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Elements of Generators Selection, Sizing and Maintenance in Nigerian Industries

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Abstract
The issue of power supply in relation to industrial revolution in the developing world cannot be overemphasized. At least, production equipment and machines have to be powered to produce goods for the polity. The paper illuminates various ways loads on generators can be estimated; it identified the importance of using correct sizes of generators for loads demand and buttresses the criteria for selecting generating sets for various usages. It discusses the fact that right conductor sizes will undoubtedly prevent voltage drops which may hamper the benefits of using the correct generators. The paper also stresses the economic importance as one of the reasons for selecting right set for specific loads. It suggests various maintenance activities that can optimize maintenance cost and minimize the repair cost thus dovetailing into high productivity and profits.

1. Introduction

The perennial power problem in Nigeria has undoubtedly encouraged proliferation of generators' systems in the polity. Though there have been concerted efforts by various governments since 1999 to solve the problems by increasing the amount of power generated and fed to the power grid, there is still pockets of darkness and its concomitant economic impasse. Industries in the country have been on the receiving side, some took unavoidable solution by shutting down their productive enterprise while scores of others do relocate to other countries in West African sub region. Also many others took the bulls by the horns by remaining in the country and face the consequence of power imbroglio; at least, they have to weather the storms occasioned by power shortages through paying exorbitant bills from the local supply authority PHCN and also expend their scarce resources on acquiring generators and their fuelling with diesel. Nevertheless, correct generator sizing coupled with good maintenance acumen will ensure power availability with an affordable costs. Maintenance may be defined as actions necessary for retaining or restoring a piece of equipment, machine, or system to the specified operable condition to achieve its maximum useful life [1]. Also, maintenance can be look as "all actions which have the objective of retaining or restoring an item in or to a state in which it can perform its required function". The actions include the combination of all technical and corresponding administrative, managerial, and supervisory actions. The primary objective of maintenance is to ensure that physical assets continue to fulfil their intended functions throughout the lifetime of the assets[2-3]. Before a generating set is acquired, one should be certain of the number of phases needed to power loads, that is, single or three phase, there should be proper analysis on the projected demands thus forestalling overloading of the unit in case of an under estimation of loads in one hand and prevention of over sizing of the facilities that always attracts high costs and continuous high running cost. An important step in sizing a generator is to identify every type and size of load it will carry. It should be noted that when non linear loads are present, it may be necessary to oversize the alternator [4]. The minimum generator set capacity should not be in anyway exceeded as running a set with a high load can lead to engine damage and reduction in reliability. Some manufacturers of generator sets do frown at running them less than 30% of the rated load [4]. Thus, a set is normally encouraged to be run at between 30 -70% for the foregoing reasons. The importance of this topic has necessitated the development of various programs for sizing generator sets while others make do with assistance of manufacturers, sales representatives, expertise.

2. Methodology

The method used is borne out of the in-depth experience of power problems in Nigeria. Also, personal industrial experiences coupled with theoretical understandings were brought to bear in the research work. Major components and inputs into generators are assembled while loads at their terminals are identified in relation to how much loading effects they would have on the system.

Concerning loading, KVA demands were considered in relation to their power factors, efficiencies and other factors that come into play going by foreknowledge of an engineer on the nature of loads. The project was also consummated by analysing the prime mover viz a viz their various rating with their fuel. Knowing the components that make up a generating set, maintenance practices proffered by their manufacturers are listed. All is done to ensure that losses are reduced with their attendant improved reliability, efficiency and availability.

2.1 Installed Loads

In order to size a generator set for a particular task, it is expedient to determine the loads that the system will carry. On the name plates of an individual machine is the information of the power to be consumed by it. So the summation of power ratings is the installed power of the installation. In actual fact, when machine efficiencies are considered, and more so that an occurrence of 100% efficiency is unattainable in practical sense, the input power to be consumed by the system will be higher than the calculated values. Therefore, the generating set will poised to supply more than what one has calculated. Electric motors which are commonly referred to as the factory workhorse are important examples, their power ratings refer to the output power at their rotating driving shaft.

