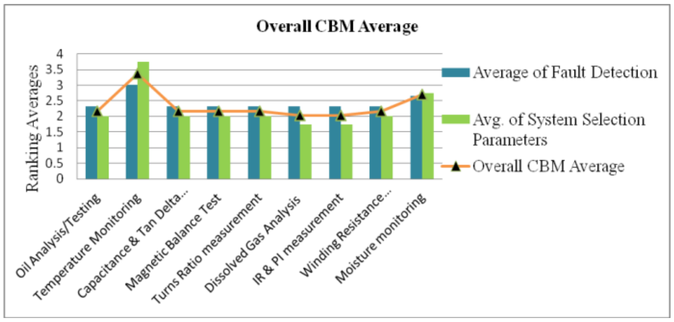

Figure 3: CBM Trend graph for PSPCL Jalandhar (Table 5)

From fig. 3, it is clear that most of the CBM techniques are good in detecting the faults especially the electrical faults. Temperature monitoring leads in System Selection Parameters category due to its high reliability, lesser post-processing efforts and lesser reaction time to respond to any changes in the system. The results show smaller variances among different CBM techniques which are a good sign of healthy CBM practices being followed in an industry. The bar graph for different CBM techniques being practiced in JIL Hamira is shown below in Fig.4:

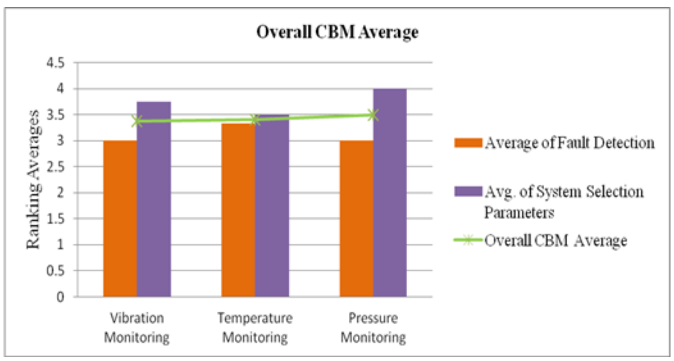

Figure 4: CBM Trend graph for JIL Hamira (Table 6)

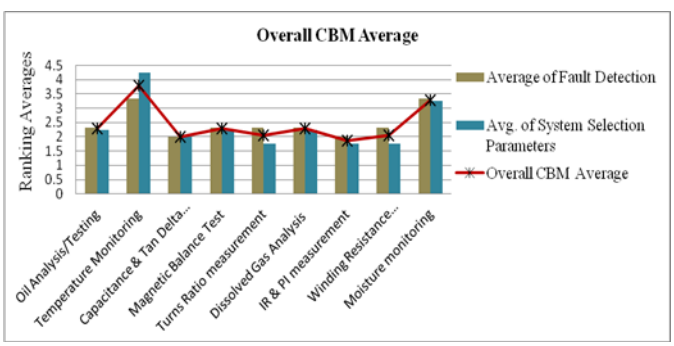

Figure 5: CBM Trend graph for PGCIL Kartarpur (Table 7)

From fig. 4, temperature monitoring proved better in overall fault detection on comparison to pressure and vibration monitoring this is because of the their lack of ability to trace electrical faults. However, all 3 techniques performed equally well in system selection parameters category due to lesser post processing efforts, high reliability and lesser reaction time. This means that overall performance of the CBM techniques is well in a company. The bar graph for different CBM techniques being practiced in PGCIL Kartarpur is shown in Fig. 5:

From fig.5, temperature monitoring proved to be best in system selection parameters category owing to its lesser reaction time, high reliability, minimum post processing efforts and less expensive technology. Temperature and moisture monitoring both are equally good in detecting the faults. The results show smaller variances among the different CBM techniques on comparing with the overall CBM average. It implies these techniques are good in finding the faults as well as in overall performance as a part of CBM activity. The bar graph for different CBM techniques being practiced in RSD Shahpur Kandi is shown below in Fig. 6:

