Preventive Maintenance of Diesel Power Generators in Indonesia's Manufacturing Industries

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Abstract

Diesel power generators have critical the task of providing electricity for industrial purposes, either as backup power or main power. One function that plays a very important role in ensuring the smooth implementation of production activities is the maintenance of machines and other production facilities. One of the maintenance methods that is often applied in various manufacturing industries is preventive maintenance. However, there is a limited study that evaluates the depth of common preventive maintenance implementation in Indonesia. This research is designed to fill the gap by evaluating and mapping the depth of preventive maintenance between the different sizes of diesel power generators. The research provides a summary of the depth of preventive maintenance implementation on conduct maintenance planning and scheduling, component replacement, condition monitoring, and maintenance evaluation. Moreover, there is no significant difference between the size of the diesel power generator and the percentage conducted maintenance aspect. So that it can be ascertained that all respondents from various types of manufacturing industries carry out preventive maintenance.

Keywords
Preventive Maintenance, Diesel Power Generator, Maintenance Strategy.

1. Introduction
The machine is one of the production tools that have a very important role in productivity within an organization or company, where productivity is highly dependent on the machine (Dimitrov and Saxer, 2012). Diesel power generators have the task of providing electricity for industrial purposes, either as backup power or as main power (Michaelson and Jiang, 2021). All manufacturing industries try to keep electric generators running normally when needed. The output of the effort is minimizing the number of electrical disturbances in the backup diesel generator during power blackouts and trying to avoid severe engine damage (Phillips et al, 2020). The smoothness of the implementation of the production process is a key thing that must be achieved (Albukhitan, 2020). One function that plays a very important role in ensuring the smooth implementation of production activities is the maintenance of machines and other production facilities (Nardo et al, 2021). Maintenance is an activity to care for or maintain and make necessary repairs so that there is a satisfactory state of production operation in accordance with what has been planned (Siregar and Nasution, 2020). This is necessary because maintenance has a very important role in determining the smooth running of production activities. In practice, one of the electricity generators used by several manufacturing industries in Indonesia is a diesel power generator (Nindhia et al, 2021).

Through machine maintenance, it is hoped that the continuity of operations and productivity of the supply of power in a factory can be maintained. Maintenance is all activities to maintain or maintain machines, facilities, and production equipment and make repairs or adjustments, as well as replacements needed so that a satisfactory production operational condition can be expected in accordance with what is planned (Napitupulu and Manik, 2020). The purpose of maintenance is carried out so that production capabilities can meet the needs of the company or organization, maintaining quality at the right level to meet what is needed by the production itself (Sahal et al, 2020). Thus, the activities carried out by the company are not disturbed. Then maintenance also aims to maintain the capital that has been invested for a specified time (Bisbey et al, 2020).

One of the maintenance methods that is often applied in various manufacturing industries is preventive maintenance (Huang et al, 2020). Preventive maintenance is maintenance and maintenance activities on production machines to prevent unexpected damage (Zhang et al, 2020). Preventive maintenance characteristics consist of maintenance planning & scheduling (Wakiru et al, 2021), component replacement (Nurcahyo et al, 2017), alignment & adjustment (Botto et al, 2020), condition monitoring, and maintenance evaluation (Nurcahyo and Azka, 2019). Production equipment will experience a decrease in function if it is used continuously. Therefore, preventive maintenance on production machines needs to be done in order to maintain smooth production (Tsarouhas, 2020). Actually, the purpose of doing preventive maintenance is to prevent loss time caused by engine damage. Loss time is the time lost due to the cessation of the production process. This of course has an impact on the company's losses. Loss time that occurs will reduce productive time at work so that the resulting product output cannot reach its maximum capacity (Tignibidin et al, 2020).

Several factors that affect the strategy and performance of maintenance are the type of industry, the size of the factory, the scope of maintenance, the reliability of a trained workforce (Saptioratri et al, 2021). By carrying out good preventive maintenance activities will produce machines that can be used for a long time, and production activities run without a hitch (Huang et al, 2020). Meanwhile, poor maintenance will certainly result in poor machine work, such as machines or equipment will be damaged quickly, so that the level of usability will quickly decline. Previous research related to preventive maintenance on wind turbines (Zheng et al, 2020), the Italian manufacturing industry (Kundu et al, 2020), energy companies (Martins et al, 2020), and hospitals (Silva et al, 2021). Based on the description above, the author is interested in analyzing the problems faced by several manufacturing industries in Indonesia as of the implementation of preventive maintenance of diesel-electric generators in several Indonesian manufacturing industries.

