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# Modeling of reciprocating renewable gas engines

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**Abstract**

Sewage and landfill reciprocating gas engines have proven to be a reliable energy power generation system when a proper maintenance schedule is done. The intrinsic nature of the stroke mechanism that creates parts movements and reciprocating masses supposes a challenge in order to improve maintenances schedules, reliability and availability. In the case of sewage and landfill gases that could not be properly cleaned, the engine reliability is more concerned. Asset monitoring systems that monitor and creates alerts when some variables are out of some limits are highly desirable. In this paper authors show how to create a virtual twin model from real data that could be optimized and compared in real time with working variables of the actual engines in order to predict future maintenance schedules and increase the engine availability. In sewage and landfill reciprocating gas engines this could have a positive impact of increasing the reliability and due to this, also the customer satisfaction. An accurate computational model is created taking some inputs and outputs to use it in an online cloud asset monitoring system so that it could be used as an extra supervisor agent.

*Keywords:* ECU, (Motor Control Unit), RDS (Remote Diagnosis System)

## 1. Introduction

Today gas engines are used mainly for power generation (including co-generations) and mechanical drive applications like compressors or pumps. In the case of power generation there are also different type of engine applications:

Continuous power generation: In this case the engines are running all day and as many hours as possible during the year in order to provide power. The fuel used can be natural gas but also other forms of gases like sewage, landfill or even hydrogen in the future. In these applications is also quite common to have co-generations that make use of the heat produced by the engine in order to maximize the plant efficiency.

Backup power generation: the engines are running just when there is no power from the grid. This is the application case of engines in hospitals, etc. In this application the engine runs a few hours a year but should be ready whenever the situation demands.

One of the key components in the gas engines today is the control system.

Figure 1: Siemens containerized CHP gen-set solution for Johannesburg, South Africa © Siemens

## 2. Background

The control systems in gas engines today are using an increasing number of sensors, actuators and have also to be integrated with other gen-sets devices. The control challenges are also increasing with extra complexity due to the new needs of operating the engines in the highest efficient points. Also, the demand for increasing complex predictive algorithms, condition monitoring and engines supervision requires that the ECUs implements a variety of communications protocols based on TCP/IP like Modbus, OPC, etc. so that other system can extract that valuable information that has the ECUs.

The reality is that all the predictive algorithms are not able to run or fit in the ECU that controls and protects the engine.
A digital twin or virtual ECU is needed that allows to complement the ECU algorithms with others based also on historic operating date, etc. (Yuan, 2018). At the same time although data is stored in the cloud the sampling capabilities and traffic demand does not allow to store data that has been sampled at a high rate like five milliseconds or 100milliseconds. This means that the actual control systems should be complemented locally by an edge device that allows to run complex algorithms that requires higher sampling. This edge device then could transfer to the cloud condition and predictive monitoring system the data from the ECU and also the result or post-processing of the complex algorithms calculations that are run in the edge device. In this way the condition monitoring system or digital twin will have sampled at a slower rate (seconds) and extra data already post-processed coming from the edge device.

The virtual ECU or digital twin will then be the responsible for running different models and comparing the results of these models against the real engine (Wang, 2018). In this way the digital twin would detect deviations from the expected engine behavior. The digital twin should be also capable of comparing itself against other digital twin models of other similar engines so that deviations from the expected behavior of one engine against other similar engine running on the same site or on other site could create or raise also deviation.

## 3. Gas engine control system – main components

The gas engine control system has the following main components:

- control ECU: It is the brain of the gas engine control. Receives the values of different sensors and digital/analog signals like power setpoints, start/stop. Etc. It controls different actuators like throttles in order to control the engine speed or engine generated power.
- power relay box: It is a cabinet or system that has higher power contactors, relays, etc. for the ECU to command the higher electrical devices like engine starter, pumps or preheating system.
- Engine electrical harness: Connects the ECU to the rest of the components (sensors, actuators, interface connectors to the customer, ignition coils, etc.).
- Engine instrumentation: Sensors for monitoring the most important variables in order to protect and guarantee the engine performance (emissions). The sensors can be basic sensors like pressure, temperature but. nowadays more advanced sensors that were just restricted for testbench environments are able to be used in the production engines like NOx Sensors, Combustion pressure sensors, etc.
- Throttles like the Mixture throttle that the ECU commands in order to produce more power when the engine is connected to the grid. The Gas valve throttle that the ECU commands in order to control the Air Fuel Ratio and engine emissions. The bypass valve throttle that the ECU commands in order to operate the turbocharger in an optimum operation point.

In the gas engines the ECU is also responsible for providing the spark through an ignition coils and spark plugs.
The ECU controls the ignition timing in order to operate the engine in the highest efficiency operating point but avoiding knocking (knock sensors).

The ECU implements also a variety of protocols like J1939, CANopen, Modbus /TPC, OPC in order to integrate with different devices.

