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Maintenance Tasks for 20 Kv Medium-Voltage Switchgear Based on Technical Judgment Experience and Manufacturer

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Abstract

A 20 kV medium-voltage switchgear is an important equipment in the electricity system that distributes electricity generated by the 20 kV electric power generator to electricity users. Calor Emag, Merlin Gerin, Alsthom, Fuji, AEG, Schneider, Meidensha, Goldstar, Modalek, Areva, and Siemens are among the companies that make products. This study describes a method for maintaining 20 kV medium-voltage switchgear, an essential equipment in the electricity system. In less technical terms, the failure rate is high at the beginning of an asset's life, which follows the curve of the bathtub. However, the failure rate quickly declines as we identify and discard defective components and eliminate early sources of potential failures, such as installation errors. This study introduces a novel approach by examining the relationship between maintenance tasks, which are based on technical judgment and experiences, and the maintenance tasks provided by the manufacturer for 20 kV medium voltage switchgear. The goal is to develop and deliver the most effective maintenance method for 20 kV medium voltage switchgear, to prevent malfunctions or even catastrophic explosions, while maintaining the lowest possible maintenance costs. Total use of labor over 2 years (24 months) for daily, monthly, 3 monthly, and 2 yearly is 3554-man hours (MH). It provides a comprehensive approach to preventing malfunctions and explosions, resulting in optimal maintenance costs and performance.

Introduction

The research background indicates that the study on maintenance tasks for 20 kV medium-voltage switchgear is based on technical judgment and experience. The manufacturer does not produce tools or application programs instead, it creates and offers a maintenance method for 20 kV (kilovolt) medium-voltage switchgear. Medium Voltage Switchgear 20 kV, often referred to as 20 kV Power Substation, 20 kV Switchboard, 20 kV Cubicle, or 20 kV PHB "Panel Hubung Bagi" (Dividend Panel), is an important piece of equipment in the electricity system that functions to distribute electricity results from the 20 kV electric power generator to electricity users. Calor Emag, Merlin Gerin, Alsthom, Fuji, AEG, Schneider, Meidensha, Goldstar, Modalek, Areva, and Siemen manufacture this equipment (Hassan et al., 2023). Data analysis needs symptoms referring to the fault before the failure (Hassan et al., 2023; Mariani et al., 2010; Zhou et al., 2023). Asset management processes and techniques can improve cost efficiency, balance the cost and risk, and prolong the service life of the aging switchgear (Nan Zhou et al,04 May 2023). In recent times, an increase in downtime has been

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observed due to various faults and failures noticeable on the network (Aıroboman, 2022; Gill et al., 2011; Faulstich et al., 2011; Mucchielli et al., 2021).

Therefore, the creation and offering of this method of proper maintenance of the 20 kV medium voltage switchgear is good and correct to avoid malfunctions or even disastrous explosions, with the most optimal maintenance costs (Hoffmann et al., 2020; Bindi et al., 2023). Switchgear is a key equipment in the power grid and its health status has a critical impact on the overall reliability of the grid (Zhou & Xu, 2022; Alsumaidaee et al., 2022; Chidambaram et al., 2022; Chennakeshava et al., 2022).

The following outline summarizes the relevant research from previous studies. According to the systematic literature review (SLR) theory, a search through the Google Scholar search engine since 2020 has yielded 45 publications; or an average of 11 publications. After conducting a quality assessment (QA) using the SLR theory, we selected only eight (eight) pieces of literature, despite gaps and shortcomings. ortcomings. In other words, to the best of the author's knowledge, there is currently a method for maintaining 20 kV medium voltage switchgear that is both correct and effective, aimed at preventing malfunctions and potentially catastrophic explosions while ensuring optimal maintenance costs (Krause et al., 2013). This is a novelty. This research is unique because it applies the factory's recommendations to maintaining medium-voltage switchgear (20 kV). The text on this backdrop employs a variation of the pyramid's structure, initially providing a basic overview, and a more in-depth explanation in subsequent paragraphs. is as follows: Because of its installation or construction, the 20 kV medium voltage switchgear holds significant importance in the electrical system, necessitating proper maintenance to prevent malfunctions or potentially catastrophic explosions. The 20 kV Medium Voltage Switchgear distributes the electricity output from a 20 kV electric source. When installed or constructed in the electrical system, the 20 kV medium voltage switchgear requires proper maintenance to prevent malfunctions or potentially catastrophic explosions. Function or even a disastrous following the advice or recommendations in the manufacturer's maintenance manual typically results in high maintenance costs for the initial maintenance of medium-voltage switchgear impacting the high maintenance costs (Subramaniam et al., 2021; Winarto et al., 2024; Neighbours & Karandikar, 2022). Figure 1 depicts the external appearance of the 20 kV medium voltage switchgear.

