DEVELOPMENT OF SOFTWARE FOR SCHEDULED MAINTENACE OF DIESEL GENERATOR SETS

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A software for scheduled maintenance of diesel generators was designed and developed. This software uses vibration level (0-0.4mm), diesel level (25-100%), water level (50-100L), temperature (20-50^{0}C), air inlet pressure (20-30bar), battery voltage (24volts) and oil level (2.8-7.1cm) to evaluate the operating condition of diesel generators. The software uses these data to recommend the required maintenance scheme to be carried out on this generator with respect to the runtime in hours. The method of collection of these data is carried out manually since it is designed to be a cost effective software in order to make it available to everyone who runs a diesel generator. The software is written in Java programming language using NetBeans IDE platform, which is cross-platform and runs on Microsoft Windows, Mac OS X, Linux, Solaris and other platforms supporting a compatible JVM. This software is designed to bring maintenance to any level of technical knowhow and reduce the rate of diesel engine failures. Hence, reducing the losses associated with unexpected breakdown of diesel generators.

Keywords: *scheduled maintenance, diesel generator, software, NetBeans IDE*

1.1 Introduction

Electricity is an important facet of any nation's development. In Nigeria, for instance, electricity is the pillar of its growth and development with roles in the nation's production of goods and services in the industrial sector as well as agriculture, health and education (Sambo, 2005). Hence, the Nigerian economy, like every other economy in the world is heavily dependent on electricity. Advancement in science and technology has made it possible to convert electrical energy to any desired form; thus, giving electrical energy a place of pride in the modern world. The survival of industrial undertakings and our social structures depend primarily upon low cost and uninterrupted supply of electrical energy. In fact the advancement of a country is measured in per capita consumption of electrical energy.

The Nigerian power sector is marked by low generating capacity relative to installed capacity. Hence, much of the country's citizens do not have access to uninterrupted supply of electricity. At present electricity generation ranges from 2,500 MW to about 3,000 MW even with the inclusion of three gas-powered independent power projects in the Niger Delta region, while estimated national consumption is in excess of 10,000 MW (Babatunde and Shaiubu, 2006; Ikeme and Obas, 2005). Potential demand in the next few years is estimated at about 15,000 MW. This is despite the fact that Nigeria is endowed with massive reserves of hydro energy, petroleum reserves and one of the largest gas reserves (Babatunde and Shaiubu, 2006; Okoye, 2007).

Electricity supply in Nigeria is bedeviled with consistent crisis as exemplified by such indicators as electricity blackouts and persistence on self-generating electricity. Indeed as noted by Ekpo (2009), Nigeria is running a generator economy with its adverse effect on cost of living. Nigeria's persistent electricity crisis has weakened the industrialization process resulting in production stoppages, high operational cost, and significantly undermining the efforts of government towards achieving sustainable economic growth and development.

Thus, causing reliance on power plants (generators).

Diesel generators are widely used in many areas where electrical power is unreliable or non-existent as a supplement to the main power supply, or as the main power supply as well as emergency backup for hospitals, banking sectors, telecommunication networks, etc.

A diesel generator consists of a number of components, often called a diesel generator set or more popular a "genset"(Diesel Service and Supply, 2013).These components include: Engine, Alternator, Fuel System, Voltage Regulator, Cooling and Exhaust Systems, Lubrication System, Battery Charger, Control Panel, and Main Assembly/Frame.

Since diesel generators often run for long hours continuously, there is need for regular and proper maintenance to prevent unexpected breakdown and ensure efficient service throughout its service life. The best generator maintenance practice is following the maintenance schedule provided by the manufacturer of the generator to ensure maximum service time for the generator and proper operation.

Having a well-designed and well-maintained standby power system is the best protection against utility power outages. For hospitals and other health-care facilities they can be life-threatening. For businesses like data centers, the outages can be enormously costly. Other critical facilities at risk include government offices, police departments, fire stations, airports, and water/sewage treatment plants.

Electricity is the backbone of any industrialized society and economy. At home, a brownout (low voltage) of some minutes or a similar blackout (complete power outage) may cause some inconveniences but a blackout of a few hours or even several days would have a significant impact on our daily life and the entire economy. Critical infrastructure such as communication and transport would be hampered, water supply would stop, production processes and trading would cease. Emergency services like fire, police or ambulance would be unreachable due to breakdown of the telecommunication systems. There would be lots of casualties in hospitals, since many patients depend on various life supporting deviceswhich are electrically powered.Financial trading and cash machines would in turn have to close down and this would ultimately cause a catastrophic scenario. If the blackout were to spread across the border lines, which is more likely today due to the interconnection of power grids between different countries, the impacts would escalate as a function of the duration of the interruption.