1.1 Objectives

The purpose of this study is to determine the relationship between diesel power generator size and the performance of preventive maintenance in Indonesia's manufacturing industries.

2. Literature Review

2.1 Intoduction of Genset

A generator set or "Genset" is an electrical power generating system consisting of an internal combustion engine and an alternator (Kai Loon Cheong 2010). It can be for stationary or mobile applications and with power ranging from several kW's to MW's. Genset (Generator Set) is a backup power generator that uses kinetic energy. The electricity that can be generated is adjusted to the size of the generator (Turan Gönen 2014). The first time the generator was invented by Michael Faraday who succeeded in discovering that there is energy that can be generated when an electric conductor moves in a straight line with respect to a magnetic field. At first, this generator engine was made using only coils of wire and U-shaped iron.

A genset or generator set is a substitute for a voltage source, in the event of a power outage from PLN (State Electricity Company). Generators are also a necessity for the community so that work activities will not be hampered by power outages, be it in office environments, in educational institutions as well as in shops and housing that must always require electricity supply at all times.

Genset or generator set can use various engines as needed. Both gasoline engines, diesel engines, gas engines, and turbine engines. In essence, a machine is used to turn a generator made of a bunch of copper wires (V.L. Maleev 2020). The results of the rotation produce a magnetic field which when rotated continuously at a constant and continuous speed will produce an electric current (Aan Ardian 2017). Gasoline-engined generator applications are widely found for household purposes, while generators with diesel engines and gas engines are widely applied for industrial purposes.

2.2 Genset Types

The first genset was called the Faraday Disc Generator. Types of engine generator sets have different ways of working based on the type of electric current. Based on the electric current, the generator is divided into 2, namely the Alternator Electric Generator Set (AC) and the Dynamo Electric Generator Set Machine (DC). For generator sets, the type of Electric Alternator (AC), has 2 magnetic poles facing each other so that they can produce a magnetic field. In the center of the magnetic field there is a rotating coil.

Because the coil continues to rotate so that the incoming magnetic force varies. The nature of the electric current produced is an alternating current that is shaped like a wave (the amplitude depends on the magnetic field, the cross-sectional area of the coil and the number of turns of the wire). Meanwhile, the generator set type Electric Dynamo (DC) has a similar way of working with an alternator generator set engine. The thing that is different from the two of them is that the DC generator uses a split ring system.

This split ring is usually called the commutator, which is usually located on the output side. Whatever the choice of generator, please note that in general the operation of a generator requires a coil of wire and magnetic poles. In addition, the generators also need fuel. The fuel that is widely used to date is of course diesel (diesel), but it cannot be denied that now many have tried and made diesel engines with new power.

2.3 Diesel Power Generator System

Diesel Power Generator work system requires a support system in order to work properly without experiencing interference. In general, these support systems are divided into several parts, including:

2.3.1 Fuel System

The fuel system is the fuel circulation system in the engine. The fuel system sequence is shown in Figure 1.

