Data Acquisition System for Preventive Maintenance of Equipment in the Urban Tunnels

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Abstract. Urban Tunnel construction for supporting the Under-ground Transit Solutions (UTS) namely Metros and Subways in highly densely populated locations involves huge power requirements. This power requirement is normally met by the power supplied by the power agencies for the over the ground requirements. However, in the cases of underground work at the drilling site or de-watering sites we need to use the smaller portable generator sets. These generator sets generate a lot of harmful gases and CO2 and in-cases of over loading lead to short circuits and also fire. In the cases of prolonged tunneling times these generators remain inside the tunnel and are not serviced on time leading to gen-sets often going out of order leading to loss of work and may also cause accidents. Regular maintenance enhances the lifespan of the generators. This paper takes the approach to provide a solution to the preventive generator maintenance problems which would take care of reliability issues. In the proposed design we monitor the vital parameters of the gen-sets like fuel levels, temperatures, loads (current and voltage), running time, last servicing time, average fuel consumption, last serviced dates, battery voltages, Air filter life etc. This information is then collected by an on-board Data Acquisition System (DAS) which is then passed on to Cloud via a Wi-Fi connection. Once this information is made available on the cloud, we can apply the Machine Learning Algorithms to predict the failure rates of the generators and calculate the RUL - Remaining Useful Life.

Keywords: Fault diagnosis, preventive maintenance, generator condition monitoring, remaining useful life.

1. Introduction

Diesel Gen-set or Diesel Generator or DG Set is an engine-generator combination i.e. an Electric Generator powered by a Diesel Engine which in conjunction is able to produce electrical energy. DG Sets use Diesel or Natural gases for their operations. Normally they are used in places where the grid supply is in scarcity or is irregular or fluctuating or requires peak-lobbing (process of adding synchronized power to the load to meet the peak power requirements of the load).

1.1. Background

The urban tunneling sites uses the power from the power supplying agencies like the national grid. Portable generators are the last point connect when the power needs to be provided for the workers and the smaller equipment like small drillers, cutters, lighting and de-watering. Based on the power of the generator the complexity increases and the reliability is of prime concern. For any tunneling operations the maintenance of all the equipment is of prime concern which also needs to take care of "Value for Money" without compromising on the congestions and safety.[1] The national electrical grids are delivering the electricity reliably to industries and homes around the world. However, in a large part of the world the power outage is random i.e. not planned, working on the tunneling sites with the power
from the grid is done for the non-critical works or the works which if interrupted will not cause any damages. All critical tasks are performed with the DG Sets which cannot be interrupted or at the end nodes where local power is required like the end of the tunnel. Thus, the reliability of these DG Sets becomes most crucial issue. Incase water is detected it needs to be pumped out at the earliest. Ground water or water found during the tunneling process can two major types of issues:

1. Inundation or water filling (flooding) of the shaft or the tunnel by the water inflow.
2. Instability of base due to unrelieved water pressure or seepage.

Thus, de-watering is a critical task that needs to be immediately and is normally done by pumps running on the DG Sets. This is one of the critical tasks being handled by the DG Sets.

1.2. Statistics

According to a study by MIT on the generator sets used in the military bases, the DG Sets were working much lower than their rated specification capacity. In certain cases, it was in the range of 10-30% of the rating on the nameplates. Due to this the fuel efficiency of the Generator goes down and the maintenance costs associated with the working rises way above the stipulated budgets. [3] Picking the data for the reliability of the generators in general from the wind power generators 25%~35% of the total maintenance costs is spent on the preventive maintenance and the rest 65%~75% is due to unscheduled, unforeseen, unplanned corrective maintenance. [4] If the smaller failures are not corrected in time the damages can go up by 100 times. For example, a normal bearing failure if not corrected can result in the damage of the entire gearbox, which might be 100 times more expensive than the bearing. This may also lead to much longer downtimes. Further due to preventive maintenance even a little increase in the efficiency of fuel and downtime can result in major savings for the industry where the generator is being used.

A portable 5.5KVA Generator weighing about 80Kgs may use about 4 Liters of fuel per hour if running at the rated loads and efficiency. Any decrease in the efficiency causes serious losses to the projects as they are in use for long hours of operations.