Today, the most common form of off-grid electricity supply is generators running on diesel or gasoline. Generators are used not only by rural households but also by grid connected households and industries as a more stable supplement to grid power. The rural incidence of diesel generators is difficult to estimate, but about 96% to 98% of the grid-connected firms surveyed reported ownership of private generators (Tyler and Gerald, 2002).

Diesel "back-up" generators are common and reliable mechanism for assisting organizations response to power disruptions. This is because they are available in different electrical and physical configurations for use in different applications. For effective operation in the event of an outage, generators must therefore be well-maintained and serviced regularly.

The development of this software will keep diesel generators running in good conditions all through their service life and reduce the losses associated with unexpected breakdown of the diesel generator.

2.1 Methodology

The materials used in the development, validation and testing of the software are as follows: Measuring tape, Calibrated diesel tank, Voltmeter (Multimeter), Oil dipstick, Thermometer, Stop watch, Pressure gauge, Netbeans IDE, Java programming language. All the parameters used in this study were obtained from 800KVA Perkings diesel generator set, since it is the most commonly used diesel generator set in companies, institutions, factories etc.

2.2 Design Concept and Considerations

The design and development of the model/software for scheduled maintenance of a diesel generator were based on the following concepts and considerations:

i. Improving the efficiency and performance of diesel generators through the development of a simple and cost effective software for preventive maintenance of diesel generators.

ii. Reducing the risks and losses associated with unexpected breakdown of diesel generator sets.

iii. Reducing the time spent on manual detection of faults on diesel generators.

iv. Developing an intelligent system, capable of automatically detecting diesel generator faults and proffering solutions. Hence eliminating the need for skilled personnel.

2.3 Software Development Procedure

Like every other software development procedure, some basic steps were taken to ensure completion of the software without any bugs. The phases the software undergoes from start to finish is called project lifecycle. A typical lifecycle (waterfall) is shown in Figure 1 below:

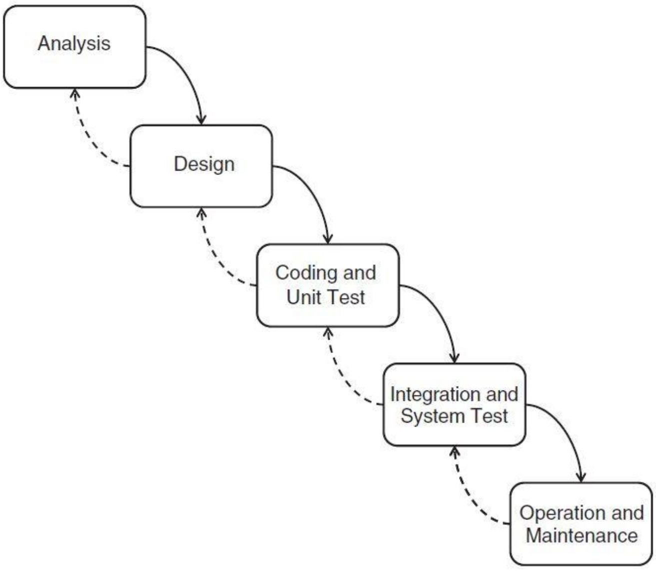

Figure 1: Classical waterfall software development cycle.

It consists of a sequence of steps, systematically proceeding from analysis to design, coding and unit test, and integration and system test.

i. Analysis

A comprehensive analysis of the system requirement was done based on data collected from the generator operators at MUOAU gen. house. The system was designed to be able to accept input, check status of generator and recommend necessary maintenance.

ii. Design

In order to make an excellent design, the block diagram was first drawn before arriving at the flow chart. The coding is then based on the flow chart. Figures 2 and 3 below show the block diagram and flow chart respectively for the developed software.

