ISSN: 2394-7659
IMPACT FACTOR- 3.775

IJERMS

International Journal of Engineering Researches and Management Studies

PREVENTIVE MAINTENANCE ACTIVITIES DOCUMENTATION FOR CIRCUIT BREAKER USED IN OMAN DISTRIBUTION POWER SYSTEM

Ghazaleh Sarfi *[1] & Amin Niaz Azari[2]
[*1]Iran University of Science and Technology, Electrical Department, Tehran, Iran
[2]Islamic Azad University, Science & Research Branch, Electrical Department, Tehran, Iran

ABSTRACT
Maintenance is the combination of all technical and administrative actions, including supervisory actions, intended to retain an item in, or restore to, a state in which it can perform a required function. In this paper, preventive maintenance activities are specified for outdoor/indoor circuit breakers (SF6/Vacuum) used in Oman Distribution Power System. Preventive maintenance activities are segregated in four categories: Routine inspections & tests, Condition monitoring activities, Minor and major preventative maintenance tasks. Business rules for acceptance of maintenance tests and condition monitoring activities, specialist tools required for each maintenance task, information that should be recorded for each maintenance task are presented in this paper. The predetermined time intervals are proposed for routine inspection and test, condition monitoring activities and major preventive maintenance tasks. This paper is a part of the project "consultancy services for preparation of network asset maintenance standards & associated asset management documentation" which are carried out by Monenco consulting engineering company (Iran) for Majan Electricity Company SAOC (Oman).

1. INTRODUCTION

The economic and technological growth currently experienced progressively require higher demand for energy and greater efficiency of the electricity sector. This quick growth has made decent opportunities for research and development of new products and services that meet the new reality of utilities and customers. Nowadays, energy is considered as a product and not only as a service and, like every product, becomes quantified by its characteristics, such as quality, price, and accessibility.

Nowadays, power quality issues have become more significant due to the increasing use of sensitive equipment to voltage interruptions [1], and loads are much more sensitive to power-quality (PQ) events [2-4], that is, variations and voltage drops. Therefore, the control and analysis of PQ [5-7] provided to customers by the electricity utilities become even more important and necessary. The main goal related to the operation of an electric power system is the continuous supply of energy, reliability, and minimal outages, loss and maintenance cost [8].

Electrical equipment such as power transformer, circuit breaker, bus bar, power line, fault current limiters [9-10] etc. are the important components in power system. Most of them have been long used for many years. During the long use, they are gradually deteriorated day by-day due to aging and operation [11-13]. The deterioration will impact on the reliability of whole system [14-16]. Especially, the deterioration of equipment in substation is very significant because substation is the junction point of generation, transmission and distribution systems [17]. Maintenance is beneficial regarding cost, time, safety and quality conditions, avoiding unanticipated outages, and subsequently increasing the life expectancy of critical assets [18]. The maintenance is become an important part in planning and operation as it is often called "asset management" in modern power system philosophy.

Asset Management is a systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life cycles for achieving its organizational strategic plan [19]. Some tools and methods can be utilized for the best implementing of asset management program in its life cycle that *Maintenance Standard Documentation* is one of them. Figure 1 shows classification of the maintenance tasks. This figure presents a procedure, which could put an asset in a situation to work for a long time. In this paper, all part of figure 1 will be illustrated for outdoor/indoor circuit breakers (SF6/Vacuum). Therefore, for the first step, maintenance activities of this asset will be shown. Then, business rules for acceptance of maintenance tests, condition monitoring activities, specialist tools required for each maintenance task, and information that should

ISSN: 2394-7659
IMPACT FACTOR- 3.775

IJERMS

International Journal of Engineering Researches and Management Studies

be recorded for each maintenance task has been indicated. The next step is about frequency of maintenance and shows how time interval for each activity will be calculated. Finally, a work sheet (table 10) is provided to summarise all parts of figure 1 and information in this paper about circuit breakers.

2. MAINTENANCE TYPE

Maintenance practices can be broadly classified into two categories: corrective maintenance and preventive maintenance. Corrective maintenance restores the functions of an item after failure has occurred or performance fails to meet stated limits.