Figure 1. Physical example of external view 1: 20 kV medium voltage switchgear (Source: PLN)

The 20 kV Medium Voltage Switchgear is crucial in distributing electricity from the 20 kV electric power generator to the transformer, electric motors, and other devices. In a catastrophic event such as an explosion in the switchgear, all other equipment, including generators, cables, power transformers, motors, and others, will cease functioning. A single-line diagram, as shown in Figure 2, can broadly describe the function of the medium voltage switchgear. The picture shows the actual condition of a geothermal plant in Indonesia. The power plant is powered by a 20 kV-60 MW power generator and an outdoor switchyard is

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powered by the TR-1411. The 80 MVA power transformer converts the 20 kV voltage to 150 kV. Through several disconnecting switches (DS) and circuit breakers (CB), the 150 kV electricity is sold to PLN, which is connected to the 150 kV transmission line. Except for the 150 kV of electricity sold to PLN, there is 20 kV of electricity for own use (PS), often called houseload or self-consumption. 20 kV electricity comes into the 20 kV Medium Voltage Switchgear (indoor) through different CBs that are used for the Motors Hot Well Pump and Motors Liquid Ring Vacuum, for the TR-1412 Power Transformer 6 MVA, which is then lowered to 6.3 kV for the PLTP's operational needs, for the Steam Gathering System, and other things. The Single Line Diagram highlights the critical role of the 20 kV (indoor) Medium Voltage Switchgear. Damage without explosion, or damage accompanied by an explosion or malfunction, would result in the complete cessation of all electricity production, including 150 kV and 6.3 kV.

