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Smart Tunnel IoT System For Surveillance And Predictive Maintenance

T. Athanasopoulos[a,*], A. Depastas[a], A. Lytis[a], P. Vlagopoulos[a], S. Polymenakos[a], K. Spyropoulou[a], G. Mavropoulos[a], G. Chasanis[b], E. Nikiforakis[c], E. Theodorou[c], A. Daskalopoulos[c], E. Zervakis[a]

[a]*European Sensor Systems, 62 I. Metaxa str, Koropi-Athens 19441, Greece*
[b]*Olympia odos, 4 Rizariou str, Chalandri-Athens 15233, Greece*
cEX Machina, 89 Chalkidikis str, Athens 11855, Greece

athanasopoulos@esenssys.com

Abstract

An advanced IIoT system called "Smart Tunnel", aims to improve the monitoring and infrastructure maintenance programs using the new Internet of Things tools and data analytics methodologies including Machine Learning and Artificial Intelligence. The system presented by ES Systems provides permanent monitoring of tunnel equipment through various sensors. The data are wirelessly transmitted to the cloud through intelligent data collection and data processing nodes and input to the predictive maintenance analytics systems and algorithms. ES Systems has recently completed the installation of the first condition monitoring system within a tunnel of a motorway in Greece for Olympia Odos. The Smart Tunnel helps increase equipment life, improve safety and service intervals, and significantly save tunnel maintenance costs by transitioning from preventive maintenance to predictive maintenance.

1. Introduction

The monitoring and maintenance of tunnels around the world is a critical and expensive task. Tunnels' equipment must be in perfect condition as it is crucial for the drivers and infrastructure safety. Usually a standard tunnel set of equipment includes:

- Jetfans that provide an airstream in the case of fire.
- Water Pumps that are used to extinguish fire.
- Battery Banks and Diesel Generators used in case of power loss
- Light Arrays
- Electrical Panels and Transformers

The systems must be continuously monitored so as to ensure perfect condition in order to be ready to respond in an emergency situation. Up to now the maintenance was based in manually scheduled heavy maintenance (preventive maintenance). ES Systems has developed a smart IIoT system that not only monitors continuously all the aforementioned equipment but also checks their condition and rases alarms in case an anomaly is detected and proposes maintenance tasks to be scheduled for a particular or a set of equipment. The integrated sensors of the system collect data from generators, pumps, Jetfans, electrical systems (batteries, UPS, electrical panels, transformers), as well as environmental parameters of the tunnels. All recorded data are used to detect any anomalies and also observe the performance of each element in order to predict any upcoming failures. As a result the system will increase equipment life, improve safety, and significantly save tunnel maintenance costs by changing from preventive to predictive maintenance.

2. System Description

In order to monitor each equipment separately the appropriate physical quantities have been chosen to be recorded.

- **Jetfans:** Vibration, Temperature, Power Consumption, Operating Hours
- **Water Pumps:** Vibration, Temperature, Power Consumption, Operating Hours, environmental humidity
- **Diesel Generators:** Vibration, Power Generated, Operating Hours
- **UPS Battery Bank:** Voltage, Charging Current, Internal Resistance
- **Environmental Monitoring:** Humidity, Temperature, Corrosion Rate

Each equipment was measured individually using vibration sensors, temperature sensors, power meters, humidity and corrosion sensors and even thermal cameras.

Data from all sensors are aggregated (wirelessly or wired) by ES Systems' smart IIoT controller. The IIoT Controller collects data from the sensors and transfers the collected data to the Cloud back end in order to store them in time series databases as raw data. The Smart Tunnel platform applies big data analytics and machine learning logic in order to provide predictive maintenance based on anomaly detection and trend analysis models. The complete system operates on an autonomous Wi-Fi network and Internet connection is based on a 4G data connection. In Fig. 1 and Fig. 2 are depicted the System description and architecture. The results will be the outcome of a set of processes running in conjunction at the edge, at the gateway and the cloud.

The system provides necessary data preparation mechanisms to support the integration of third party analytics software, data processing for the local analysis algorithms, data processing on the platform itself allowing for machine learning models to be trained on the data sets and presentation of deduced results on the platform. This is done by applying specific models for each type of equipment. Where applicable models and data fusion will take place for all the data to generate useful equipment insights in terms of equipment health, operating conditions, effective operating duration and maintenance schedule decision support.

Each type of equipment is handled separately but data from different equipment or environmental data from different locations will be used to conduct fused data analysis.[1]

Figure 1: System Description.