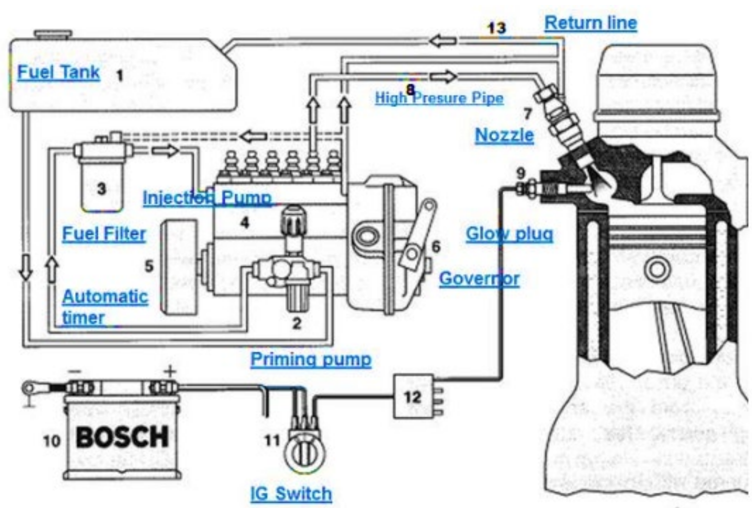


Figure 1. Diesel Genset Fuel System Sequence

a) The fuel (diesel) in the tank flows through the feed pump.
b) This feed pump functions when air enters the engine. By pumping, there is a flow of diesel fuel into the entire system. In a diesel engine there is no air void in the fuel pipe.
c) After that it is flowed into the fuel filter, this fuel filter functions to filter fuel from impurities that enter the fuel.
d) From the fuel filter flows to the injection pump, in the fuel injection with the pressure from the rotation, the resulting pressure is very high so that the injection pipe must be strong and sturdy without leakage.
e) From this injection pipe into the nozzle to be atomized into small particles, some of the fuel pumped is used for atomization, the remaining fuel in the nozzle is returned to the fuel storage system.

2.3.2 Cooling System
Only part of the energy contained in the fuel supplied to the engine can be converted into mechanical power while the remaining part is left as heat. The remaining heat will be absorbed by the cooling material in the walls of the cylinder tube that forms the combustion chamber, as well as parts of the cylinder head cooled with water. while the piston is cooled by lubricating oil and the heat absorbed by the cooling oil is then channeled through the oil cooler, where the heat is absorbed by the refrigerant.

In diesel engines with high pressure compressed air, the compressed air by the turbocharger is then cooled by water in the air cooler (intercooler), circulating cooler with finned radiators and fans (circuit cooling).

2.3.3 Lubrication System
Inside the machine there are many moving and rotating parts. This movement and rotation will cause friction between the metal material so that it tends to cause wear and heat. To avoid this situation, it is necessary to lubricate every moving and rotating part of the machine.

2.3.4 Air System
The intake of oxygen in the diesel engine in the combustion chamber is normal (Natural Aspirated), namely the composition of oxygen that enters the combustion chamber is only taken because of the vacuum in the piston when it moves down. Through the air filter then enters the combustion chamber through the intake valve.

2.3.5 Electrical System
Applies to direct current (DC) generators where the commutator must be maintained. If an alternating current (AC) generator is used, there is no commutator, but a combination of slip rings and brushes that must be checked or replaced every 2500 to 3000 hours. In the latter case, the alternating electric power is converted into direct current electric power and used to charge the battery.

2.4 Diesel Power Generator Capacity
Diesel Power Generator are not only used in large industries or hospitals but have also been widely used in housing that requires backup electricity. Generally, there are 3 types of generators based on their capacity from 1 KVA to 3000 kVA.

2.4.1 Prime Capacity
The first type of Diesel Power Generator based on its capacity is prime capacity, which is the load capacity that is expected to be able to bear the generator in an unlimited time. The load can also go up or down. But the total expected load itself usually ranges from 60 to 70 percent of the stated prime capacity value.

2.4.2 Continuous Capacity
Next is continuous capacity where this is a constant load that can be borne by a generator in continuous time. The keyword itself is constant. Where the constant load is a relatively more stable load which does not change and has minimal shock loads.

In this condition alone the generator is able to run for 24 hours except for maintenance. The continuous capacity listed is 90 to 95% of prime capacity. For example, the prime capacity listed is 1000 KVA, so the continuous capacity can tartar up to 90-95 KVA. Ideally, this generator itself is only loaded with 70-80% continuous capacity.

2.4.3 Stand by Capacity

Stand by capacity or standby capacity is the capacity of the generator set with the consideration that the generator is rarely used so that it has more time to rest. This type of generator usually has a listed capacity of 5-10% larger than the prime capacity that has been listed. For example, if the prime capacity is 1000 kva, then the stand-by capacity that can be listed is around 105-110 kva.