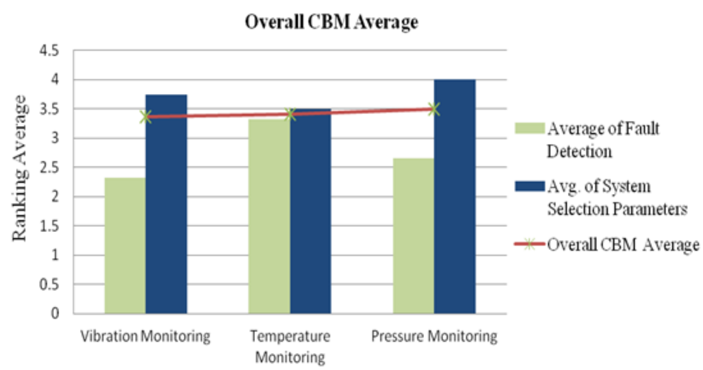

Fig. 6 CBM Trend graph for RSD Shahpur Kandi (Table 8)

From fig. 6, temperature monitoring proved to be better in both finding the fault as well as in overall performance. Vibration and pressure monitoring were limited in their ability to detect the electrical faults and hence positioned below the overall CBM average line.

Table 9 (Appendix) shows radar charts for better understanding of results considering single CBM technique for all industries together. Radar charts were drawn considering the overall CBM average value (Table 4 to 8) of fault detection rank and system selection parameters rank. The radar chart for a parameter/test having greater coverage area indicates its wider usage as well as better overall performance and vice-versa. A zero value on the axis represents no usage of parameter/test for CBM of equipments in the corresponding industry.

5. CONCLUSIONS

Based on data gathered and its subsequent analysis, various conclusions were derived which are discussed below:

- CBM is helpful in indentifying the current status of machine's operating condition by providing real time quantitative data. All the respondents interpret the output signals or signatures of various equipments in such a way that it helps them in deciding whether to do maintenance or not. All the respondent companies considered CBM as operating conditions based maintenance activity, whereas two respondents also considered it as time table based fixed interval maintenance activity.

- The three most widely used techniques for mechanical equipments found to be temperature, vibration, and pressure monitoring. In temperature monitoring, RTD sensors, temperature gauges and infra-red thermal camera are mainly used for measuring temperature. In rotating machines, bearing is important component for which temperature monitoring is mainly done. For electrical equipments, temperature of winding and oil are important parameters to be monitored.

- In case of pressure and vibration monitoring, pressure gauges and piezo-electric sensors are used for pressure monitoring and microphone, sound level meter and vibration transmitters are used for measuring vibrations. The major reasons for vibrations in equipment came out to be bearing defect, gear noise and misalignment of mechanical components in a machine. For electrical equipments like transformer, core vibration is the major reason for vibrations. Thrust pad bearings worn out also came out as the major reason of vibrations in turbine units.

- The most widely used CBM technique for electrical equipments like transformer or other sub-station equipments includes temperature monitoring and oil testing. The frequency of oil testing varies with the type, size age, use of the transformer and as per customer requirement.

- The oil is tested with the help of various test kits available in NABL certified laboratory for the various parameters involving breakdown voltage (Kv), water content (ppm), resistivity (Ω-cm), tan delta, interfacial tension, total acidity (mg KOH/g) and flash point (°C).

- Continuous CBM was backed by software support for continuous data recording and its subsequent analysis in the form of trend charts. The various softwares in use include SYSTEM 1 software, SCADA, Data Manager 2000 system and software by Yokogawa India Ltd. No company goes for 100% continuous CBM of its equipments due to huge investment involved in it. Some companies asked for external consultants, who are expert in CBM field, for the condition monitoring of their equipments and its subsequent analysis.

- Different industries have different schedules of monitoring the equipments. But the most prominent was on hourly basis where data is recorded and noted down in check sheets or log books for further analysis. Electrical equipments' frequency of conducting the CBM tests also involved annual schedules. Instruments and test kits are mainly used in schedule based condition monitoring for mechanical and electrical equipments.

- Every company is having an expert task force which deals with all the CBM activities. Some companies (NFL) asked for external consultants who are expert in CBM field for the condition monitoring of their equipments. Moreover, companies like PSPCL and PGCIL provides their CBM expertise to other companies in context of CBM.