Preventive maintenance may be carried out at regular intervals or according to prescribed criteria to reduce the probability of failure or to detect a hidden fault. This can be condition based and achieved by monitoring its condition until failure is imminent, or by functional checks to detect failure of hidden functions, and then performing maintenance. It can also be predetermined based on a fixed interval consisting of regular refurbishment or replacement of an item or its component.
Preventive maintenance includes these categories:

Routine inspections & tests
Condition monitoring activities
Minor preventative maintenance tasks
Major preventative maintenance tasks

Routine inspections & tests as well as condition monitoring activities are executed in equipment running condition without necessity of shutdown.

Routine inspections and tests are usually based on the visual aspects. Thermography survey, partial discharge test, Corona discharge test, sample test of oil, and analyze SF6 gas/SF6 Quality test are some examples for condition monitoring test and activities. The appropriate condition monitoring activities should be applied for the specified equipment such as circuit breakers in this paper.

Minor and major preventive maintenance tasks contain tasks to be executed in equipment after shutdown. Minor preventive maintenance tasks are condition-based corrective actions. It means that if the results of Routine inspections & tests and condition monitoring activities are not acceptable, minor preventive maintenance tasks should be conducted (figure 1).

In this regards, business rules for acceptance of tests and condition monitoring activities should be specified. Hence, minor preventive maintenance tasks are condition based and no predetermined time intervals are designated to these tasks. Besides, major preventive maintenance tasks are planned and time-based maintenance tasks.

All types of preventive maintenance tasks, inspections, performances and activities for outdoor/indoor circuit breakers (SF6/Vacuum) are presented in the fallowing parts of this paper. In each part, there are some instructions to help user to figure out how to follow the procedure and do his duty [20-22].

Routine Inspections & Tests

- Inspect physical and mechanical condition and then repair or remove defective devices
- Inspect anchorage and alignment.
- Inspect grounding connection.
- Monitor number of breaker operations and if that exceed rated values, follow manufacturer's recommendation.
- Check for any abnormal sound.
- Check for any Relay indication.
- Check SF6 pressure gauge (for SF6 type).
- Check mechanical indicators of spring charge.
- Check for proper operation of all indicators.

ISSN: 2394-7659
IMPACT FACTOR- 3.775

IJERMS

International Journal of Engineering Researches and Management Studies

- Check for dust & dirt in body, bushing, etc.
- Check bushing for damage, crack and tracking.
- Check mechanism for corrosion and fraction.

Condition Monitoring Activities

- Perform a thermographic survey. Thermograph inspection is a valuable way that can be done while the equipment is energized. Suggested actions based on temperature rise shall be as table 1.

Table 1: Temperature Rise Chart

Severity	Degree F	Degree C
Minor	18 - 36	10 - 20
Serious	37 - 89	21 - 49
Critical	over 90	Over 50

- Perform Corona Discharge Test (table 2).

Table 2: Corona inspection limits

Criteria	Corona Reading	Action Required
Low	Less than 5000 counts	Monitor
Medium	Between 5000 - 10000	Repair
High	More than 10000counts	Scheduled Repair

- Perform Partial Discharge test to confirm that no voids, cracks, flaws or etc. happened during the operation time. PD results must be in accordance with table 3 or manufacture's data and repair or substitute the equipment if it is necessary. In table 3, HFCT, AA and TEV mean High Frequency Current Transformer, Airborne Acoustic and Transient Earth Voltage, respectively.

Table 3: PD Detection Level Guide of Different Sensors

HFCT (pC)	AA (dB)	TEV (mV)	Recommended Action
0 – 600	0 – 12	0 – 20	Good condition, Re-test within 12 months
600 – 3000	12 – 19	20 – 30	Re-test regularly & monitoring recommended
3000 – 20000	19 – 26	30 – 40	Investigate source of PD
20000 – 30000	26 – 30	40 – 45	Test to determine cause, locate & restrict access if necessary

- Analyze SF6 gas/SF6 Quality test (for SF6 CB) using SF6 analyzer according to table 4.