2.5 Preventive Maintenance

One of the maintenance methods that is often applied in various manufacturing industries is preventive maintenance (Huang et al, 2020). Preventive maintenance is maintenance and maintenance activities on production machines to prevent unexpected damage (Zhang et al, 2020). Preventive maintenance characteristic consist of maintenance planning & scheduling (Wakiru et al, 2021), component replacement (Nurcahyo et al, 2017), alignment & adjustment (Botto et al, 2020), condition monitoring, and maintenance evaluation (Nurcahyo and Azka, 2019). Production equipment will experience a decrease in function if it is used continuously. Therefore, preventive maintenance on production machines needs to be done in order to maintain the smooth production (Tsarouhas, 2020). Actually, the purpose of doing preventive maintenance is to prevent loss time caused by engine damage. Loss time is the time lost due to the cessation of the production process. This of course has an impact on the company's losses. Loss time that occurs will reduce productive time at work so that the resulting product output cannot reach its maximum capacity (Tignibidin et al, 2020).

3. Methods

3.1 Survey Methodology

The question is designed based on a different perspective of maintenance practice that understands the object of observation. The questionnaire contains questions related to the general and specific characteristics of the diesel generator maintenance strategy of each industry. This method is used to obtain data about the perception of the diesel generator maintenance strategy from maintenance expert respondents. A total of 30 respondents from various manufacturing industries with a working period profile is shown in Figure 2.

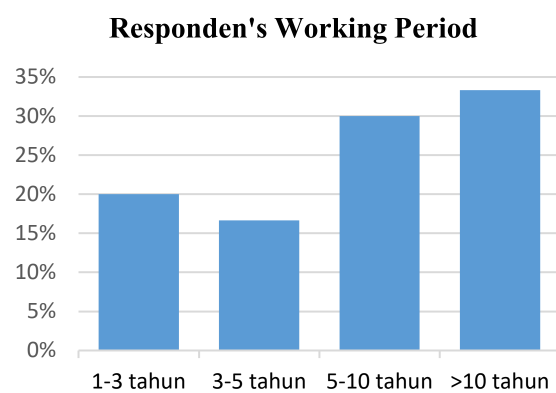


Figure 2. Characteristic Respondent

We classify the commonly used measures of preventive maintenance characteristic into four major categories based on their focus, they are: 1) Maintenance planning & scheduling; 2) Component replacement; 3) Condition monitoring; 4) Maintenance evaluation.

3.2 Data Collection

Maintenance has an important role in business performance in the Industry. Lack of maintenance or inadequate maintenance can lead to dangerous situations accidents and health problems. The objective of this research is to evaluate the appropriate maintenance strategy based on the maintenance characteristics of the diesel generator capacity.

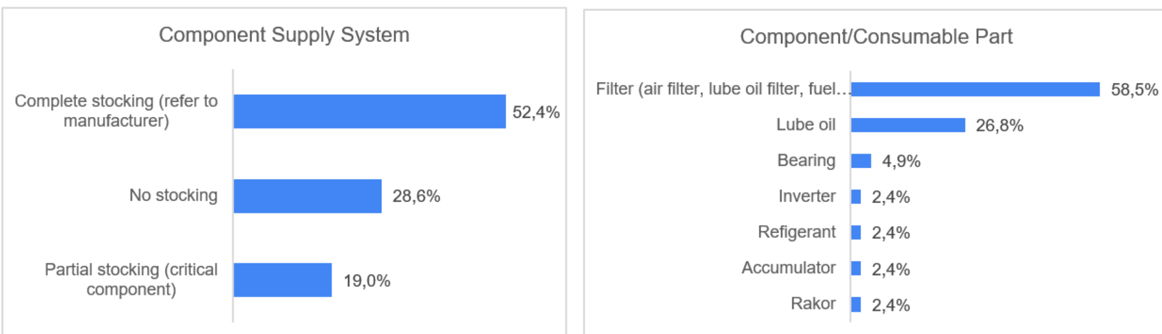
3.2.1 Maintenance Planning & Scheduling

In the maintenance activities, planning and scheduling are two functions that work together to create a maintenance program. Effective scheduling plans must be supported by accurate and updated information about the overall status of equipment, spare parts, workforce, policies, and procedures (Integrated Maintenance Planning in Manufacturing). (Duffuaa et al 1999) divides maintenance scheduling into three categories based on the time horizon of planning and implementation. First stage to cover 3 months – 1 years, second stage in weekly schedule, and third stage in a daily schedule.