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Appendix

Table 1. Type of Industries

S.No.	Name of Industry	Type of Industry	Type of Equipments
1.	National Fertilizers Ltd. (NFL) Bathinda	Manufacturing	Motor, pumps, turbine, etc.
2.	Punjab State Power Corporation Ltd. (PSPCL) Jalandhar	Electricity Transmission	Transformer & sub-station equipments
3.	Jagatjit Industries Ltd. (JIL) Hamira, Kapurthala	Manufacturing- FMCG (Beverages)	Turbine
4.	Power Grid Corporation of India Ltd. (PGCIL) Kartarpur	Electricity Transmission	Transformer & sub-station equipments
5.	Ranjit Sagar Dam (RSD) Shahpur kandi, Pathankot	Electricity Generation & Transmission	Turbine

Table 2. Questionnaire

S.No.	Type of Questions
I.	What type of industry your organization belongs to?
II.	Which of the following CBM technique(s) do you practice?
III.	How do you monitor the condition of machine or equipment?
IV.	Please indicate to what extent do you use the following types of instruments in CBM activity?
V.	Please indicate to what extent do you use the following types of sensors in CBM activity?
VI.	How frequently do you monitor the health of machines?
VII.	How do you implement CBM in your industry?
VIII.	Please indicate to what extent you agree with following probable reasons of vibrations in your equipment?
IX.	Please indicate the different oil analysis techniques or tests used by your CBM team?
X.	Please indicate which of the following are mainly focused for thermography or thermovision?
XI.	Please indicate the effective method of analyzing the CBM data.
XII.	Please indicate to what extent you agree with the given statement regarding your expectations from CBM?
XIII.	What do you understand by the output signals or signatures of CBM of machine or equipment?

Table 3. Fault Detection and System Selection Parameters

Rank	Fault Detection			System Selection Parameters			
	Mechanical Faults	*Electrical Faults*	*Structural Faults*	*Reliability*	*Post processing*	*Reaction Time*	*Price Range [Rs.]*
1	Poor	Poor	Poor	Poor	Poor	Poor	>1,00,000
2	Average	Average	Average	Average	Average	Average	50,000-1,00,000
3	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	10,000-50,000
4	Good	Good	Good	Good	Good	Good	1000-10,000
5	Extremely Good	Extremely Good	Extremely Good	Extremely Good	Extremely Good	Extremely Good	0-10000

Table 4. NFL Bathinda

CBM Techniques	Fault Detection				System Selection Parameters					
	Mech.	*Elect.*	*Structural*	*Avg.*	*Reliability*	*Post-Processing*	*Reaction Time*	*Price*	*Avg.*	*Overall CBM Avg.*
Temperature Monitoring	3	4	3	3.33	4	5	1	1	2.75	3.04
Pressure Monitoring	3	1	1	1.66	3	5	5	4	4.25	2.95
Vibration Monitoring	5	3	3	3.66	3	1	4	3	2.75	3.21
Corrosion Monitoring	1	1	5	2.33	3	1	1	4	2.25	2.29
Wear Monitoring	1	1	5	2.33	3	2	3	3	2.75	2.54

Table 5. PSPCL Jalandhar

CBM Techniques	Fault Detection				System Selection Parameters					
	Mech.	*Elect.*	*Structural*	*Avg.*	*Reliability*	*Post-Processing*	*Reaction Time*	*Price*	*Avg.*	*Overall CBM Avg.*
Oil Testing	1	5	1	2.33	4	1	2	1	2	2.16
Temperature Monitoring	3	4	2	3	4	5	5	1	3.75	3.37
Capacitance & Tan Delta Test	1	5	1	2.33	3	3	1	1	2	2.16
Magnetic Balance Test	1	5	1	2.33	4	2	1	1	2	2.16
Turns Ratio measurement	1	5	1	2.33	3	2	2	1	2	2.16
DGA	1	5	1	2.33	4	1	1	1	1.75	2.04
IR & PI measurement	1	5	1	2.33	3	2	1	1	1.75	2.04
Winding Resistance Test	1	5	1	2.33	3	2	2	1	2	2.16
Moisture monitoring	2	4	2	2.66	3	3	4	1	2.75	2.7

Table 6. JIL Hamira

CBM Techniques	**Fault Detection**	**System Selection Parameters**

	Mech.	*Electrical*	*Structural*	*Avg.*	*Reliability*	*Post-Processing*	*Reaction Time*	*Price*	*Avg.*	*Overall CBM Avg.*
Temperature Monitoring	5	1	3	**3**	4	5	5	1	**3.75**	**3.37**
Pressure Monitoring	5	3	2	**3.33**	4	5	4	1	**3.5**	**3.41**
Vibration Monitoring	5	1	3	**3**	4	5	4	3	**4**	**3.5**