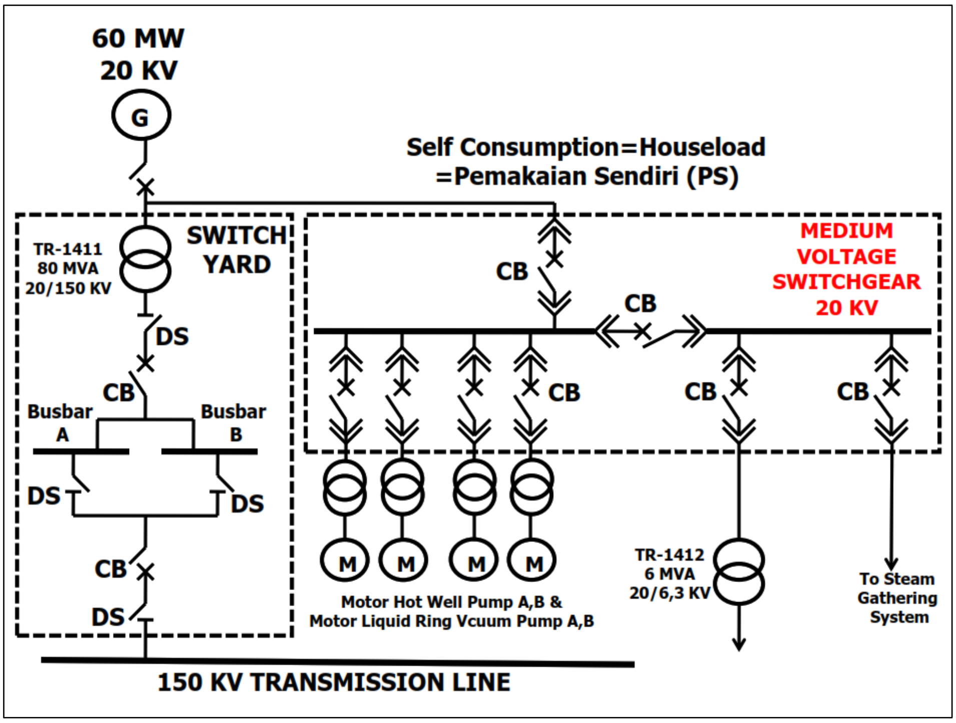

Figure 2. Single line diagram medium voltage switchgear 20 kV (Source: A Geothermal Power Plant)

Methods

Reliability engineering widely uses the bathtub curve in Figure 3, although the general concept also applies to people. The curve describes a particular hazard function consisting of three parts: i) The first part is a decreased failure rate, known as early failure or infant mortality. This is similar to our childhood; ii) the second part is the constant failure rate, known as random failure. This is similar to our adult lives, and iii) the third part is the increased failure rate, known as failure wear. This is comparable to the onset of old age. We generated the bathtub curve by mapping the initial infant failure rate of mortality upon its introduction, a low random failure rate that remained constant over its useful life, and finally the failure exit wear rate as the asset approached its design lifetime. The proper maintenance strategy is based on component arrangement and assets. The best way to reach these goals. This strategy uses RCM or reliability-centered maintenance (Mirhosseini et al., 2022). Time from the last failure is more informative as many of the failures are recurrent. According to the design, installation process, and installation environment, operation condition analysis isolating switch does not reach the designated position defects existing in the development and fault formation (Yu et al., 2020; Katipamula & Brambley, 2005). The bathtub curve is

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generated by mapping the rate of early infant mortality failures when first introduced, low random failures with a constant failure rate during its useful life, and the rate of wear-out failures as the asset approaches its design lifetime (Gulati, 2013).

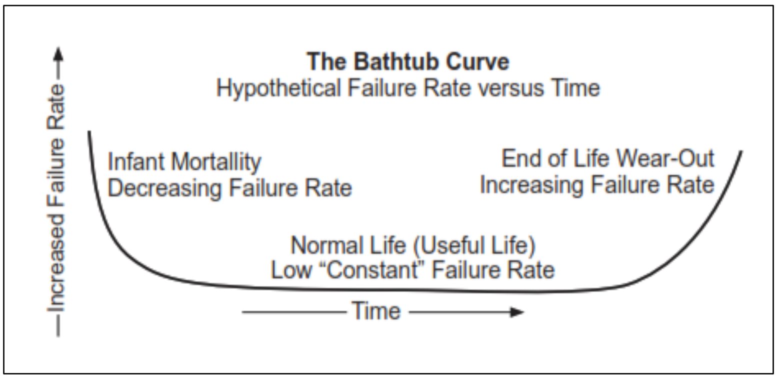

Figure 3. Bathtub Curve (Source: Book Maintenance and Reliability Best Practices Second Edition 2013 Ramesh Gulati, Page 161)

To improve the efficiency of switchgear maintenance, a double-action switchgear is presented to realize the purpose of on-line maintenance (Wang et al., 2021). Figure 4 shows a series of these failure patterns based on original study data. The failure patterns are categorized into two groups age-related and random. Fewer than 20% of failures follow an agedegradation pattern; the remaining follow a random pattern with constant failure rate (Gulati, 2013). It is divided into two categories, namely the Age-Related category, and the Non-Age Related or Random category. The Age Related is less than 20%, which is broken down to 4% like Bathtube curve, 2% Age Related, and 5% Fatique Related. Meanwhile, more than 80% are random which is divided into 7% Rapid Increase to random, 14% Random Failure, and 68% Infant Mortality (fail early).