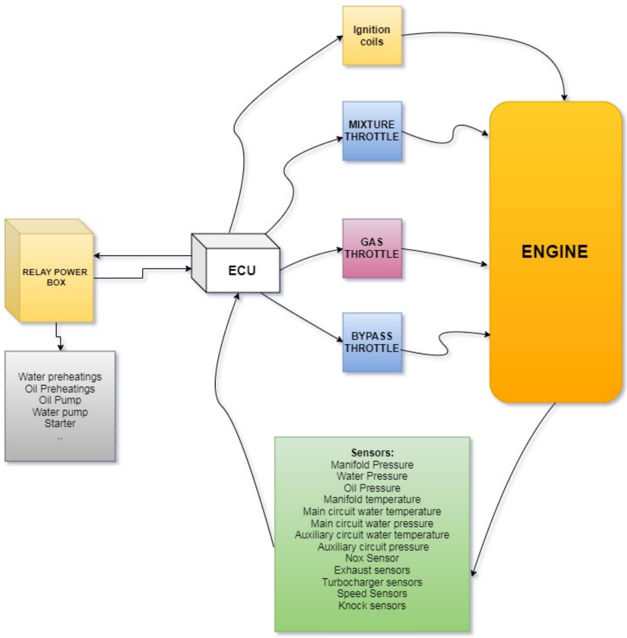


Figure 2: *Simplified Model of Gas Engine control system.*

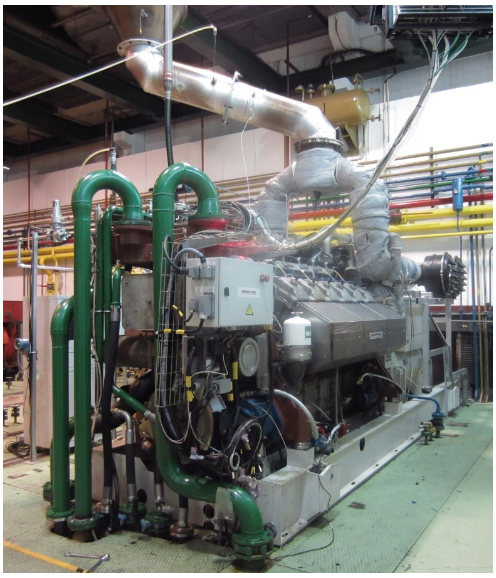

Figure 3: © Siemens Energy - Gas Engine

### 4. Diagnostics Service Center - Concepts

Nowadays in order to increase the engine availability the industry provides normally reactive technical supports that has the following flow: The control system detects an issue. A warning or shutdown alarm is generated. The customer contacts technical support in order to solve or troubleshoot the issue so that the engine can be restarted and again at full power the maximum time.

The industry is transitioning to a more proactive support in which a digital twin or extra algorithms are run in a cloud or virtual environment (GE, 2016). The digital twin is receiving real time date from the engine control system in a secure way. Extra algorithms or supervision is done in this digital twin environment, for example, checking values against similar engines running on the same site. Deviations are raised in the remote diagnosis center and a proactive approach is done so that the customer is advised before a shutdown takes place maximizing engine availability.

The main benefits of proactive support are:

- Train performance improvements: As extra algorithms that complements the control system are used, it is possible to detect deviations against the normal operation profile and analyze and understand in a better way the engine status by looking at online data and historic data.
- Forced outage avoidance: The deviations can prevent a possible shutdown in some weeks.
- Forced outage transformed into a planned activity: As engine hours, etc. are monitored an outage request can be automatically raised and an offer can be submitted to the customer with enough time for planning resources and parts

### 4. Data acquisition options

Different redundant data acquisition systems are already used in gas engines to record data:

- ECU email data: The ECU is able to send emails with periodic and mortem data to some mail server.
- CAN J1939 data logger: The ECU is connected to a J1939 bus in which a local data logger is connected. This logger is able to record data at a high sampling rate. The main drawback is that it requires also time for connecting to the logger and downloading the files.
- PLC data log System: The ECU is connected to a PLC device that add extra genset controls or site controls. The PLC is able to log files into an SD card. Data is stored always locally but when the SD card is full previous data is lost. It requires time to download the files and analyze them
- Remote diagnosis system: A data collector is used to transmits the data in a safe way to a cloud/datacenter environment. The data collector takes data from the PLC and the PLC takes the data from the ECU. It is possible to perform predictive algorithms in the cloud environment and monitor the data by using a browser without the need to download files

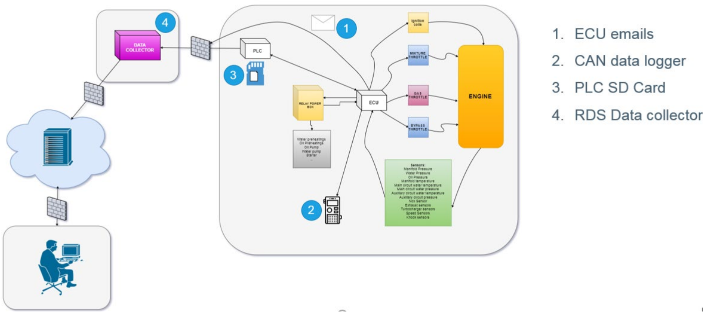


Figure 4. Different data adquisition systems

### 5. Conclusions

Digital Twins from provide an extra layer of predictive protection to an asset. It allows triggering new deviations before the ECU could have a real. This is happening nowadays and will become more important in the future as machine learning systems are democratized. Business that understands the importance of this predictive/proactive approach will have a competitive advantage from others that are focused only in reactive support.

### References

Yuan He, Junchen Guo, Xiaolong Zheng School of Software and BNRist Tsinghua University. 2018. From Surveillance to Digital Twin: Challenges and Recent Advances of Signal Processing for Industrial IoT, IEEE Signal Processing Magazine 35(5):120-12 DOI:10.1109/MSP.2018.2842228

Wang, Jinjiang & Ye, Lunkuan & Gao, Robert & Li, Chen & Zhang, Laibin. 2018. Digital Twin for rotating machinery fault diagnosis in smart manufacturing. International Journal of Production Research. 1-15. 10.1080/00207543.2018.1552032.

GE, 2016. https://www.ge.com/digital/sites/default/files/download_assets/ Digital-Twin-for-the-digital-power-plant-pdf?gecid=extref_dig_gepowercom