Considering equations 1 and 2, the input power to be supplied by the generating sets will be evidently higher in order to account for losses. The lesser the losses, the greater will be the efficiency of that electric motor. The ubiquitous fluorescent lighting units comprising ballasts are other cases in which

The nominal power specified on the lamps are less than power consumed by them and their ballasts. The power demand by them would be more than the summation of the nominal power stated on their nameplates.

$$\eta = \text{Efficiency} = \frac{\text{Output Power}}{\text{Input Power}} \quad (1)$$

$$= \frac{\text{Output Power}}{\text{Output Power+Losses}} \quad (2)$$

2.2 The Power Factor

The Apparent Power demand of a load is obtained from the nominal power rating and the application of coefficients like Efficiency and the Power factor [6]; (3) and (4). Industries processes are made possible by Induction motors; they impart motions on the mechanical subunits. Due to their windings, they are inductive, in these systems; current lag the voltage applied thus gendering low power factor [6]. The resultant is the flow of wattles current which are solely used to produce magnetism [1]. Power factor is the ratio of nominal power in kilowatts to the apparent power [7]. So, the more the current lags the voltage, the lower the power factor. And a low power factor causes the current to be drawn from the generator to be higher. The cables sizes and switchgear rating will be higher with their concomitant costs.

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Another point of note is the occurrence of inrush current that flows during motor starting process; the situation can be as high as five times the normal running current. Some engineers size generators by taking running wattage of their largest motor and multiply by ten; then add running wattages of all smaller motors as well as the wattage of all other loads. The resultant is the total load [8-9].

$$\text{Power factor} = \frac{\text{Nominal Power in KW}}{\text{Apparent Power in KVA}} \quad (3)$$

Therefore, the Apparent Power KVA demand of the load is

$$Pa = \frac{Pn}{\eta \times \cos\theta} \quad (4)$$

Where, Pn = Nominal Power (KW)
Pa = Apparent Power (KVA)

In single phase system, the current taken by the load is

$$Ia = \frac{Pa \times 10^3}{V} \quad (5)$$

And for a three phase balanced load

$$Ia = \frac{Pa \times 10^3}{\sqrt{3} \times U} \quad (6)$$

Where, V = Phase to Neutral Voltage (V)
U = Phase to Phase Voltage (V)

In a nutshell, the total KVA of Apparent Power is not the arithmetical sum of the calculated KVA ratings of individual loads unless all loads being considered are at the same power factor [10]. Nevertheless, in practice, it is common to make simple arithmetical summation, the result of which will give a KVA value that exceeds the true value by an acceptable design margin [10].

3.Utilization and Simultaneity Factor

Utilization factor is based on the assumption that some loads are not usually used at full load. By using electric motors as example, they are not commonly used at full load hence an average value of 75% is proffered. In case of incandescent lighting, a factor of 100% is employed. Simultaneity factor buttresses the fact that not all the loads are used at the same time, that is, there is a degree of diversity [10]. In automobile industries, spot welding machines are used for welding car bodies, these machines draw current of several kilo-ampere in the duration of few milliseconds but welders do not weld simultaneously. They can be deduced with the ample knowledge of the installation engineer of the system. Factors of Simultaneity is equal to the inverse of a diversity factor which itself is always greater than one.

3.1other Factors

To purchase a generator set, other considerations must be kept in mind, for example, which set to be acquired, where to install it and how to install it. Other questions could be, is it going to be standby unit or a prime power unit? The former signifies that the set would be engaged each time the PHCN power goes off while the latter means the industry or individual has no other source of power.

3.2Type of Fuel

In selecting generator to be purchased, an engineer is expected to determine which fuel will be used to power the prime mover. There are four main fuel namely, diesel, natural gas, liquid petroleum and gasoline. Diesel is compression ignited while others are spark ignited [9]. For heavy duty and industrial installation, diesel is the best choice since it last longer. Its less combustiveness makes it to be safe in handling and storage [11].