Table 4: SF_6 Gas Test

Test	Serviceability Limits
Moisture	Per manufacturer or ≥ 200 ppm
SF6 decomposition byproducts	≥ 500 ppm
Air	≥ 500 ppm

ISSN: 2394-7659
IMPACT FACTOR- 3.775

IJERMS

International Journal of Engineering Researches and Management Studies

- Check dew point temperature SF6 Quality/Quantity test, Acidity test to manufacturer's instructions and if necessary SF6 gas should be recycled, refilled or renewed according to table 4

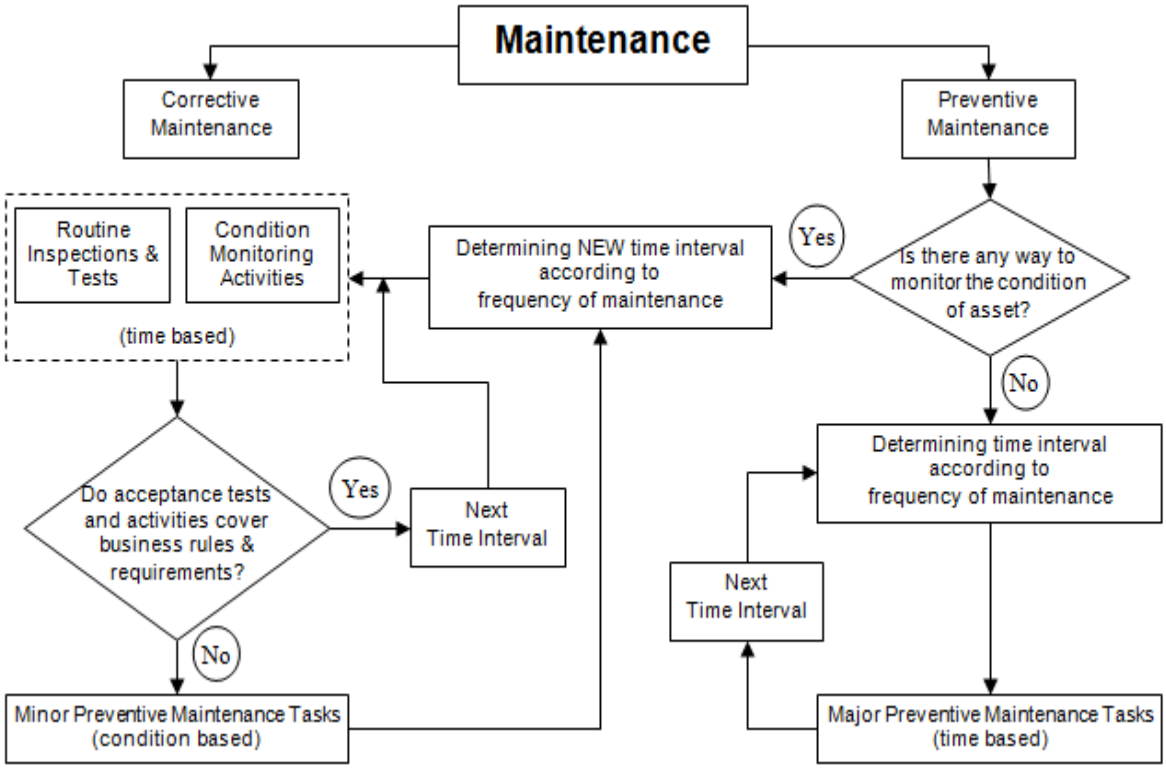

Figure1: procedure of developing Maintenance Standard Documentation for an asset (see table 10)

Minor Preventive Maintenance Tasks

- Check for dust & dirt in body, bushing, etc. Inter-phase barriers should be removed and cleaned along with all other insulating surfaces.
- Inspect bolted electrical connections and jumpers for high resistance. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with table 5.

Table 5: Stainless Steel Fasteners Torque

Bolt Size		**Torque (Pound-Feet)**
Metric (mm)	English (inches)	
M8	5/16	15
M10	3/8	20
M12	1/2	40
M16	5/8	55
M20	3/4	70

- Inspect interrupter bottle assemblies (if visible for Indoor CB). An inspection should be made for signs of corona, tracking, or thermal damage.
- Check bushing for damage, crack and tracking.
- Check contact terminals for any evidence of darkness, spot, deformation, etc.
- Check contact terminals for proper alignment, and broken or weak springs (for indoor CBs).
- Check mechanism for corrosion and fraction.