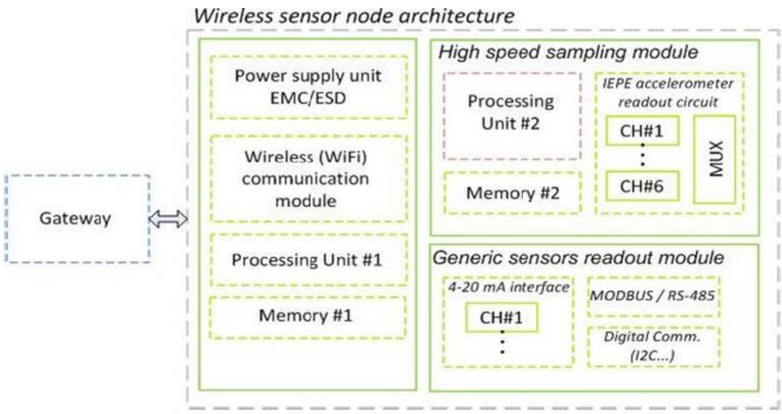

Figure 2: Wireless sensor node architecture.

Status and temperature data are transmitted every minute whilst vibration and power data transmission is triggered on generator start up. In Fig. 3 is depicted the vibration sensor location in the Jetfans. Three single axes vibration sensors are installed on each Jetfan. In Fig. 4 and Fig. 5 are depicted the data collected from one vibration sensor during the operation of a Jetfan. [2],[3]

Figure 3: Installed vibration sensors on a jetfan.

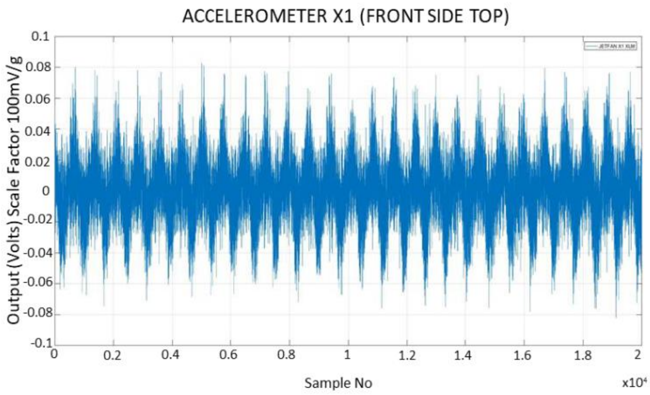

Figure 4: Jetfan vibration sensor output.

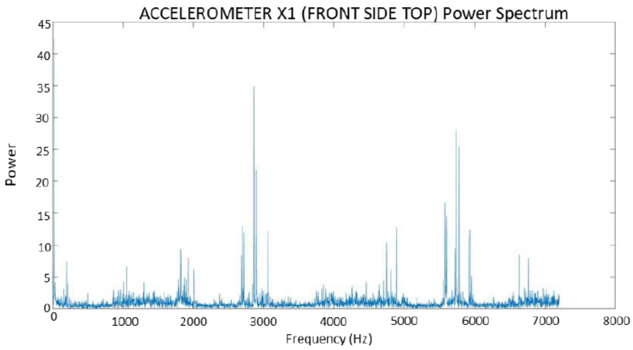

Figure 5: Jetfan power spectrum.

The battery monitoring system depicted in figure Fig. 6 is checking and recording continuously the battery voltage, temperature and internal resistance. The total battery string voltage is also monitored. Additionally relative humidity and temperature measurement of the battery room is recorded. The sensor nodes are connected via Wi-Fi and transmit data using the MQTT protocol to the gateway. Status data transmitted every 5 minutes and data every one minute.

Figure 6: UPS Battery String.

Fig. 7 shows a snapshot of the battery monitoring software.

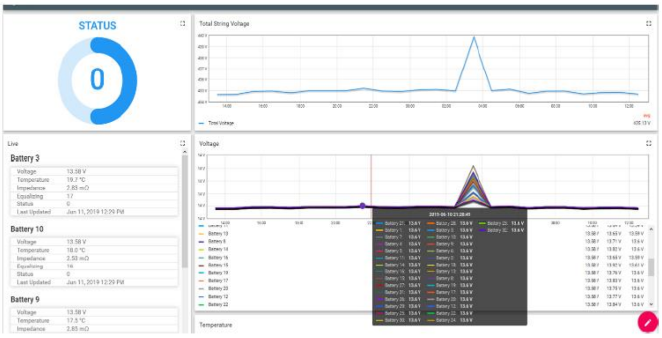

Figure 7: UPS battery string data.