Based on our observations, as many as 97% of respondents, have implement planned and scheduled maintenance on the diesel power generator unit. The planning and maintenance schedule for diesel generators is mostly implemented in the industry by applying scheduling every 6 months (semesterly). Most industries that are used as a reference in the maintenance schedule are based on time and run hour.

3.2.2 Component Replacement

Diesel Power Generator are generally used as backup power in industries that make them as a critical equipment. A production process is very dependent on the condition of the machine to be used. One of the obstacles in the machine is that the components are damaged, so that the machine cannot work properly. To optimize the performance of the engine, the replacement of components/consumable parts is required. Total 73% of respondents replace the component/consumable spare parts based on their life service. Most frequent replacements occur on the filter as much as 58.8% and the second is lube oil replacement by 26.8%. Detail information is shown on Figure 3.

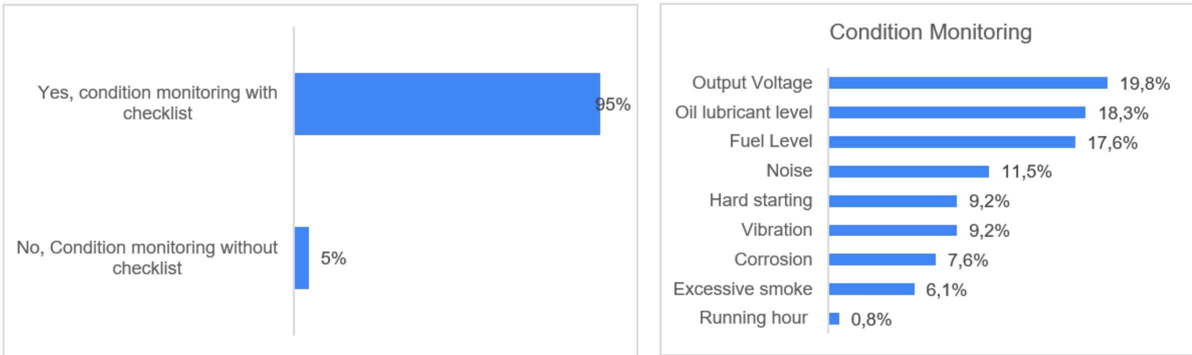


(a) Pareto Component Supply System (b) Pareto Component Part Replacement

Figure 3. Component Replacement Maintenance Characteristic

3.2.3 Condition Monitoring

Condition monitoring (CM) is a tool commonly used for early detection of faults/failures thereby minimizing downtime and maximize productivity (Fausto Pedro García 2012). It is necessary for condition monitoring to be carried out in order to more quickly diagnose damage/abnormalities in equipment, so that it will increase reliability maintenance. Based on observations, almost all respondents carry out condition monitoring that assisted by a checklist to determine the condition of an equipment. Most of the aspects monitored on the Diesel Power generator are the output voltage with a result of 19.8%; oil lubricant level 18.3%; fuel level 17.6%; and 11.5% noise. Detail information is shown on Figure 4.