ISSN: 2394-7659
IMPACT FACTOR- 3.775

IJERMS

International Journal of Engineering Researches and Management Studies

- Lubricate and adjust mechanical devices.
- Check for loose nuts and bolts in mechanism.
- Check for mechanical and electrical interlocks. In particular, the positive interlock feature that prevents the insertion and withdrawal of the circuit breaker should be tested while it is in the closed position.
- Perform operation tests on circuit breaker.
- Check shutter mechanism (For indoor CBs)
- Check trip-free and anti-pump functions.
- Perform rack in and rack out mechanism and their limit switches.
- Check for loose or broken cabling strap.

Major Preventive Maintenance Tasks

- Monitor control circuit continuity and any discontinuity should be repaired.
- Monitor voltage in control circuit, compare it with minimum pickup voltage, and conform to manufacturer's published data.
- Perform insulation-resistance tests on all control wiring with respect to ground. Any damaged wire or devices should be replaced. Its values could be compared with table 6.

Table 6: Insulation Resistance Test

Nominal Rating of Equipments (Volts)	**Minimum Test DC Voltage (Volts)**	**Recommended Minimum Insulation Resistance (Mega ohms)**
110, 220	500	25
6000	2500	2500
11000	2500	5000
33000	5000	20000

- Perform a contact pole-resistance test. Micro ohm or mill volt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar circuit breakers by more than 50 percent of the lowest value.
- Monitor trip coil, close coil and motor currents and resistance should be conformed to manufacturer's published data.
- Perform minimum pickup voltage tests on trip and close coils. Minimum pickup for trip and close coils should be conformed to manufacturer's published data.
- Timing test and Monitor primary current start during change of state of operating mechanism. They should be comparable to previously obtained results or manufacturer's data. Closing time and tripping time for each pole shall be equal.
- Perform an AC over-potential test on each phase with the circuit breaker closed and the poles not under test grounded according to table 7.

Table 7: Overpotential Test Voltages

Nominal System (Line) Voltage (kV)	**Maximum Field Applied AC Test (kV)**
6	12
11	16.8
33	42

ISSN: 2394-7659
IMPACT FACTOR- 3.775

IJERMS

International Journal of Engineering Researches and Management Studies

- Perform a vacuum bottle integrity test across each vacuum bottle with the breaker in the open position in strict accordance with table 7.

3. FREQUENCY OF MAINTENANCE

The time frequencies of all activities will be determined based on the asset type. In addition, the condition of the equipment and equipment reliability requirement are considered for determining time intervals. Table 8 specifies the correction factors that should be considered for maintenance frequency based on the equipment condition and equipment reliability requirement. Each factor should be multiplied by the time interval that is equal to 12 months for Routine inspections & tests and Condition monitoring activities of Circuit Breakers and 24 months for Major preventive maintenance tasks of this asset.

Table 8: Correction Factor

		Equipment Condition		
		Poor	Average	Good
Equipment Reliability Requirement	Low	1	2	2.5
	Medium	0.5	1	1.5
	High	0.25	0.5	0.75

In table 8, Equipment Condition can be obtained based on the Health Index of the equipment [23]. For obtaining Equipment Reliability Requirement, following factors should be specified for the equipment.

- Loss of load (LOL): loss of load is the amount of load (MW) which is interrupted caused by the absence of the equipment from the system. Based on the LOL, equipments are categorized into 3 following groups:

Category 1: LOL < 0.5 MW
Category 2: 0.5 MW < LOL < 2 MW
Category 3: 2 MW < LOL

- Importance of the connected loads

Category 1: Normal loads, such as household loads, agricultural loads, public lighting, etc.
Category 2: Important loads, such as industrial loads, commercial loads, etc.
Category 3: Very important loads, such as hospital, governmental special services, etc.

- Personnel Safety

Category 1: failure of the equipment does not constitute threats to the personal life or injury.
Category 3: failure of the equipment constitutes threats to the personal life or injury.