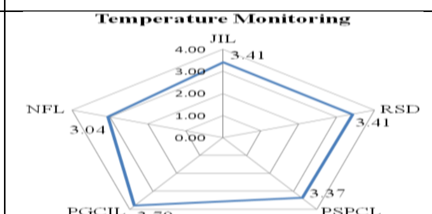
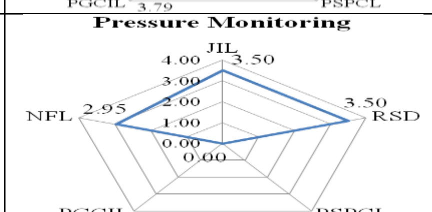
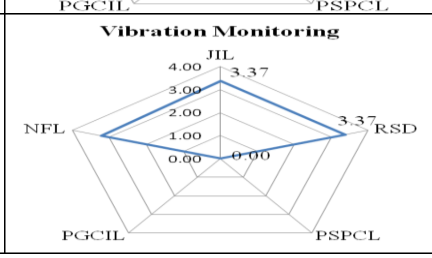
Table 7. PGCIL Kartarpur

CBM Techniques	**Fault Detection**				**System Selection Parameters**					
	Mechanical	**Electrical**	**Structural**	**Avg.**	**Reliability**	**Post-Processing**	**Reaction Time**	**Price**	**Avg.**	***Overall CBM Avg.***
Oil Testing	1	5	1	**2.33**	5	1	2	1	**2.25**	**2.29**
Temperature Monitoring	4	4	2	**3.33**	5	4	5	3	**4.25**	**3.79**
Capacitance & Tan Delta Test	1	4	1	**2**	4	2	1	1	**2**	**2**
Magnetic Balance Test	1	5	1	**2.33**	4	3	1	1	**2.25**	**2.29**
Turns Ratio measurement	1	5	1	**2.33**	3	2	1	1	**1.75**	**2.04**
DGA	1	5	1	**2.33**	4	3	1	1	**2.25**	**2.29**
IR & PI measurement	1	4	1	**2**	3	2	1	1	**1.75**	**1.87**
Winding Resistance Test	1	5	1	**2.33**	3	2	1	1	**1.75**	**2.04**
Moisture monitoring	2	3	5	**3.33**	3	4	4	2	**3.25**	**3.29**

Table 8. RSD Shahpur Kandi

CBM Techniques	**Fault Detection**				**System Selection Parameters**					
	Mech.	*Electrical*	*Structural*	*Avg.*	*Reliability*	*Post-Processing*	*Reaction Time*	*Price*	*Avg.*	*Overall CBM Avg.*
Temperature Monitoring	4	1	2	**2.33**	4	5	5	1	**3.75**	**3.37**
Pressure Monitoring	5	3	2	**3.33**	4	5	4	1	**3.5**	**3.41**
Vibration Monitoring	4	1	3	**2.66**	4	5	4	3	**4**	**3.5**