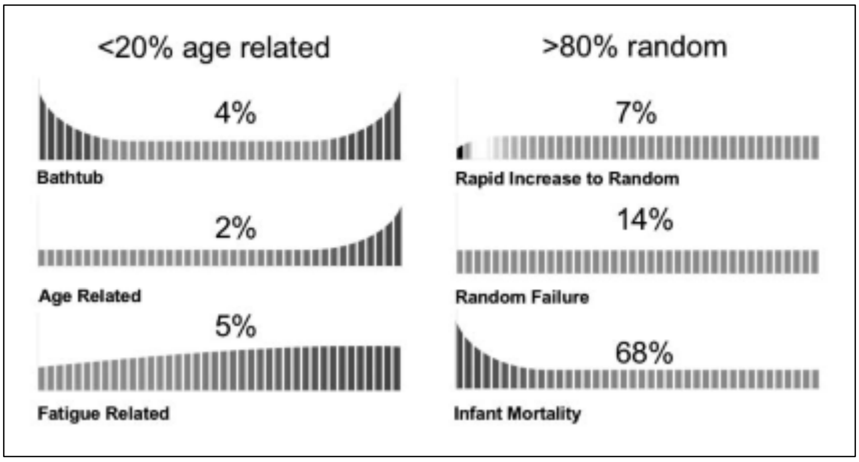

Figure 4. Failure Patterns (Source: Book Maintenance and Reliability Best Practices Second Edition 2013 Ramesh Gulati, Page 162)

Results and Discussion

Frame of mind

The frame of mind and Systematic in this research method are illustrated in Figure 5.

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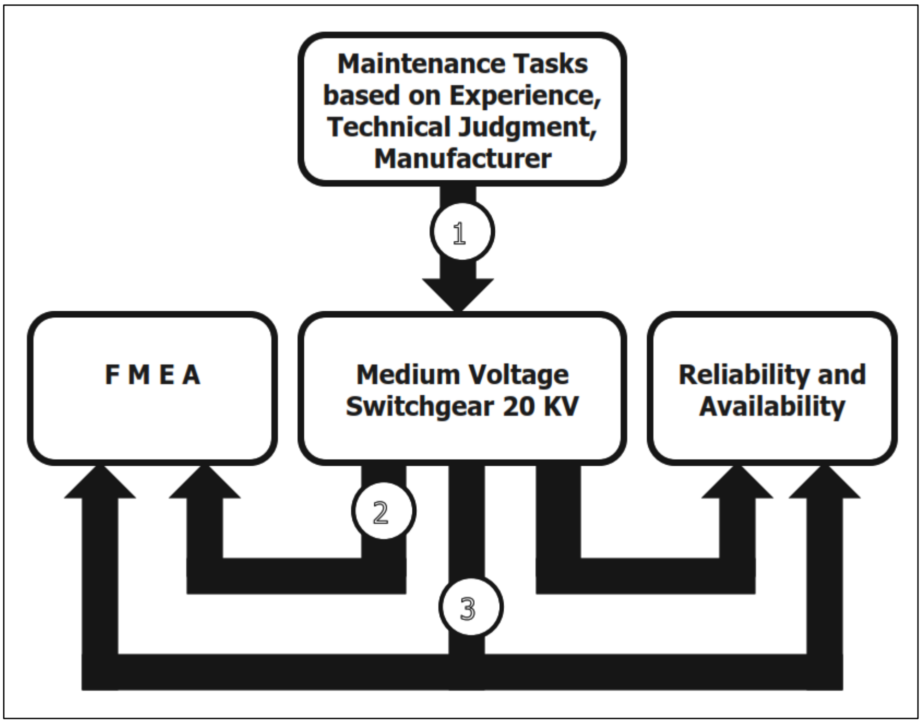

Figure 5. Frame of mind and Research Cystatics

Medium voltage switchgear is used to distribute electricity from the power transformer to the feeder or consumer (Kamaludin et al., 2020). Such an approach overlooks the critical role of process design in mitigating failure**,** while simultaneously considering the effects of such failure on process economic performance (Al-Douri et al., 2020). One way of handling short-time short-circuits without causing equipment failure is the management of the reclose function (Holcsik et al., 2020).