- Equipment/repairing cost:

Category 1: Insignificant cost.
Category 3: Significant cost.
Based on these factors, equipment reliability requirement is specified according to table 9.

Table 9: Equipment reliability requirement

Equipment Reliability Requirement	**Category of all four factors for equipment**
Low	All factors are in category1
Medium	All other conditions
High	At least one of the factors is in category3

ISSN: 2394-7659
IMPACT FACTOR- 3.775

IJERMS

International Journal of Engineering Researches and Management Studies

4. CONCLUSION

Medium Voltage Circuit Breakers are the most important equipment in a distribution power network. Records of Majan Electricity Company SAOC (Oman) show that Medium Voltage grid outage related to CBs are much more critical than any other kind of failures. Therefore, in this paper, a procedure has been developed to retain circuit breakers working as long as they can and remove, repair or restore them whenever is necessary. This procedure includes inspections and activities that can monitor condition of CBs and then decides which preventive maintenance task should be selected to perform if this performance is necessary based on circuit breakers' condition. As a result, table 10 has been developed and filled based on Maintenance Standard Document for circuit breaker used in Oman Distribution Power System. Time intervals for each inspection and performance of this worksheet will be determined by frequency of maintenance of CBs according to the last part of this paper.

References

1. *R. N. Azari, M.A. Chitsazan and I. Niazazari, "Optimal recloser setting, considering reliability and power quality in distribution networks," American Journal of Electrical Power and Energy Systems, vol. 6, no. 1, pp. 1-6.*
2. *W. Edward Reid, "Power Quality Issues-S tandards and Guidelines", IEEE Trans. On Industry App., vol. 32, no. 3, pp. 625-632, 1996.*
3. *M. A. Chitsazan, A. M Trzynadlowski, "Harmonic mitigation in interphase power controllers using passive filter-based phase shifting transformer", Energy Conversion Congress and Exposition (ECCE), 2016 IEEE, pp. 1-5, Sep. 2016.*
4. *A. Padilha-Feltrin, D. A. Q. Rodezno, and J. R. S. Mantovani, "VoltVAR multiobjective optimization to peak-load relief and energy effi- ciency in distribution networks," IEEE Trans. Power Del., vol. 30, no. 2, pp. 618–626, Apr. 2015.*
5. *G. Tsagarakis, A. J. Collin, A. E. Kiprakis, and S. McLaughlin, "Voltage control of UK residential customers for power reduction," in Proc. IEEE Grenoble PowerTech (POWERTECH), Grenoble, France, 2013, pp. 1–6.*
6. *M. A. Chitsazan, M. Sami Fadali, Amanda K. Nelson, A. M Trzynadlowski, "Wind speed forecasting using an echo state network with nonlinear output functions", American Control Conference (ACC), 2017 IEEE, pp. 5306-5311, May. 2017.*
7. *M. A. Chitsazan, M. S. Fadali, A. M Trzynadlowski, "State estimation of IEEE 14 bus with unified interphase power controller (UIPC) using WLS method", Energy Conversion Congress and Exposition (ECCE), 2017 IEEE, pp. 2903-2908, Oct. 2017.*
8. *S. M. R. Tousi and S. Aznavi, "Performance optimization of a STATCOM based on cascaded multi-level converter topology using multi-objective Genetic Algorithm," in Electrical Engineering (ICEE), 2015 23rd Iranian Conference on, 2015, pp. 1688–1693.*
9. *Sarfi, V., V. Hemmati, and M. M. Arabshahi. "Simulation of PTC devices as fault current limiters in power systems by finite element method." In High Voltage Engineering and Application (ICHVE), 2014 International Conference on, pp.1-4. IEEE, 2014. Doi: 10.1109/ICHVE.2014.7035503*
10. *S. Wang et al., "Dynamic-feature extraction, attribution, and reconstruction (DEAR) method for power system model reduction," IEEE Trans. Power Syst., vol. 29, no. 5, pp. 2049–2059, Sep. 2014*
11. *J. Quintero, V. Vittal, G. T. Heydt, and H. Zhang, "The impact of increased penetration of converter control-based generators on power system modes of oscillation," IEEE Trans. Power Syst., vol. 29, no. 5, pp. 2248–2256, Sep. 2014.*
12. *J. H. Chow, A. Chakrabortty, M. Arcak, B. Bhargava, and A. Salazar, "Synchronized phasor data based energy function analysis of dominant power transfer paths in large power systems," IEEE Trans. Power Syst., vol. 22, no. 2, pp. 727–734, May 2007.*
13. *S. Aznavy, A. Deihimi, "Determining Switching Angles And Dc Voltages In Cascaded Multilevel Inverter For Optimizing Thd In Different Output Voltage Levels Using Genetic Algorithm", in 6th International Conference on Technical and Physical Problems of Power Engineering, pp. 449-453, September 2010.*
14. *Sarfi, V., Hemmati, V. "Simulation of partial discharge in closely coupled cavities embedded in solid dielectrics by finite element method" Int. Conf. High Voltage Engineering and Application (ICHVE) 2014, 2014, pp. 1–4. Doi: 10.1109/ICHVE.2014.7035406*