3.3 Generator's Operating Speed

In Nigeria, Australia and Europe, the main frequency is 50Hz. In other words, equipment to be powered is rated likewise. But to have this fixed frequency, there must be a fixed engine speed. And to have 50Hz, most engines are expected to operate at a synchronous speed of 1500rpm or 3000rpm. Table 1

$$N_s = \frac{120f}{P} \quad (7)$$

So $$f = \frac{N_s P}{120} \quad (8)$$

Where, Ns = Synchronous Speed (rpm)

P = Number of poles
F = Frequency in Hz

The most common is the four pole sets which produce 1500rpm. In all, both designs have their shortcomings. Four pole, 1500 rpm offer best balance of noise, efficiency, cost and engine life [9]. Since the speed is half of the two pole design, so also is the wears to be expected. The 3000 rpm, two pole design are smaller and lighter in weight hence best suited for portable and light duty usages [11].

3.4 Rating of the Internal Combustion Engine

Each engine model manufactured is given a certain power rating according to the service in which the set will be engaged. Makers of sets do key-in into this fact by incorporating engines from various prime mover makers according to their requirements. In other words, they may not necessarily be the sole makers of the complete units. This is done to limit the maximum power output so that the desired engine life could be attained. Three distinct ratings for engines are Continuous Duty, Prime Power and Standby ratings [11]. Continuous Duty Rating can be defined as the power output and speed at which the engine can be operated steadily with a life expectancy of 10,000 hours or more. It the amount of horsepower the engine is allowed to deliver when operated 24hours a day, 365 days a year while powering a constant fixed load at constant fixed operating rpm. If the engine is properly maintained and its power and speed is not exceeded, the desire life expectancy can be attained.

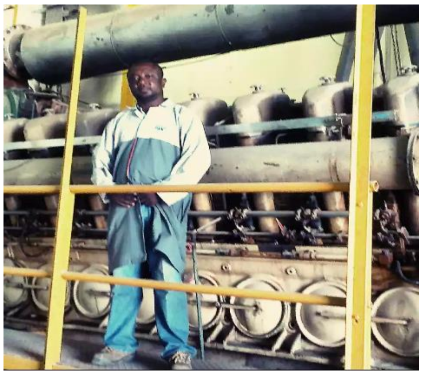

Fig.1: 3MVA Cockerill Generator Prime Mover

A standby set has limited running time in service. It is expected that the engine be able to produce its standby rated horsepower continuously for the duration of each power failure from the supply authority. In Prime power rating, the set is expected to be the sole or normal power source, and is expected to work optimally

3.4 Selection of Conductors

Most of the times, power cables are usually selected by putting into consideration the application. The undermentioned factors will be invaluable for selection of conductors required to transfer energy from one point to the other. There are standard data sheets specifying the amount of current a particular size of conductor can carry within allowable voltage drop. As the length increases resistance increases as well, that is, resistance is directly proportional to the length of the conductor. In the same vein, the resistance also is inversely proportional to the cross sectional area of the conductor [7].

$$R \propto l \quad (9)$$

$$R \propto \frac{1}{A} \quad (10)$$

By combining (9) and (10)

$$R = \rho \frac{l}{A} \quad (11)$$

Where, l = length of conductor (m)
A = Cross sectional area of the conductor (m^2)
ρ = Constant of proportionality depending on the material of the conductor and is known as its specific resistance or resistivity.

The bigger the size of a conductor, the better is its current carrying capacity. A $35mm^2$ armoured cable is expected to carry more current than $25mm^2$ type. An engineer is expected to select an optimum size taking into consideration the cost and load to be powered by it. Apart from the above mentioned criteria, other ones worthy of mentioning is the maximum operating voltage, the frequency, insulation level, flame retardants properties and as well its mode of installation by considering the environmental factor.