In Figure 5, number 1 is Maintenance Tasks based on Experience, Technical judgment, and Manufacturer. The Maintenance Tasks consist of Maintenance in Service Inspection for Dailty Period, Monthly Period, Three Monthly Period, Two Yarly Period, Conditionals, and Maintenance in Service Measurenenbt which consist of Monthly Period, Conditionals.

Maintenace tasks based on Technical Judgement Experience and Manufacturer

Maintenance in Service Inspection

When the cubicle is operating or under voltage, we conduct an in-service inspection. The purpose of in-service inspection is to detect early abnormalities that may occur in the cube without conducting blackouts. During in-service inspection, we carry out several checks using the following methods: 1. Checking with the five senses (visual, olfactory, and hearing); 2. Checking with simple measuring instruments (thermogun, thermometer, etc.). Cubicle maintenance is inspected daily, monthly, three times per month, and every two years. In addition, there are several maintenance procedures that are implemented depending on the condition of the bicycle equipment.

Daily Period

Daily Period Maintenance in Service Inspection is Maintenance Tasks which are conducted every day. The obectives of the Daily Period are to ensure that Mechanical Spring and SF6 Gas pressure in proper condition. The Maintenance Tasks in Daily Period is listed below.

Inspection of mechanical spring indicators on the CB of the spring system.

SF 6 low Gas pressure monitor (CB type with gas media equipped with a pressure indicator).

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Monthly Period

Monthly Period Maintenance in Service Inspection is Maintenance Tasks which are conducted every month. The obectives of the Monthly Period are to ensure that no foreign bodies, no noises, no odors. Also make sure that instruments (meters), Protective Relays, control cabinets, heaters, lighting lamps, Cubicle, wiring control room are in good condition. The Maintenance Tasks in Monthly Period is listed below: 1) Visual inspection of foreign bodies, noises and odors; 2) Visual inspection of measuring instruments (meters) and Protective Relays; 3) Inspection of control cabinets, heaters, lighting lamps; 4) Cubicle cleanliness check and wiring control room.

Three Monthly Period

Three Monthly Period Maintenance in Service Inspection is Maintenance Tasks which are conducted every three months. The obectives of the Three-Monthly Period are to insure that CB close or open position indicator and work counter are in proper condition. The Maintenance Tasks in Three Monthly Period is listed below; 1) Check the CB Close / Open position indicato; 2) CB work counter check.

Two Years Period

Two Years Period Maintenance in Service Inspection is Maintenance Tasks which are conducted everytwo years. The obectives of the Two years Period are to insure that the mechanical structure of the cubicle is in good condition. The Maintenance Tasks in Three Monthly Period is listed below.

Examination of the mechanical structure of the Cubicle.

Conditionals

Conditionals Maintenance in Service Inspection is Maintenance Tasks which are conducted conditionaly. The obectives of the Conditionals are to insure that the no sounds and no odors when doing other work. The Maintenance Tasks in Three Monthly Period is listed below.

Visual inspection of sounds and odors can be done simultaneously when doing other work, for example when recording Cubicle business data.

Maintenance in Service Measurement

We conduct a measurement at a specific time when the equipment is under tension. The purpose of the measurements and/or monitoring is to determine or track the condition of the equipment using advanced measuring instruments, such as thermal image thermovision. We conduct in-service cube maintenance measurements at monthly and conditional intervals.

Monthly Period

Monthly Period Maintenance in Service Measurement is Maintenance Tasks which are conducted every month. The obectives of the Monthly Period are to insure that AC and DC Cubicle voltage supply, temperature of terminals and connections on rails, CT, PT, cables and other equipment supplied with current in Cubicles are in proper numbers. The Maintenance Tasks in Monthly Period is listed below; 1) Measurement of AC and DC Cubicle voltage supply; 2) Cubicle temperature measurement; 3) Temperature measurement of terminals and connections on rails, CT, PT, cables and other equipment supplied with current in Cubicles. The implementation of thermovision is carried out through reconnaissance holes in the cubicle.