1.3. Preventive Maintenance

For any industrial growth and prosperity, the equipment and machines play a very important role and hold the central position. Loss of time due to the failure of the equipment leads to loss of market and competition getting undue advantage. To tackle this kind of problems preventive maintenance is of utmost requirement. As of now, every year approximately € 7,000 billion globally and € 1,500 billion in EU is spent of MRO - Maintenance, Repair and Renovation. [5] Preventive Maintenance is a periodic action that can detect, avoid and mitigate the component deterioration to extend / maintain the life degradation to an acceptable level. This maintenance can be of two types: 1. 'Strictly Periodic' and 2. Device status based. For 92% of the components 'Strictly Periodic' maintenance is too expensive hence we propose capturing of the data from the equipment (DG Sets in this case) and help maintaining it. [5].

2. Proposed Method

The techniques required to perform the preventive maintenance works on the data being collected from many devices over a long period of time. Any Machine Learning algorithm would require the data from the devices to be present at a common location say a server where the code in python or R may be executed and the model can then predict the RUL. This data needs to be acquired by the DAQ which is connected to the Generator set which will have various sensors connected to it. The research being conducted requires the sensors data to be present on a cloud location. The next part of this research work will be on predicting the maintenance cycle required by the Generator set based on the live data which would be acquired by this mechanism. In the scope of this paper we would be collecting the data from various sensors connected to the DG Set and pushing the same to the cloud using the 'GET Methodology'. This pushed data would be stored in a SQL database and the same can be depicted on various charts and graphs. In this paper we will be demonstrating the data reaching a cloud space. In
this paper we will be sharing the various steps taken to make this project which would require planning for the block diagrams, flowcharts, and then taking it to the actual schematic and PCBs and then to the final form factor required to be mounted on the DG Set.

3. Block Diagram
The Sensor Data Collection System for DG Sets (SDCSDGs) primarily consists of the following components:

1. Main Controller - PIC18F26K22.
2. Analog Sensors on the Input side.
3. Wi-Fi Transceiver ESP8266.
4. Power Supply to the circuit.
5. Debugging ports.
6. Alarming / Alerting system by means of a Buzzer.

![Figure 1. Block Diagram of the Generator set DAQ (Data Acquisition System)](image)

The system provides a mechanism to collect the data from various sensors listed below which are polled in a sequential order and converted into the data to be evaluated and pushed onto the cloud.

1. **Float Sensor** - A resistive type float sensor is utilized in our design to sense the level of the fuel in the Generator set. Based on the readings from this sensor we will be able to calculate important features like the fuel consumption rate, fuel leakage, remaining running time and can be used for planning for the next fueling scheduling.

2. **NTC Temperature Sensor** - In our design we are using TANRD103R1B3977M35Lxxx the NTC thermistor with Resistance at 25°C has resistance as 10000 Ohm with ±1% accuracy. The B-Value (25/85°C) is 3977K with ±1% accuracy. The DG Sets during their running time will get heated and can become very heated incase the DG Set gets over loaded. At such times the system needs to be switched OFF soon as failing to do so may cause fire hazard and permanent damages...
to the DG Sets. Inside the tunnel a fire case can cause heavy casualties.

3. **Current Transformer** - A HK050T03 Split core Hall effect current sensor capable of measuring up to 50A in an Open loop configuration which is a voltage O/P sensor is used to measure the current being utilized from the DG Set. Split core sensor was utilized to avoid any cutting of load wires to insert in series.

4. **Potential Transformer** - A 230V AC in and 3V-0-3V AC output 250mA transformer is utilized to measure the AC voltage generated by the DG Set. This would also be utilized to calculate the power being generated in the system. The system will have to sample over longer times to measure the Max value and use it in the calculations.

5. **Battery Voltage** - The On-Board battery need to be always kept charged. This is achieved by providing trickle charging. However, many a times there can be issues with the charging system and also from the battery life point of view it might be reaching the EOL (End of Life). In such cases we connect the battery voltage via a potential divider to match the allowable voltage levels.