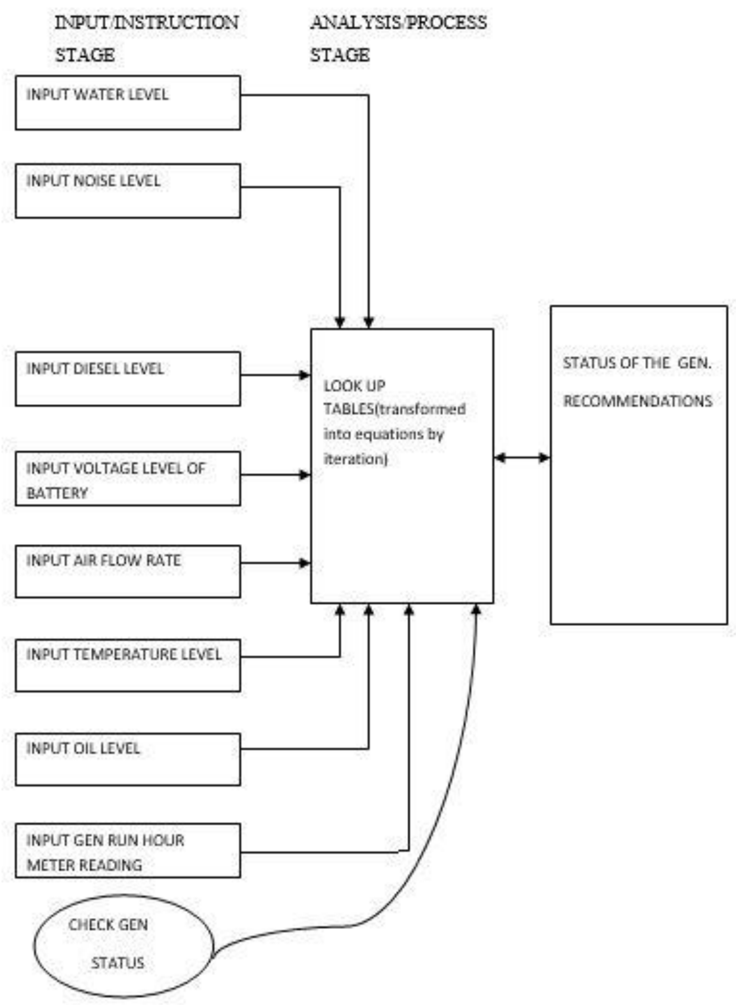

Figure 2: Block diagram

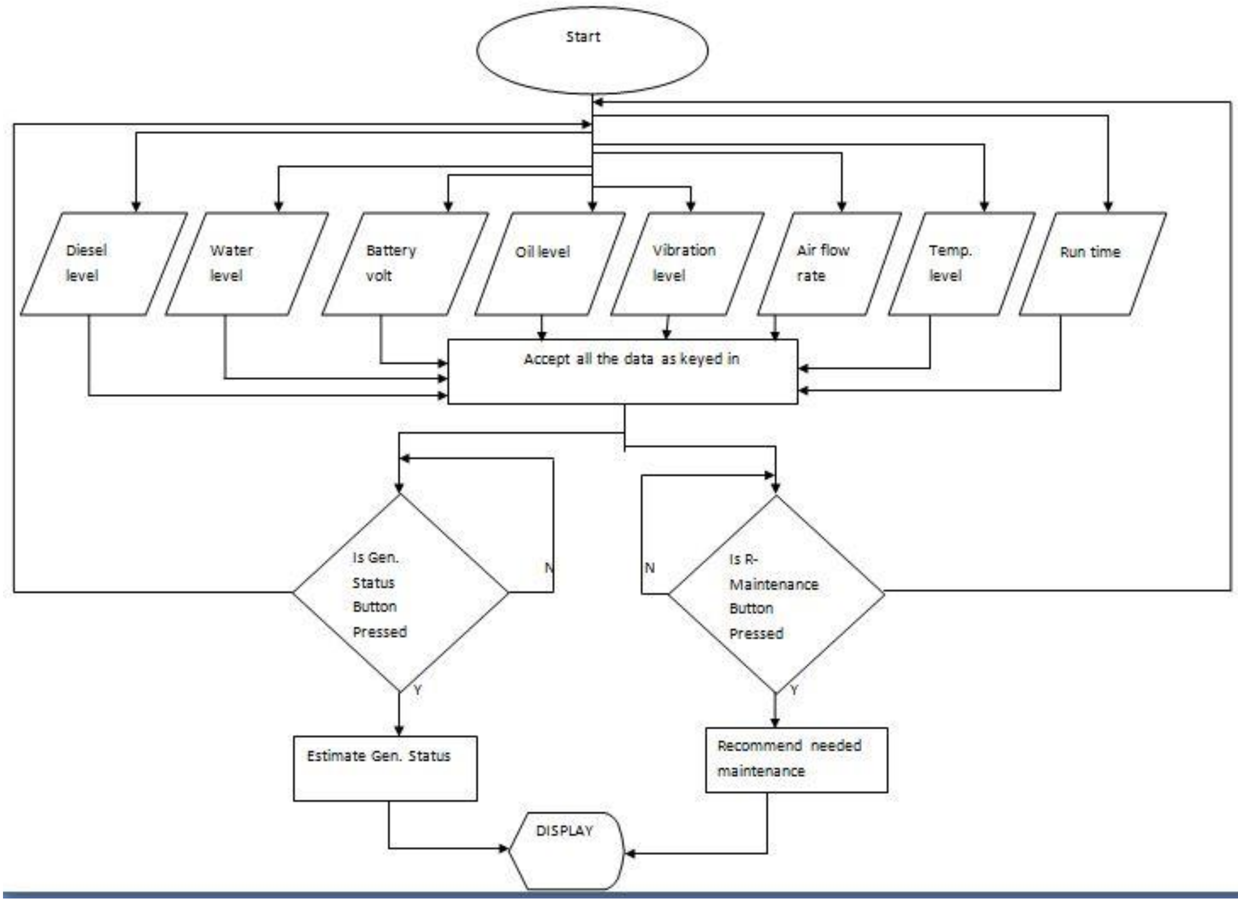

Figure 3: Flow chart

iii. Coding

The code was written with Java on NetBeans IDE. Digital logic was utilized in decision process of the software. After the coding which is done modularly, there is need to integrate the codes to run as a whole, this processes is called "code integration".

iv. Testing

Using the parameters gotten from the MOUAU generator set, the software was tested to ensure that it is gives the required output. Where correction was required, it was traced back to the string and changes where effected as necessary.

2.4 The Diesel Generator Maintenance Software

The developed software works with eight (8) parameters which include; diesel level, water level, battery voltage, oil level, vibration level, air flow rate, temperature level and the total run time. These readings are taken manually from the diesel generator set using different measuring instruments, some of which are standard instruments while others were developed specifically for this purpose. Some of the instruments include; measuring tape, thermometer, calibrated tank, voltmeter, pressure gauge, calibrated dipstick, stop watch, etc.

The software also contains R Maintenance, Add run time, Clear, Exit, Check Gen Status operational buttons and a display window which helps to analyze the generator status for a given set of values. The operating window of the developed software is shown in figure 4 below.