Inside the tunnel a corrosion sensor is installed which provides real-time measurements (shown in Fig. 8) of the amount of corrosion forming on copper and silver surfaces by corrosive gases present in the local environment. It also measures the temperature and relative humidity of the environment, both of which can affect the corrosion rate of these metals. It is important to take corrective action at the time these dangerous atmospheric shifts occur instead of after damage from corrosion has taken place.

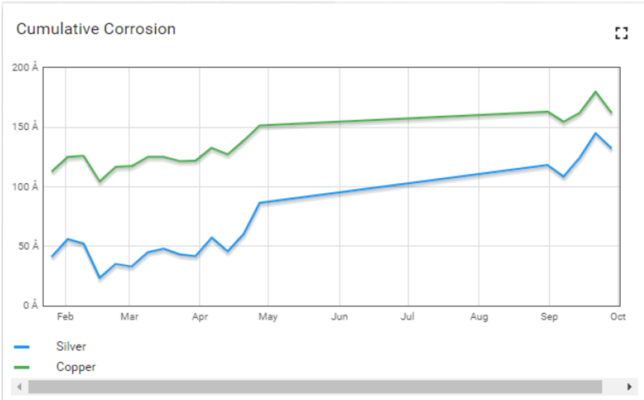

Figure 8: UPS battery string data.

In Fig. 9 and Fig. 10 are depicted the results form temperature and humidity sensors respectively.

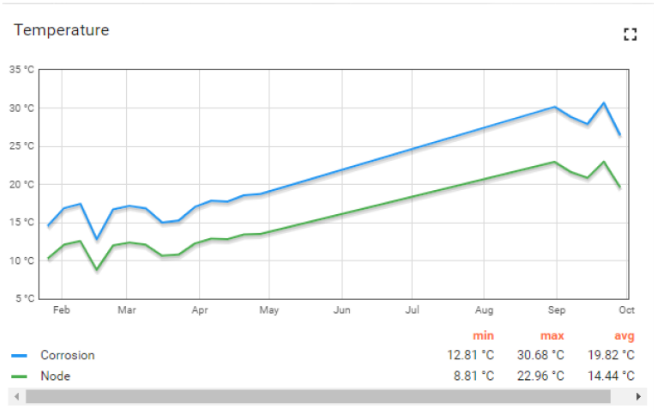

Figure 9: Temperature sensor data.

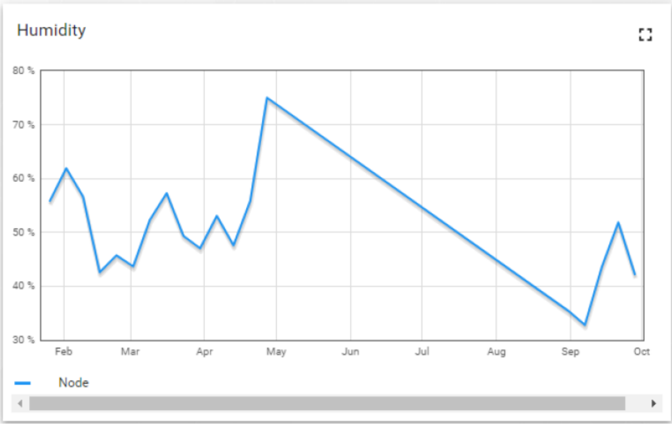

Figure 10: Humidity sensor data.

As soon as the data analytics goals are achieved, for example anomaly detection mechanisms are operational, an alerting mechanism has to be enhanced, for users to take advantage of the platform's insights promptly.

3. Conclusions

In this first pilot phase only one tunnel equipment was monitored towards the feasibility of data acquisition and data transmission and storage as well as the data sanity and measurement quality. Each tunnel pair is supported form the corresponding control station. One set of each type of equipment has been monitored within this pilot phase. More specifically a jet fan, 3 water pumps, a diesel generator and a string of 32 UPS batteries were installed with sensors and monitored. Additionally the environment conditions were monitored inside the tunnel and the control room. Each equipment was monitored using different kind of sensors appropriately selected for each operation and physical metric taking into account the application environment. All data were gathered and processed through the Sensor Node of ES Systems. The system proved the feasibility of the architecture and at the same time provided information for changes in the architecture of the next phase system to improve operating performance and cost allowing at the same time for system contingencies. The next step is the installation in more 4 tunnels in order to enhance the data set creating a data lake from a larger number of equipment with the same characteristics operating under the same conditions. This is the phase where the ML and AI will be implemented and evaluated.

Acknowledgements

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References

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[3] Mounting 4-20 mA vibration sensors on fans