Conditionals

By observing the cube's loading conditions, we can also measure the temperature of the cube, its terminals and connections on rails, CT, PT, cables, and other equipment supplied with

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current. The higher the load it transmits, the longer the temperature measurement period with thermovision needs to be.

Duration of Application of Manufacturer's recommendation

Work duration in the application of experiences, technical judgement, and manufacturer's recommendation is estimated to exclude Conditionals. This is important to forcast financial budget to be prepared in certain period for example for every two years. Every maintenance task is estimated to average 2 MH (Man Hour).

Table 1 below expresses the Execution Daily Duration of the Maintenance tasks based on Technical Judgement Experience and Manufacturer for 20 KV medium-voltage Switchgear.

Table 1. Execution Daily Duration of the Maintenance Tasks based on Technical Judgement Experience and Manufacturer for 20 KV medium-oltage Switchgear

No	Maintenance tasks based on Experiences Technical judgement and Manufacturer for Medium Voltage Switchgear 20 kV	Average of execution duration [MH (Man Hours)]
1.	DAILY Level 1 Inspection (In Service Inspection) Electrical current Carrying: SF6 low Gas pressure monitor (CB type with gas media equipped with a pressure indicator)	2 MH
2.	Drive Mechanics: Checking the mechanical spring indicator on the CB spring system	2 MH
	Total Man Hours (MH) DAILY	4 MH

The Table 2 below express the Execution Monthly Duration of the Maintenance tasks based on Technical Judgement Experience and Manufacturer for 20 KV medium-voltage Switchgear.

Table 2. Execution Monthly Duration of the Maintenance tasks Based on Technical Judgement Experiences and Manufacturer for 20 KV medium-voltage Switchgear

1.	MONTHLY The Daily is definitely included in the Monthly Electrical current Carrying: SF6 low Gas pressure monitor (CB type with gas media equipped with pressure indicator)	2 MH
2.	Drive Mechanic: Spring indicator check on CB spring system	2 MH
3.	Electrical current Carrying: Visual inspection of foreign objects, sounds, and odors Control system: Visual inspection of measuring instruments (meters) and relay Cubicle cabinets : Visual examination of foreign bodies, sounds and smells, Inspection of control cabinets, heaters, lighting lamps.	2 MH
4.	Control system: Visual inspection of measuring instruments (meters) and relay	2 MH
5.	Cubbicle cabinets : 1.Visual examination of foreign bodies, sounds and smells*)	2 MH
6.	2.Inspection of control cabinets, heaters, lighting lamps.	2 MH
7.	3. Cubicle hygiene check	2 MH

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8.	Level 2 Inspection (Inservice Measurements) Electrical current carrying: Measurement of the temperature of terminals and joints on rails, CT, PT, cables and other equipment supplied with current in cubicles.	2 MH
9.	Control system: Measurement of AC and DC Cubicle voltage supply	2 MH
10.	Cubicle cabinet: Cubicle temperature measurement	2 MH
	Total Man Hours (MH) MONTHLY	20 MH

Table 3 below expresses the Execution of Three-Monthly Duration of Maintenance tasks based on Technical Judgement Experience and Manufacturer for 20 KV medium-voltage Switchgear.

Table 3. Execution Three Monthly Duration of the Maintenance tasks based on Technical Judgement Experiences and Manufacturer for 20 KV medium-voltage Switchgear