ISSN: 2394-7659
IMPACT FACTOR- 3.775

IJERMS
International Journal of Engineering Researches and Management Studies

15. *Sarfi, V., Mohajeryami, S. and Majzoobi, A., 2017. "Estimation of water content in a power transformer using moisture dynamic measurement of its oil" High Voltage, 2(1), pp.11-16. Doi: 10.1049/hve.2016.0075*
16. *A. Forooghi Nematollahi, A. Dadkhah, O. Asgari Gashteroodkhani, and B. Vahidi, "Optimal sizing and siting of DGs for loss reduction using an iterative-analytical method," Journal of Renewable and Sustainable Energy, vol. 8, no. 5, p. 055301, 2016.*
17. *O. A. Gashteroodkhani, B. Vahidi, and A. Zaboli, "Time-time matrix z-score vector-based fault analysis method for series-compensated transmission lines," Turkish Journal of Electrical Engineering & Computer Sciences, vol. 25, pp. 2647-2659, 2017.*
18. *Niazazari, and H. Livani,"A PMU-data-driven disruptive event classification in distribution systems," Electric Power Systems Research, vol. 157, pp. 251-260, 2018.*
19. *"PAS 55 Asset Management", published by BSI, 2008*
20. *ANSI/NETA MTS, American National Standard "Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems", 2007.*
21. *NFPA 70B "recommended practice for electrical equipment maintenance", 2006.*
22. *Oman Operational Experiences*
23. *"Transmission Baseline Study", Prepared for British Columbia Transmission Corporation April, 2005*

Table 10: Maintenance Standard Document for circuit breaker used in Oman Distribution Power System

Maintenance Type	Short Description Tasks	Business Rules for Acceptance of Maintenance Tests and Condition Monitoring Activities (Note 1)	Specialist Tools	Result to be Recorded
Routine inspection & tests	Inspect physical and mechanical condition	Not Applicable	Not Applicable	Nil
	Inspect anchorage and alignment (for outdoor CBs)	Not Applicable	Not Applicable	Nil
	Inspect grounding connection	Not Applicable	Earth Tester	Nil
	Monitor number of operations	For M1 mechanical class 2.000 and for M2 mechanical class 10.000	Not Applicable	Number of operations
	Check for any abnormal sound	Not Applicable	Not Applicable	Nil
	Check for any Relay indication	Not Applicable	Not Applicable	Nil
	Check SF6 pressure gauge (for SF6 type)	It should be in normal condition (green LED)	Not Applicable	Pressure value
	Check for mechanical indicators for spring charge	Not Applicable	Not Applicable	Nil
	Check for proper operation of all indicators	Not Applicable	Not Applicable	Nil
	Check for dust & dirt in body, bushing, etc. (for outdoor CBs)	Not Applicable	Not Applicable	Nil