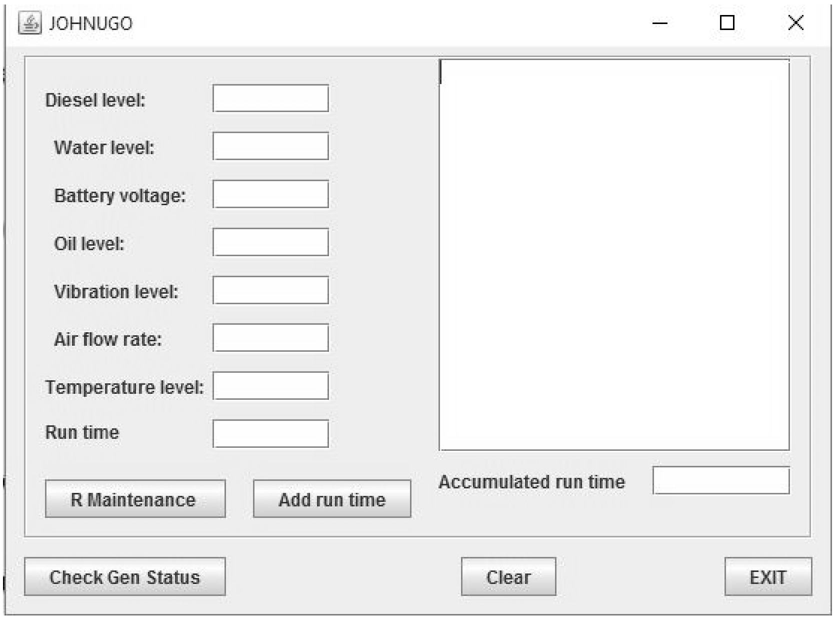

Figure 4: Software operating window

The "Check Gen Status" button is used to check the status (operational condition) of the generator for any given set of operational values obtained from the diesel generator. The overall condition of the generator is displayed on the display window. With the result displayed, the R Maintenance (run maintenance) button is then used to generate the required maintenance operations to be carried out on the generator set to ensure excellent service life of the diesel generator set. The clear button which means clear the screen is used to delete the content of the display window after every evaluation. To avoid confusion, it is required to clear the display window before entering new values or values from another generator.

The "Add runtime" button is used to save the total working period (in hours) of the generator set in order to effectively predict required maintenance operations for specified time intervals.The exit button which is located at the bottom right end of the software is used only when the operator wants to leave the software environment.

2.5 Procedure for Determining the Operating Condition of the 800kva Generator

The parameters used in this study to ascertain the operating condition of diesel generators include: diesel level, water level, oil level, battery voltage, vibration, air flow rate and temperature level.