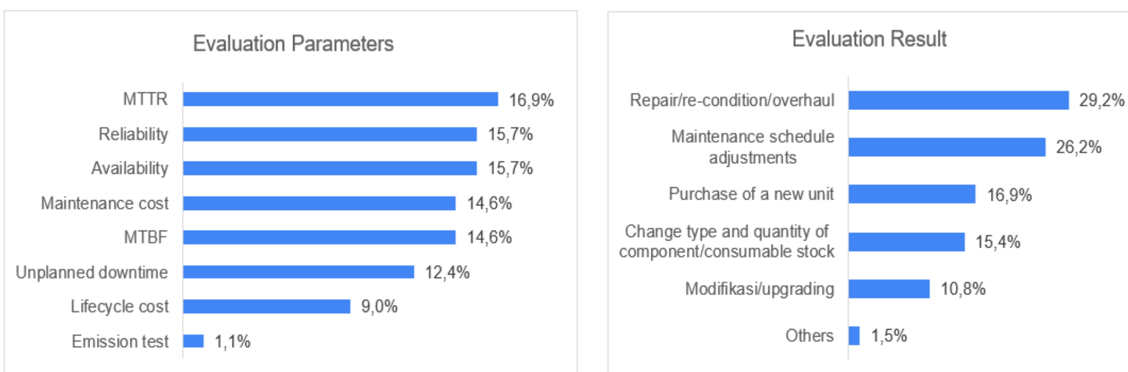


(a) Trend Condition Monitoring (b) Pareto Condition Monitoring

Figure 4. Condition Monitoring Maintenance Characteristic

3.2.4 Maintenance Evaluation

Maintenance evaluation is an assessment of the maintenance arrangements of a facility and further describes what is needed to make improvements to a maintenance best practice situation. MTTR, Reliability, availability are the most analyzed parameters for evaluating generator maintenance success in the industry. Total 29.2% of respondents decided to re-pair / recondition / overhaul after the maintenance evaluation was carried out. Detail information is shown in Figure 5.



(a) Pareto Evaluation Parameters (b) Pareto Evaluation Result

Figure 5. Maintenance Evaluation

4. Data Collection

4.1 Differences Between Diesel Power Capacity

Among 30 respondents, we divide them into two groups based on the diesel power generator's capacity. The first group has a capacity of less than 1000 kVA (n=13), while the second group has a capacity of more than or equal to 1000kVA (n=17). As shown in Figure 6, both groups conduct maintenance planning & scheduling, and maintenance evaluation 100%. This show that those two preventive maintenance aspects are common basic practice in the industry without any restriction in capacity. It may be caused that both activities are the most critical factor to maintenance success since both activities are the first and the last step in the maintenance strategy program.

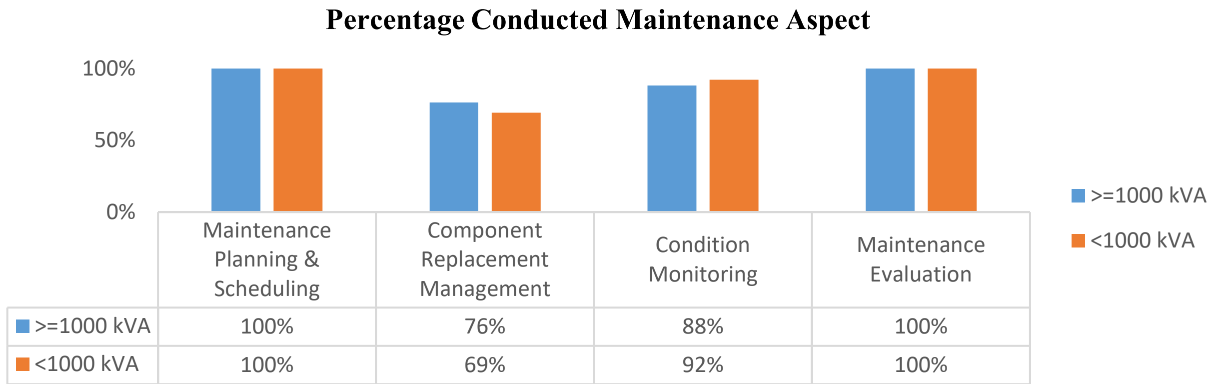


Figure 6. Percentage Conducted Maintenance Aspect Comparison

On the other hand, not all respondents conduct component replacement management and condition monitoring. It is observed that in a bigger capacity, conduct component replacement management is 13% more than the smaller group. This difference may be because the bigger capacity usually requires more expensive components and limited ready stock components in the market. So, conducting component replacement management may help to keep the availability of diesel power generators higher. This pattern could be seen in condition monitoring aspects. Only 88% in the bigger group conduct condition monitoring, while 92% in the smaller group conduct this aspect. Although the difference is just about 4% this shows that no proof that bigger capacity conducts more in monitoring their diesel power generator condition.

Specifically, on maintenance planning and scheduling, we find that both groups could be classified into three categories based on maintenance activity period baseline: run hour, time, and both. Figure 7 summarizes the comparison among groups. Bigger group capacity conducts based on both baselines about two times than the smaller groups. Most small groups rely on time, while most of the bigger groups rely on both times and run an hour. Moreover, we evaluate the detailed maintenance period in both groups. Figure 8 shows that only a bigger capacity group conducts weekly maintenance. It is significant that 38.5% of respondents in bigger groups conduct weekly maintenance, while smaller groups do not do this at all. Another maintenance period is observed conducted by both groups but with the difference in the percentage. In general, the bigger group conduct maintenance period mostly on yearly, semester, monthly and weekly basis. While smaller groups mostly on semester, yearly, and quarterly basis.