All these sensors would get sensed on the 10 Bit ADC which is available on the PIC18F26K22 IC. The Power for the electronics part is being generated from the output power of the DG Set so the system would always wake up and be ready when the DG Set is in use. The power supply consists of a step-down transformer which would convert it to nearly 12V AC which is then cleaned by filter capacitors and then passed through a Linear Regulator - LM317 is the variable regulator used in the design.

![Flowchart for the Sensor Data Collection done in the Microcontroller](image)

**Figure 2.** Flowchart for the Sensor Data Collection done in the Microcontroller
4. Flow Charts
The following stage by stage steam graph depicts the generalized flow of the code that will be running in the PIC18 Controller. This would involve the configuring of the various registers inside the controller starting from the peripherals like the power timings, Clock settings, IOs, UARTs, ADCs and the memories. Next stage is the initializing the variables to some known variables. After this begins the collection of the sensor data from various ADC channels involving the switching and selection of the ADC channels in the internal Multiplexer. After this we need to initiate the calibration and final values results calculation of the values to be depicted and posted on the cloud. For this we need to configure the UART with the ESP settings and then select the URL and using the get methodology we will be able to push the data to the cloud.

The url which we are using as of now to push the data is www.thingsoncloud.com which is a domain blocked for testing our data being pushed on the cloud. Later on, if the data size increases, we would move to the Amazon Cloud Services. Presently in the scope of this project we will be only pushing the data to the cloud and in the next part work on developing the algorithm to predict the servicing requirement and calculation of RUL which is the Remaining Useful Life.

5. Data Packet Information
A protocol involving the Data Packet formation is then initiated which will pack the data in some format involving the structure comprising of the following:
1. Start of packet Identifier.
2. Header
3. Device Identifier
4. Payload Data
5. CRC Check
6. End of packet Identifier

| Sr. No | Particulars            | Size in Bytes | Example             |
|--------|------------------------|---------------|---------------------|
| 1.     | Start of packet Identifier | 5             | `<****`             |
| 2.     | Header                 | 5             | MAMTZ               |
| 3.     | Device Identifier      | 10            | ABCDE12345          |
| 4.     | Payload Data           | 40            | 12345123451234512345123451234512345123451234512345123451234512345 |
| 5.     | CRC                    | 1             | 0x55                |
| 6.     | End of packet Identifier | 1             | >                   |

Table 1. Data packet formation and example

| Sr. No | Particulars            | Size in Bytes | Example       |
|--------|------------------------|---------------|---------------|
| 1.     | Float Sensor Data      | 5             | 01024          |
| 2.     | NTC Temperature Sensor | 5             | 01000          |
| 3.     | Current Transformer Reading | 5         | 00255          |
| 4.     | Potential Transformer Reading | 5            | 00512          |
| 5.     | Battery Voltage        | 5             | 00768          |
| 6.     | Miscellaneous          | 15            | 123451234512345 |

Table 2. Payload Data Identifier
6. Results and Discussion

Our device is configured and able to push the data to the cloud which can be seen in the screenshot in the figure 3. The website is using php, html and MySQL as of now to make sure that the data is captured and stored in the database. The variables can be seen distinguished in the current snapshot on the web in figure 3. Further the hardware is capable of collecting the data from the sensors which can also be seen in the figures 4 and the box design can be seen in figure 5 and figure 6. We can see that PIC18F26K22 is being mounted on the PCB and ESP8266 along with the Bluetooth HC05 is being used for pushing the data to the cloud and also to perform the PC Debug feature.

Figure 3. Snapshot of the data being available on the cloud which has been developed in php

Figure 4. Snapshot of open box design displaying the PCB with Wi-Fi and Bluetooth Device
7. Conclusion
With the current solution we feel that the data across the DG Sets can be collected and placed on the cloud and then many preventive and predictive maintenance calculating Machine learning algorithms can be developed. With this paper we have shown the methodology that be used to collect the data from various sensors used to collect the data from the DG Sets. This data will be available with us for long time and we will be able to develop algorithms. Futuristically, the same data acquisition system might also be able to collect data from other equipment employing the same design and data path. With this equipment we will be able to make prediction about the maintenance of the DG Sets and suggest usage patterns and the Remaining Useful Life (RUL). Because of this device the tunnel making agencies would be benefitted in pre-planning their schedules and would be clear about the downtimes.
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