A normal 800KVA generator has a fuel tank (which is usually calibrated) that could last for 8hours of service at full load i.e. 172 l/hr. Depending on the nature of work the generator does, this tank can be replaced by a larger tank. Where a different tank is used, there is need to calibrate the tank for easy determination of diesel level to prevent unexpected shutdown of the generator set as a result of empty fuel tank. In this work, the tank is divided into five sections; empty ($^0/_4$=0%), one-quarter ($^1/_4$=25%), half ($^1/_2$=50%), three-quarter ($^3/_4$=75%) and full (1=100%). The diesel level is thus measured by eye gauge, i.e. looking at the diesel level in the tank and comparing it with the division stated earlier. This is for easy interpretation by operators. Once the diesel goes below 25% mark, the software indicates the need to refill the tank within a specified time to prevent shutdown.

The diesel generator is a water cooled engine, hence the need to maintain an acceptable water level to prevent engine overheat. The 800KVA Perkings generator has a 100 litres radiator which is the required quantity with its low mark at 50 litres. Hence, the water level should not go below half.

The oil level is read using a dipstick which has three calibrations; low mark, good mark and full mark. The oil dipstick of an 800KVA Perkings generator is 28cm in length having 2.7cm for the low mark region, the accepted region covers 5.4cm after the low mark (8.1cm from the tip of the dipstick), and any point above this accepted region is considered as full, which also is not acceptable like the low mark region because it may cause oil overflow. Oil level should be measured before the engine is put on.

The generator key started is usually powered by a battery. This battery should be maintained at a certain voltage to effectively start the generator when needed. Weak or undercharged batteries are common causes of standby power system failures. Even when kept fully charged and maintained, lead-acid batteries are subject to deterioration over time and should be replaced as specified by the manufacturers. A fully charged lead-acid battery has a voltage of about 12Volts (some having 12.6Volts) and a specific gravity of 1.260. The 800KVA Perkings generator uses two of such battery connected in series (giving an effective output voltage of 24Volts). Once the battery goes below a specific gravity of 1.215 (which is 75% of the battery), it is recommended to charge the battery (Rolls Battery Engineering, 2014). A battery hydrometer is used to check the specific gravity of the battery electrolyte in each cell while a multimeter is used to measure the battery voltage at the terminals.

Dynamic balancing of the generator rotor assembly has been carried out during manufacture to ISO 1940 Class G2.5 (KATO Engineering Inc., 2010). However, torsional vibration occurs in all engine-driven shaft systems and may be of a magnitude to cause damage at certain critical speeds. It is therefore necessary to consider the torsional vibration effect on the generator shaft and couplings. This can be determined mathematically using equation 1 below (Khurmi and Gupta, 2005; Sharma and Aggarwal, 2006).

$$\theta = \frac{\frac{60p}{2\pi n} \times L}{\frac{\pi d^4}{64} \times G} \quad (1)$$

Where:

L= Length of shaft (m)

G= Modulus of rigidity of crankshaft material (GPa)

p= Rated power output (KW)

n= Speed (rpm)

d = Shaft diameter (mm)

θ= Angular deflection as a result of vibration (mm)

Vibration value determined from equation 1 is compared with vibration levels displayed in table 1 below.

Table 1: Vibration levels measured on the generator (KATO Engineering Inc., 2010).

Engine RPM	KVA	**Vibration displacement mm (rms)**	**Vibration velocity mm/s (rms)**	**Vibration acceleration m/s2 (rms)**
Four pole	10<KVA≤50	0.64	40	25
1500 rpm, 50Hz	50<KVA≤125	0.4	25	16
1800rpm, 60Hz	125<KVA≤250	0.4	25	16
	250<KVA	0.32	20	13
Six pole	250<KVA≤1250	0.32	20	13
1000rpm, 50Hz	1250<KVA	0.29	18	11
1200rpm, 60Hz				

Starting the 800KVA Perkings generator, the air inlet valve is adjusted to let in air, this air is called the starting air. The starting air is used to initially turn the main engine and other auxiliary engines during starting by the use of pressurized air. The maximum air needed to crank the engine is air flowing at a pressure of 30 bars, but it ranges from 20-30bars.

For the sake of this work, a pressure gauge is attached at the air inlet valve, to measure the amount of air entering the engine at startup.

Efficient performance of the generator set entails maintaining moderate operating temperature. Normal operating temperature of 800KVA Perkings generator is 20°C-50°C. This temperature can be monitored using a thermometer attached to the body of the generator.

2.6 Software Validation Test Procedure

Data collected from the three generator houses (800KVA Perkings generator) in Michael Okpara University of Agriculture Umudike, MOUAUie: Administrative block generator, School generator and new hostel generator were used for the software validation. The Administrative Block generator runs an average time of nine (9) hours daily while the other two generators (as listed above) run for an average of five (5) hours daily. As a result the Administrative Block generator is serviced within 3months interval while the other two are serviced once in six months except when unexpected breakdown occurs.