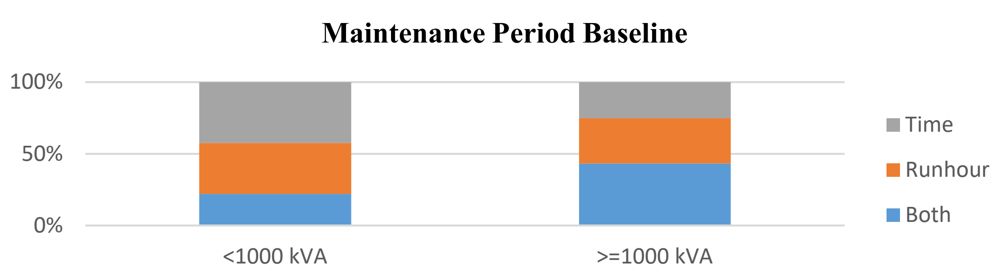


Figure 7. Maintenance Period Baseline Comparison

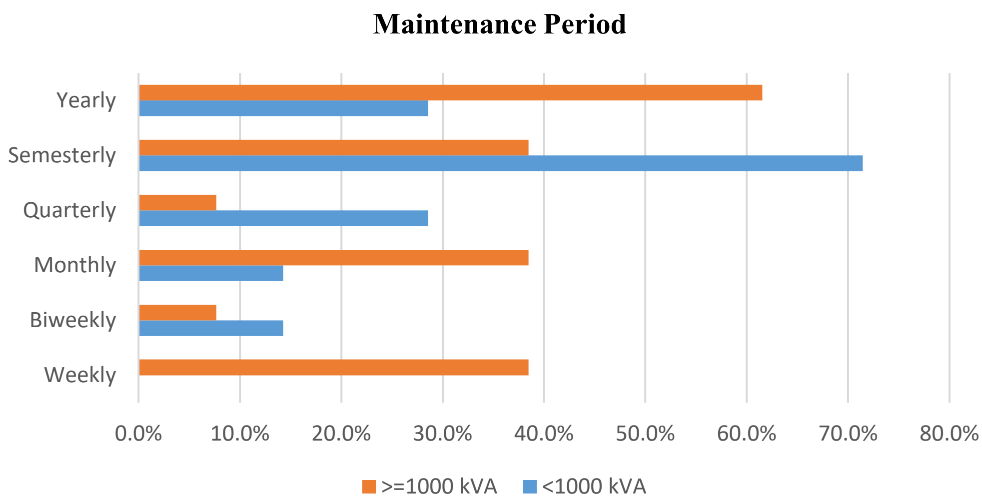


Figure 8. Maintenance Period Baseline Comparison

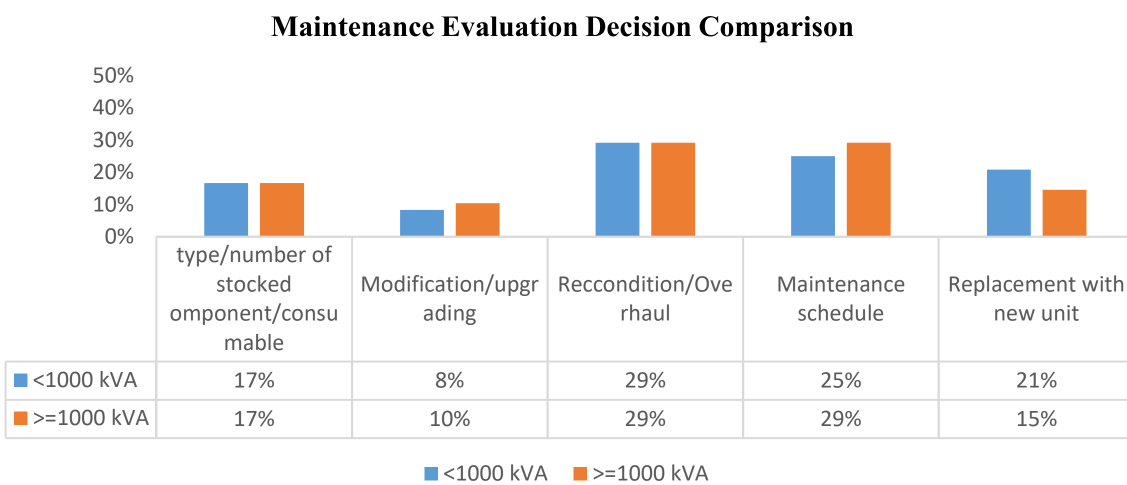


Figure 9. Maintenance Evaluation Decision Comparison

Lastly, we evaluate the differences between groups on the maintenance evaluation aspect. Figure 9 shows that both groups most likely have a similar pattern. Recondition/overhaul and changes in maintenance schedule are the highest output decision that respondents may decide after maintenance evaluation, followed by replacement with a new unit, type/number of stocked components and consumables, and the last one is modification or upgrading. It is observed that there is a small percentage difference in both groups, especially in maintenance schedule and replacement with a new unit.

5. Results and Discussion

5.1 Result

From a survey of 30 respondents, it was found that all respondents carried out preventive maintenance on their diesel power generators. In terms of maintenance planning & scheduling, 31% applied maintenance period based on time, 13.8% applied maintenance period based on run hours and 55.2% applied maintenance period both of them. The majority of respondents do maintenance period on a semester basis. In terms of component replacement, 52.4% of respondents did complete stocking of the diesel power generator components. Then for consumable parts, 58.5% of respondents stated that every time preventive maintenance was carried out, they always made replacements related to filters (air filters, lube oil filters, etc). While 26.6% of respondents stated that they always replace lube oil. Other respondents stated that they have replaced bearings, inverters, refrigerants, accumulators, coordination meetings, etc. In terms of condition monitoring, it is known that 95% of respondents carry out condition monitoring. The 3 biggest items monitored are output voltage, oil lubricant level, and fuel level. In terms of maintenance evaluation, the 3 largest items that become evaluation parameters are MTTR 16.9% respondents, reliability 15.7% respondents, and availability 15.7% respondents. Meanwhile, for the 3 largest items that must be considered in the evaluation results, 29.2% of respondents stated that repairs could be done, 26.2% said they could wait for a maintenance schedule adjustment, 16.9% said they purchased a new unit.

5.2 Discussion