4.Generators Maintenance

Maintenance enhances generating set reliability [12]. It is certain that generators become more likely to fail after a number of years in operation. This is as a result of components ageing. Experience has also shown that high ambient temperatures, high vibration levels, humidity, dirt or heavy loads can reduce components lifetimes thus hastens failures. OEM maintenance manuals are required to be referred to for such items as torque values, voltage settings and other settings [13]. The result is the reduction of maintenance and component replacement intervals.

Fig. 2: 5kVA Diesel Generator Assembled

An organisation employing qualified technicians will undoubtedly have peace of mind when it comes to power supply. A deployment of various preventive maintenance operations is sine-qua-non to improved power availability for production purposes. It will also optimise maintenance cost and minimise repair costs. The following are various preventive maintenance schemes recommended for diesel powered generators.

4.1General Inspections

A generator operator is expected to check the set when it is not running. Check the fuel system for leakages, cracks and abrasions of tubing. If any abnormal situation is discovered, make amendment immediately. When the set is not running, ensure that the body of the set is clean and devoid of oils or dirt as this will enable all abnormalities on the unit to be discovered easily.

Check the exhaust system for leakages during operations. Check the battery terminals for clean and tight connections.

4.2 Lubrication System's Maintenance

Check the engine oil level when it is shut down. By using dipstick, ensure that the oil level is as close as possible to the full mark. You are to add the same brand of oil in case it is lower than the full mark. Follow the manufacturer's directives on intervals for changing oil and filters. Some manufacturers, as normal policy advocates changing of lubricating oil and oil filters every 250 hours or 24 months whichever comes first [14]. With the advent of oil analysis, the oil would be changed depending on the test results. This practice is environmental friendly and prevents waste of financial resources [3].

4.3 Cooling System's Maintenance

Using a prepared checklist, you can also check the coolant solution that is recommended by the manufacturer. Maintenance service man can also use soft brush to clean the exteriors of the radiator – the latter should be done without damaging the fins. Also, a low pressure compressed air can be used in the opposite direction of the normal air flow to clear the radiator.

4.4 Fuel System's Maintenance

Fuel system comprising tanks, fuel filters, hoses, piping, gauges and safety mechanisms should be properly checked. The diesel fuel should also be checked for condensations and water in fuel.

4.5 Air Intake System's Maintenance

All the components for the air intake should be checked. That is, air filter elements, piping and connections and crank case breather. Air cleaners' elements can be cleaned and reused if not damaged

4.6 Battery's Maintenance

Batteries for starting generators must have their terminals and connections cleaned always. Use always battery hydrometer to check the specific gravity of the electrolyte in each battery cell. You should charge the battery if the reading is below 1.215. A fully charged battery has its value to be 1.260 while a battery in good condition when fully charged will read 12.6 to 12.8VDC on its terminals [15].

4.7 Generator's Maintenance Checklist

In order to implement the aforementioned maintenance systems effectively, the use of checklists will be priceless. The checklist will divide the activities into daily, weekly, monthly and annual basis. Manufacturer's suggestions on maintenance of their products can be employed in this case. Proper implementation of the maintenance schemes will extend the lifetime of the generator and enhance its reliability.

5.Conclusions

Going by the lucid explanations on the topic, it should have become clear that the information provided should be taken into consideration before acquiring a generator set either for industrial or domestic use. An adherence to the information will always ensure efficient deployment of the system.

Normally electric generators do provide alternatives to power supply in case of incessant power outages from the PHCN supply terminals. Also, cognizance should be given to proper terminations of conductors on electrical panels' busbars; if the quality of terminations of conductors during installation is bad, safety hazards do ensue with its concomitant costs thus making the standby power system becoming unreliable. Other recommendations of note are:

1. A generator should be selected based on its ability to carry non linear load instead of unnecessary over sizing it.
2. Lubricating oil can be changed after proper oil analysis but not necessarily depending on running hours.
3. Introduction of Total Productive Maintenance methodology would ensure generator availability and efficiency [1].
4. There should be proper reference to the generator's manufacturers' manuals in order to ascertain various periodical maintenance to be carried out.

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