The administrative block generator works 5days a week (working days) making a total of 45hours a week hence, a total of 540 running hours for 3 months before each maintenance. The school generator and new hostel generator run seven (7) days a week making a total of 35 operating hours a week and 140 hours a month. Hence, both generators run a total of 840 hours in 6 months before their respective maintenance.

3.0 Results and Discussion

The operational parameters taken from the three generators discussed in the previous section is presented in Table 2 below.

Table 2: Operating conditions of selected generators in MOUAU

S/n	Parameter	Acceptable Range	Administrative block gen (a)	School gen (b)	New hostel gen (c)
1	Water level (L)	50-100	100	100	80
2	Temperature (°C)	20 -50	45	38	40
3	Air inlet pressure (bar)	20-30	25	25	25
4	Battery voltage (Volts)	24	24	23.7	23.6
5	Oil level (cm)	7.1-2.8	6.5	6.7	5.6
6	Diesel level (%)	25 – 100	50	75	75
7	Vibration (mm)	0-0.4	0.31	0.38	0.35

These values were inputted into the developed software and the overall status of the three generators were displayed as shown in figures 5 to 7 below by clicking the check gen status button.

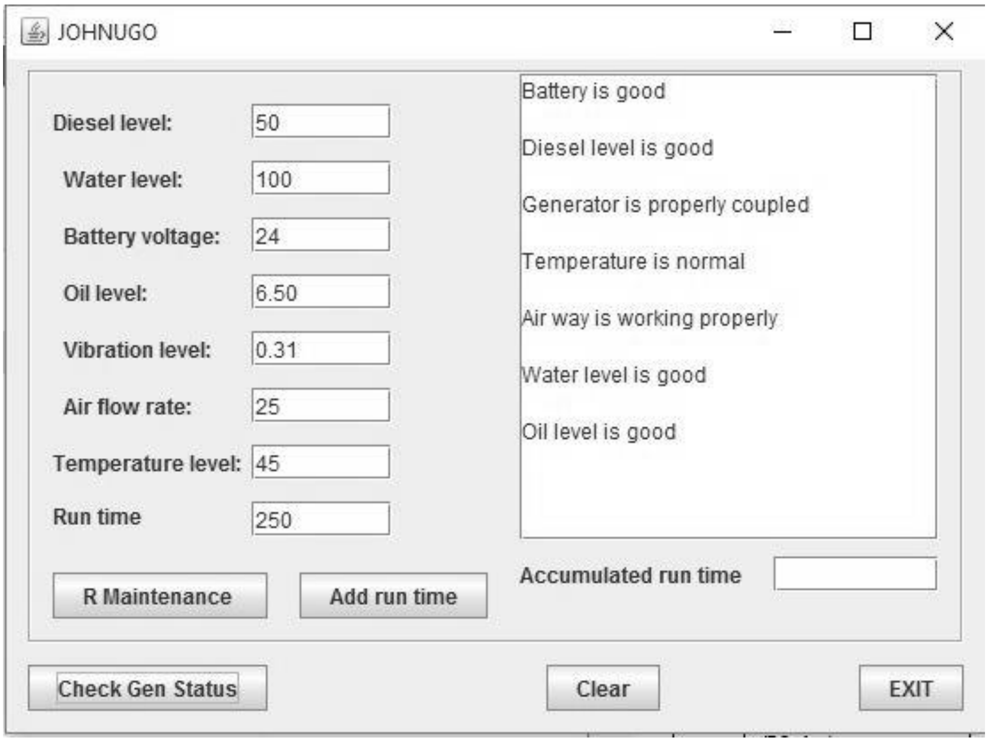

Figure 5: Operating condition of the Administrative Block generator

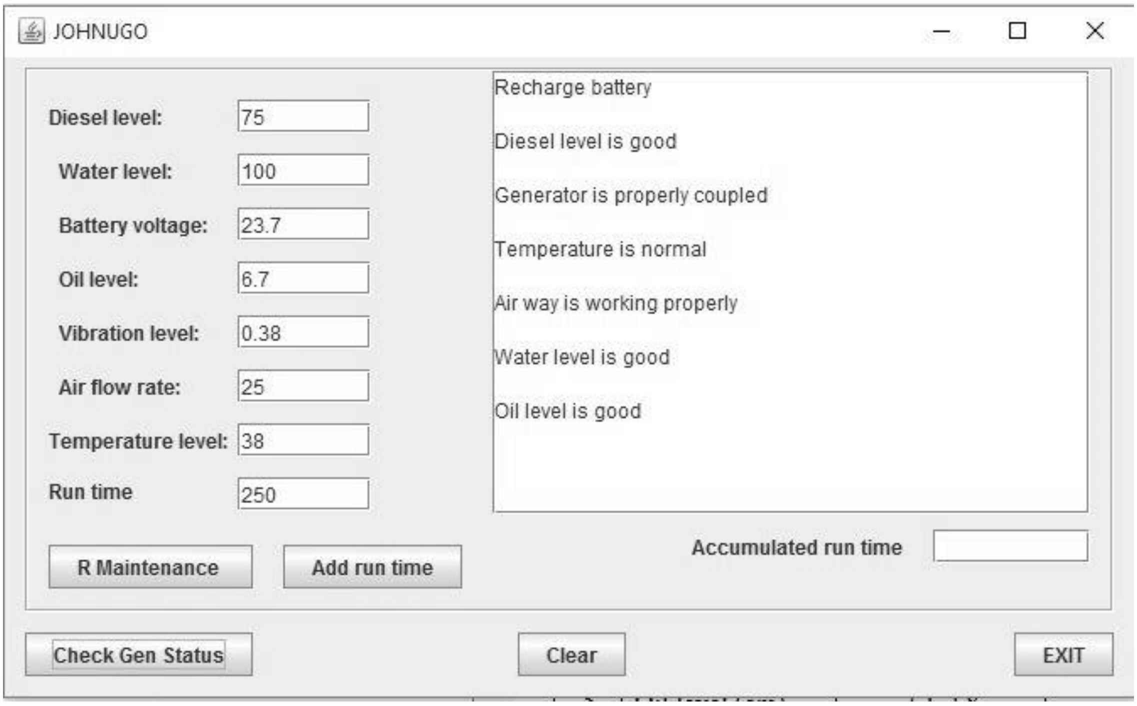

Figure 6: Operating condition of the School generator

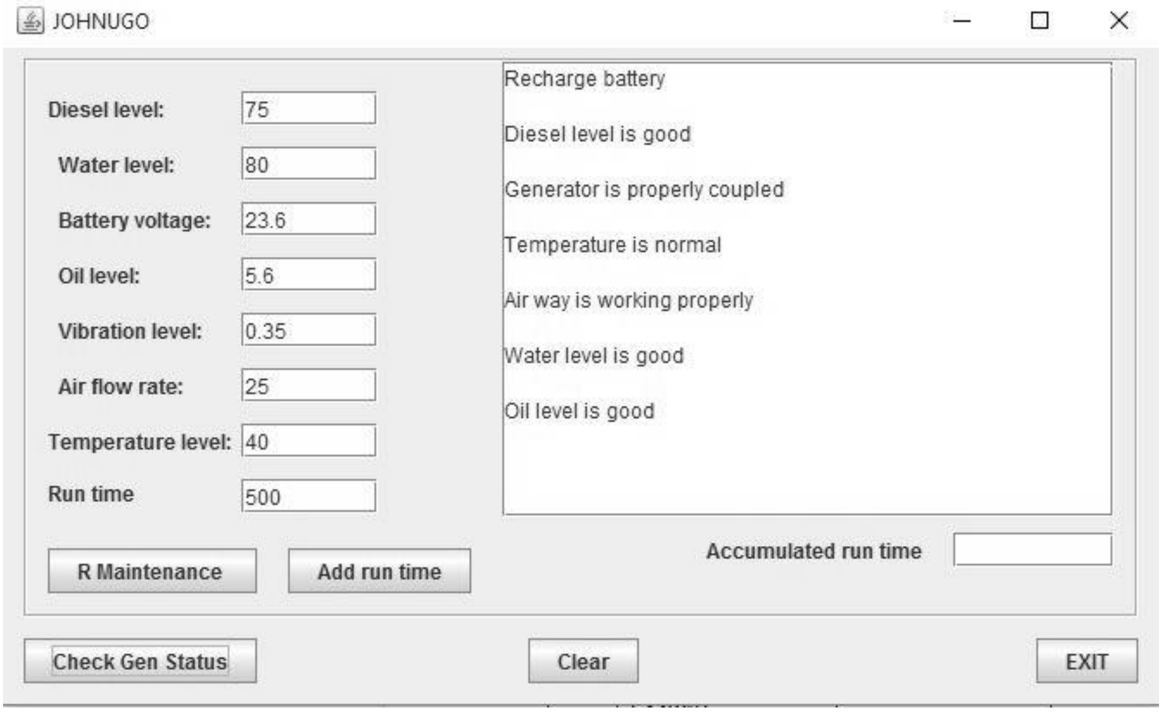

Figure 7: Operating condition of New Hostel generator

The software recommends inspection/adjustment of the alternator and fan belts after every 250 running hours. If this measure is not taken, the belts may slip or twist as the case may be leading to unexpected breakdown of the generator set. Maintenance operations recommended by the software after 500 running hours are shown in figure 8 below.