1.	3 MONTHLY The Monthly is definitely included in the 3 (Three) Monthly Electrical current Carrying: SF6 low Gas pressure monitor (CB type with gas media equipped with pressure indicator)	2 MH
2.	Drive Mechanic: Spring indicator check on CB spring system	2 MH
3.	The Monthly ones are definitely included in the 3 Monthly Electrical current Carrying: Visual inspection of foreign objects, sounds, and odors	2 MH
4.	Control system: Visual inspection of measuring instruments (meters) and relay	2 MH
5.	Cubicle cabinets: Visual examination of foreign bodies, sounds and smells*)	2 MH
6.	Inspection of control cabinets, heaters, lighting lamps Cubicle hygiene check	2 MH
7.	Cubicle hygiene check	2 MH
8.	Level 2 Inspection (Inservice Measurements) Electrical current carrying: Measurement of the temperature of terminals and joints on rails, CT, PT, cables and other equipment supplied with current in cubicles.	2 MH
9.	Control system: Measurement of AC and DC Cubicle voltage supply	2 MH
10.	Cubicle cabinet: Cubicle temperature measurement	2 MH
11.	Drive mechanics: CB Close / Open position indicator	2 MH
12.	Check CB work counter check	2 MH
	Total Man Hours (MH) 3 MONTHLY	24 MH

Table 4 below expresses the Execution Two Yearly Duration of the Maintenance tasks based on Technical Judgement Experience and Manufacturer for 20 KV medium-voltage Switchgear.

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Table 4. Execution Two Yearly Duration of the Maintenance tasks Based on Technical Judgement Experiences and Manufacturer for 20 KV medium-voltage Switchgear

1.	2 (TWO) YEARLY Inspection Level 3 (Shutdown Measurements) The Daily is definitely included in the Monthly Electrical current Carrying: Monitor Gas SF6 low pressure (CB type with gas medium provided by pressure indicator)	2 MH
2.	Mechanical Mover: Inspection mechanical spring indicator on CB spring system	2 MH
3.	The Monthly definetely included in 3 Monthly Electrical current Carrying: Visual inspection of foreign objects, noises and odors	2 MH
4.	Control system: Visual Inspection of meter and Relay	2 MH
5.	Switchgear Cabinet: Visual Inspection of foreign objects, noises and odors	2 MH
6.	Inspection of control cabinets, heaters,lighting	2 MH
7.	Switchgear hygiene check	2 MH
8.	Inspection Level 2 (Inservice Measurement) Electrical current carrying: Temperature measurement of terminals and connections on rails, CT, PT, cables and other equipment that is current-flowed in Switchgear.	2 MH
9.	Control system: AC and DC Switchgear voltage supply measurement	2 MH
10.	Switchgear Cabinet: Switchgear temperature measurement	2 MH
11.	The 3 Monthly definetely included in 2 Yearly Mechanial Mover: CB Close / Open position indicator check	2 MH
12.	CB work counter inspection	2 MH
13.	Switchgear Cabinet: Mechanical structure inspection of Switchgear	2 MH
14.	Electrical current carrying: Insulation resistance measurement	2 MH
15.	Electrical Switching: 1. CB physical condition examination	2 MH
16.	2. CB main terminal bolt nut tightness check	2 MH
17.	3. CB insulation resistance measurement	2 MH
18.	4. CB contact resistance measurement	2 MH
19.	5. CB opening / closing time speed measurement	2 Mh
20.	Electrical Insulation: 1.Measurement of insulation medium (For CB vacuum or oil)	2 MH
21.	2.SF6 CB gas pressure and leakage measurement (if manometer installed)	2 MH
22.	3.Rail insulation resistance testing	2 MH
23.	4.For CB type oil: 4.1. Oil level check	2 MH
24.	4.2. Oil condition / color check	2 MH
25.	4.3. Oil leak / seepage inspection	2 MH