Table 9. RADAR Charts

<table>
<tr><th>S.NO.</th><th>CBM PARAMETER/ TEST</th><th>RADAR CHART</th><th>REMARKS</th></tr>
<tr><td>1.</td><td>Temperature Monitoring</td><td>
</td><td>Temperature is the most widely used parameter for condition based monitoring of mechanical as well as electrical equipment(s).</td></tr>
<tr><td>2.</td><td>Pressure Monitoring</td><td>
</td><td>Pressure is the second most widely used technique. It finds application mainly for mechanical equipments. No such use of it was found in electricity distribution industries.</td></tr>
<tr><td>3.</td><td>Vibration Monitoring</td><td>
</td><td>Vibration is also second most widely used CBM technique for detecting faults due to abnormal vibrations in the system. It is mainly used for rotating machines and found its presence in industries having mechanical and electro-mechanical equipments.</td></tr>
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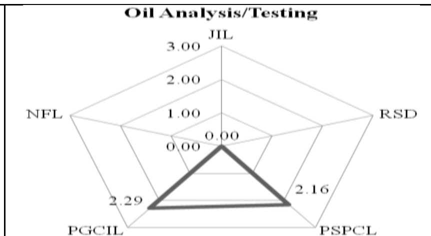
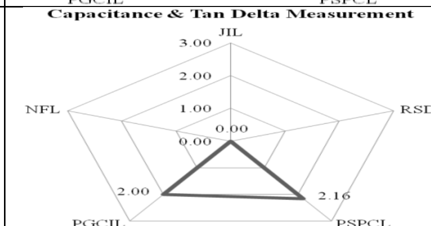
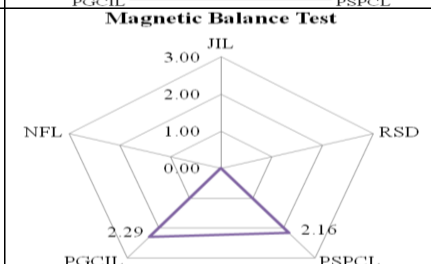
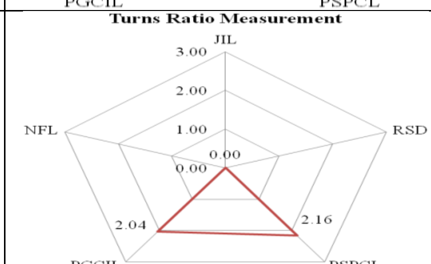
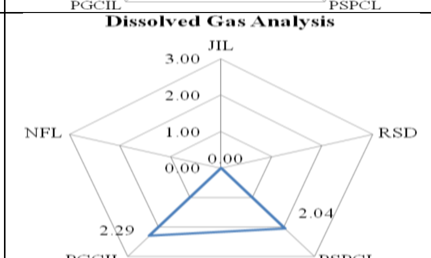
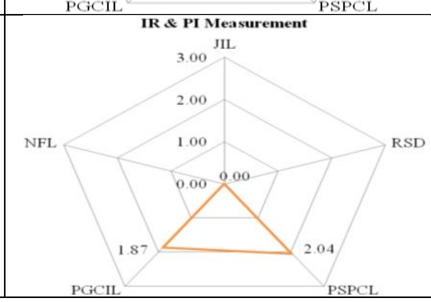
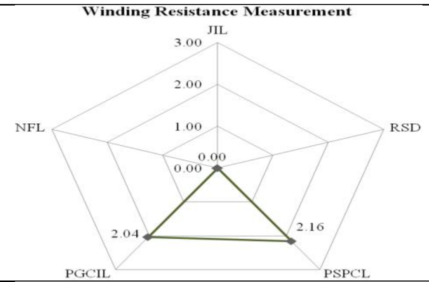
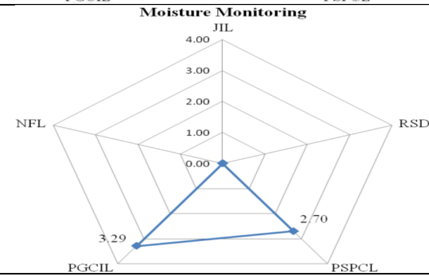
4.	Oil Testing		Transformer oil condition is mainly checked with this CBM technique and is used for electrical equipments. It is mainly used in electricity transmission units.
5.	Capacitance & Tan Delta Measurement		This test is mainly conducted during the pre-commissioning of transformers and is employed in electrical power transmission industries. No such application was found in other industries.
6.	Magnetic Balance Test		This test is conducted to check the condition of magnetic core of transformer and is used for electrical units only. This test along with oil testing shows better overall performance for CBM of electrical equipments due to its higher area coverage in radar chart.
7.	Turns ratio Measurement		This test is mainly done to identify any abnormality in tap changers which is used for regulating the output voltage. This is used for electrical equipments only and found greater extent of its usage in PSPCL as compared to PGCIL.
8.	Dissolved Gas Analysis (DGA)		DGA test is used to check the condition of the oil by identifying the various gases released by the breakdown of the insulating materials within the transformer unit. PGCIL rating is higher than PSPCL because of lesser post-processing efforts required for former due to its in-house advance NABL certified lab.
9.	IR & PI Measurement		This CBM test is used to check the insulation condition of transformer and is used in electricity transmission units and found no such application in manufacturing units. The value for PGCIL is found minimum as compared to System Selection Parameters/test thus indicating limited usage or usage.

10.	Winding Resistance Measurement		This test is conducted in order to check for any abnormalities due to loose connections, broken strands and high contact resistance in tap changers. The higher area coverage represents efficient performance of this test in both industries as compared to other tests for electrical equipments.
11.	Moisture Monitoring		This technique is used to check the levels of moisture presence in the transformer. The value for PGCIL is found maximum due to its continuous online moisture monitoring system compared to traditional approach of sampling the oil at regular intervals in case of PSPCL.