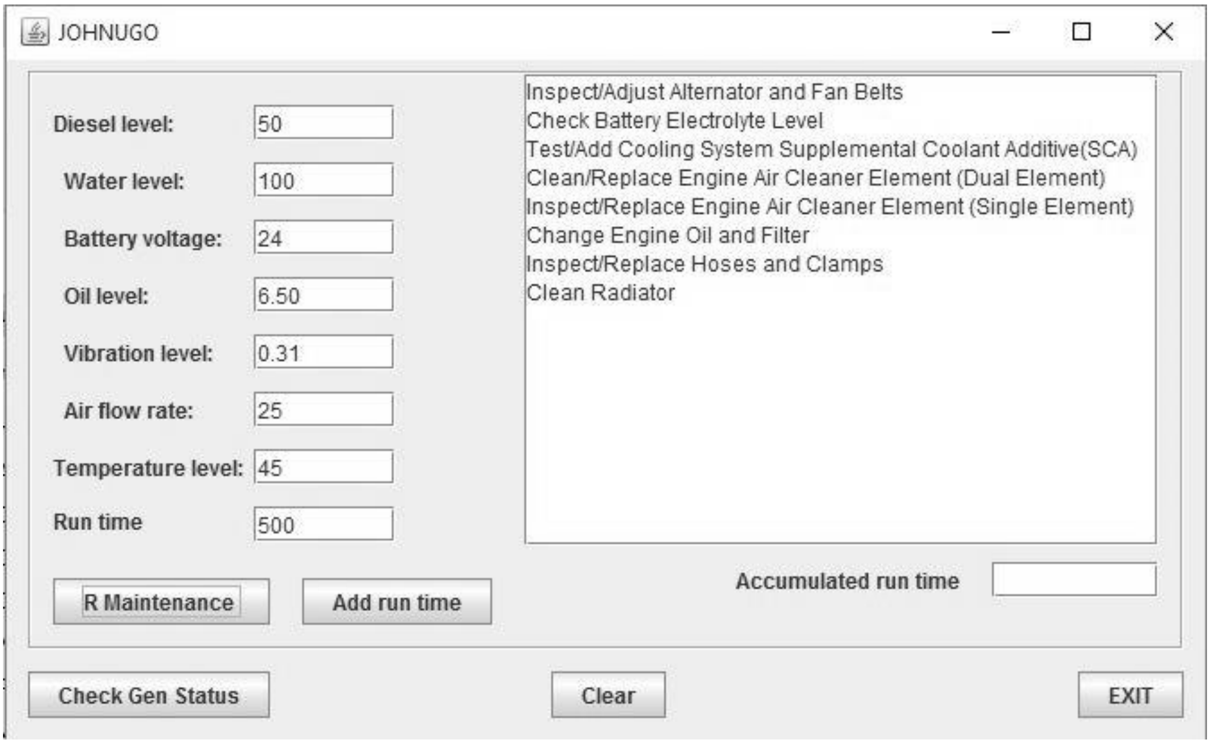

Figure 8: Recommended Routine maintenance for 500 run hours

From figure 8 above, it can be seen that the service scheme of the three generators are inappropriate. The Administrative generator which is serviced after 540 hours of operation run a risk of 40 hours without servicing while the School and New Hostel generators which are serviced after 840 hours of operation run even a greater risk of 340 hours without due maintenance. This explains the reason of the frequent breakdown encountered by these generators, especially the School and New Hostel generators. The fan belt for instance should be checked and adjusted 3 times within 840 running hours of the generator.

4.0 Conclusion

A software for scheduled maintenance scheme of a diesel generator set was designed, developed and tested using 3 800KVA Perkings generators located in Michael Okpara University of Agriculture Umudike (MOUAU). This software was designed to improve the efficiency and performance of diesel generators and reduce the risks and losses associated with unexpected breakdown of diesel generator sets. Also, the developed software automatically detects faults and proffers solutions when some operating conditions (diesel level, water level, battery voltage, oil level, vibration level, air flow rate and temperature) are taken from the generator and fed into the software.

The developed software will reduce the rate of diesel generator failures and reduce the losses associated with unexpected diesel generator breakdowns. This software being user friendly will bring diesel generator maintenance to the level of anybody who can read and write. Hence, saving the expenses incurred in frequent hiring of skilled technicians.

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