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26.	4.4. Oil dielectric testing	2 MH
27.	5. For CB type SF6 Gas: 5.1. SF6 Gas pressure check	2 MH
28.	5.2. SF6 Gas leak check	2 MH
29.	6. For CB vacuum type: DC high voltage testing (vacuum tube) Mechanical Mover: 6.1. Bolt nut tightness check	2 MH
30.	6.2. Spring system testing	2 MH
31.	6.3. Testing of spring system	2 Mh
32.	6.4. Testing of the start & stop function of the drive motor	2 MH
33.	6.5. Measurement of drive motor load current	2 MH
34.	6.6. Measurement of insulation resistance of drive motor windings	2 MH
35.	Control system: 6.7. Measurement of minimum working stress of CB coil	2 MH
36.	6.8. CT measurement / testing	2 MH
37.	6.9. PT measurement / testing	2 MH
38.	6.10. LA measurement / testing (if LA is installed)	2 MH
39.	6.11. Pengujian OCR / GFR / DGR relays	2 MH
40.	6.12. Testing of voltage relays / UFR (if installed)	2 MH
41.	6.13. AC and DC voltage measurement	2 MH
42.	Grounding: Checking the grounding wire and the tightness of its bolt nuts	2 MH
43.	Measurement of the grounding resistance of the Switchgear	2 MH
44.	Switchgear Cabinet: Bolt nut tightness check	2 MH
45.	Switchgear cabinet lighting inspection	2 MH
46.	Heater inspection	2 MH
47.	Switchgear hygiene check	2 MH
48.	Checking the condition of the Switchgear cabinet foundation	2 MH
49.	Inspection Level 3 (Shutdown Measurements) Electrical switching: Cleaning the contactor	2 MH
50.	Electrical insulation: Cleaning the surface of the insulator	2 MH
51.	Cleaning the surface of the CB chamber	2 MH
52.	Mechanical Mover: Cleaning the limit switch	2 MH
53.	Cleaning and lubricating gears	2 MH
54.	Membersihkan dan melumani pegas	2 MH
55.	Cleaning the box	2 Mh
56.	Switchgear Cabinet: Cleaning the box	2 MH
57.	Inspection Level 4 (Shutdown Function Check) Control system: Close and open function testing (local/remote and SCADA)	2 MH
58.	Emergency trip testing	2 MH
59.	Alarm function testing	2 Mh
60.	Mechanical and electrical interlock function testing	2 MH
61.	Testing of the trip function of the protection relay	2 MH
	Total Man Hours (MH) 2 YEARLY	**122 MH**

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DAILY:

Assumed 1 month = 30 days.

In 1 (one) month = 29 times DAILY work due to 1 (one) time include in MONTHLY work as stated in Table 5 below.

Table 5 below expresses the Daily work in the Maintenance tasks based on Technical Judgement Experience and Manufacturer for 20 KV medium-voltage Switchgear.

Table 5. Daily work

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
DAILY																													**M**

M = Monthly

Therefore in 2 (two) years need = 29 days x 24 months = 696 times DAILY @ 4 MH = **2784 MH**

MONTHLY:

In 2 years (24 months) = 23 times MONTHLY work due to 1 time include in Two Yearly work.

Table 6 below expresses the Monthly work in the Maintenance tasks based on Technical Judgement Experience and Manufacturer for 20 KV medium-voltage Switchgear.

Table 6. Monthly work

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
MONTHLY																							**2Y**

2Y = Two Yearly work.

Therefore in 2 (two) years need = 23 @ 20 MH = **460 MH**

THREE MONTHLY:

In 2 years (24 months) = 8-time Three Monthly work.

Table 7 below expresses the Three-Monthly works in the Maintenance tasks based on Technical Judgement Experience and Manufacturer for 20 KV medium-voltage Switchgear.

Table 7. Three Monthly work

1	2	3	4	5	6	7	8
THREE MONTHLY							

Therefore in 2 (two) years need = 8 @ 24 MH = **192 MH**

TWO YEARLY:

In 2 years (24 months) =1 time @ 122 MH = **122 MH**

Total Man Hours for 2 years (24 months) = 2784 MH + 460 MH + 192 M + 122 MH = 3558 MH.

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Conclusion

This study examined the upkeep of a 20 kV medium-voltage switchgear, an essential component of the electrical system. It emphasized the significant rate of failures that occur at the initial stages of the asset's lifespan, which follows a bathtub-shaped curve. This study employed an innovative methodology to examine the correlation between maintenance tasks derived from practical experience, maintenance tasks derived from technical expertise, and maintenance tasks recommended by manufacturers for 20 kV medium voltage switchgear. This approach offers an optimal maintenance strategy for 20 kV medium voltage switchgear, with the goal of preventing malfunctions or potentially disastrous explosions, while minimizing maintenance expenses.

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