There is no significant difference between the size of the diesel power generator and the percentage conducted maintenance aspect. Time-based preventive maintenance goes by a variety of names, the main one being «calendar-based» maintenance. Usage-based maintenance also called «runtime maintenance» is an approach that triggers maintenance after a certain amount of asset runtime. Usage-based preventive maintenance makes sure that equipment continues to operate as the manufacturer intended.

Air filters, fuel filters, and oil filters, are essential components that play a big role in the operation of any Diesel Generator. Diesel generators should be operating at maximum generator efficiency. This means it is important that the right supporting parts are installed correctly and maintained properly within user generator. User need the right air filters, fuel filters, and oil filters for the right generator – ensuring that only genuine parts are used in user diesel generator. Air Filters are integral in maintaining the well-being of user diesel generator. Diesel generators require outside air for their combustion process. This means that if it is not replaced as per the maintenance log, user diesel generator can become less efficient, leading to an increase in the consumption of fuel. The three biggest items that become the evaluation parameters for maintenance are MTTR, availability, and reliability. This availability can be used to assess the success or effectiveness of the maintenance activities that have been carried out. Oil analysis is one of the most important techniques applied for condition monitoring and must be understood as a diagnostic maintenance tool. Used oil analysis is comparable to a medical analysis with a blood test.

6. Conclusion

There is no significant difference between the size of the diesel power generator and the percentage conducted maintenance aspect. In determining the majority of respondents stated that the maintenance period is based on time and run-hour. Respondents stated that every time preventive maintenance was carried out, they always made replacements related to filters. The three biggest items that become the evaluation parameters for maintenance are MTTR, availability, and reliability. The way to do condition monitoring of diesel power generator performance after the repair is to look at the output voltage, oil lubricant level, and fuel level.

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