ISSN: 2394-7659
IMPACT FACTOR- 3.775

IJERMS

International Journal of Engineering Researches and Management Studies

Maintenance Type	Short Description Tasks	Business Rules for Acceptance of Maintenance Tests and Condition Monitoring Activities (Note 1)	Specialist Tools	Result to be Recorded
	Check bushing for damage, crack and tracking (for outdoor CBs)	Not Applicable	Not Applicable	Nil
	Visual check mechanism for corrosion, linkage fraction (for outdoor CBs)	Not Applicable	Not Applicable	Nil
Condition Monitoring Activities	Perform a thermographic survey (for outdoor CBs)	Refer to table 1	Infrared Camera	Temperature rise
	Corona discharge test (for outdoor CBs)	Refer to table 2	Corona Camera	Corona counts
	Perform Partial Discharge test	Refer to table 3	HVPD surveyor	1- dB level 2- partial discharge pulse 3-milliV
	Analyse SF6 gas/SF6 Quality test (for SF6 CB)	Refer to table 4	SF6 analyzer	ppm
	Check dew point temperature (for SF6 CB)	Refer to table 4 (It should be at least -30˚C)	Hygrometer	dew point
Minor Preventive Maintenance Tasks	Check for dust & dirt in body, bushing, etc. Then clean the unit	Not Applicable	Not Applicable	Nil
	Inspect bolted electrical connections and jumpers for high resistance	Refer to table 5	Torque wrench	Nil
	Inspect interrupter bottle assemblies (if visible for Indoor CB)	Not Applicable	Not Applicable	Nil
	Check bushing for damage, crack and tracking (for indoor CBs)	Not Applicable	Not Applicable	Nil
	Check contact terminals for any evidence of darkness, spot, deformation, etc.	Not Applicable	Not Applicable	Nil
	Check contact terminals for proper alignment, and broken or weak springs (for indoor CBs)	Not Applicable	Not Applicable	Nil
	Check mechanism for corrosion, linkage fraction	Not Applicable	Not Applicable	Nil
	Lubricate and adjust mechanical devices	Not Applicable	Not Applicable	Nil
	Check for any loose nuts and bolt in mechanism	Not Applicable	Not Applicable	Nil
Minor Preventive Maintenance Tasks	Check for mechanical and electrical interlocks (earth interlock, rack in and rack out, service or test position for indoor CB)	Not Applicable	Not Applicable	Nil
	Perform operation tests on circuit breaker (Open and close commands)	Not Applicable	Not Applicable	Nil

ISSN: 2394-7659
IMPACT FACTOR- 3.775

IJERMS

International Journal of Engineering Researches and Management Studies

Maintenance Type	Short Description Tasks	Business Rules for Acceptance of Maintenance Tests and Condition Monitoring Activities (Note 1)	Specialist Tools	Result to be Recorded
	Check shutter mechanism (for indoor CBs)	Not Applicable	Not Applicable	Nil
	Check anti-pump functions	Not Applicable	Not Applicable	Nil
	Perform rack in and rack out mechanism and their limit switches (for indoor CBs)	Not Applicable	Not Applicable	Nil
	Check whether any cabling strap is loose or broken and connection tightness	Not Applicable	Not Applicable	Nil
Major Preventive Maintenance Tasks	Monitor control circuit continuity	Not Applicable	Micro Ohmmeter (buzzer check)	Nil
	Monitor voltage in control circuit	70 up to 110% rated voltage for trip circuit and 85 up to 110% for close circuit (110V/OR/125V)	Voltmeter	voltage
	Perform insulation-resistance tests on all control wiring	Refer to table 6	Insulation Resistance Tester (with 500v capacity)	resistance in each circuit (mega ohm)
	Perform contact pole-resistance test	Investigate values that deviate from adjacent poles or similar air break switch by more than 50 percent of the lowest value.	Contact tester	resistance in each phase (micro ohm)
	Monitor trip coil, close coil currents	Manufacturer's published data	Ohmmeter, ammeter	current and resistance in each circuit
	Perform minimum pickup voltage tests on trip and close coils	50% of rated voltage (110V or 125V)	DC variable voltage power supply (110V or 125V)	voltage for each coil
	Perform Timing test	In according with nameplate	Circuit breaker analyzer/Test equipment	closing/ opening time
	Perform an AC over-potential test	withstanding applied voltage (refer to table 7)	AC High voltage unit tester (refer to table 7)	Nil
	Perform interrupter bottle integrity test	withstanding applied voltage (refer to table 7)	Vacuum tester (refer to table 7)	Nil