Dynamic fault-detection in shipboard electric load sharing

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Introduction

Marine diesel electric power systems are increasingly being utilized in the global maritime industry, and have become the industry standard for vessels with high need of electric power and large variations in power demand. In a marine diesel electric power system engines connected to synchronous generators are used to produce electric power. The power is then distributed to thrusters, drilling drives and other consumers. Since marine diesel electric vessels, are dependent on reliable power supply, the power system is among the most important systems on a marine vessel. The safety systems protecting a marine power plant consist of several levels. The power plant safety hierarchy can be divided in [6]:

- Primary protection system in breakers and switchboards.
- Power management system and blackout prevention/consumer control system.
- Load sharing monitoring system.

This work mainly focuses on level 3 in the hierarchy. The purpose of the load sharing monitoring system, is to prevent generator trip.

This work gives an introduction to typical failure modes, and state-of-the art fault detection in marine power systems. Further, a model for a marine power plant is introduced. In this model, different failure modes, common in marine diesel electric power plants, are modeled. Then three different fault detection systems are developed. Both the model of the power plant, failure modes, and fault detection systems are implemented in Simulink/MATLAB, in order to demonstrate the model performance.

References

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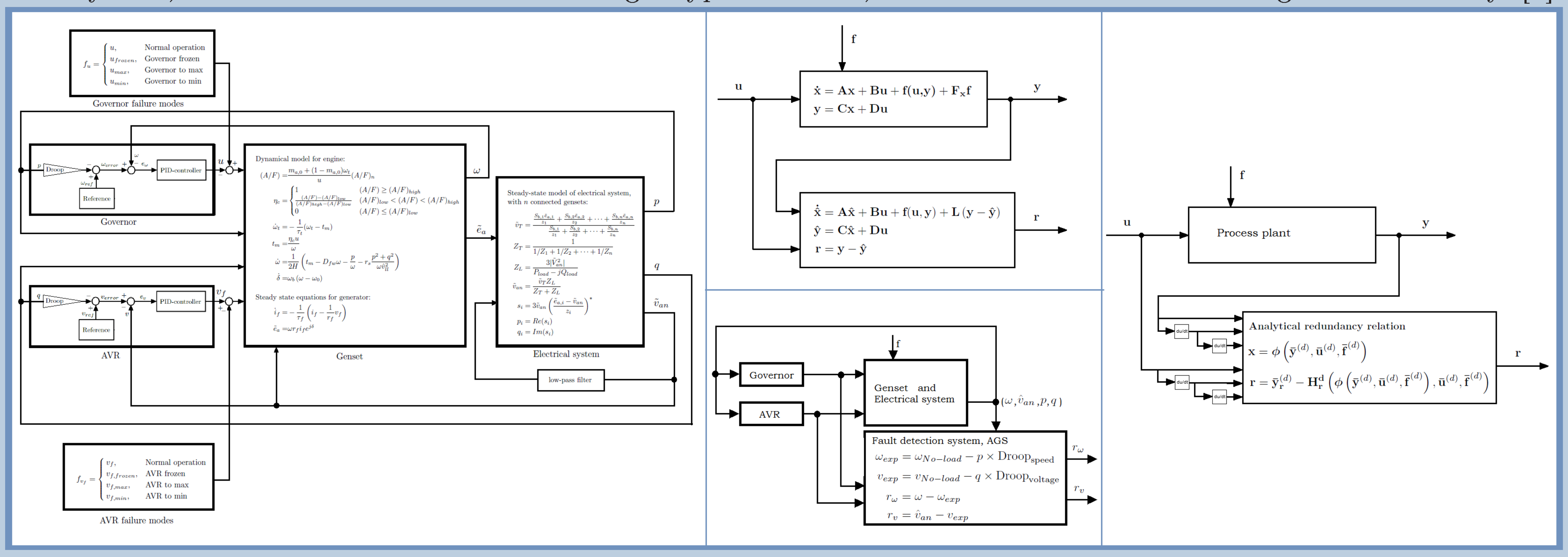
Modeling

The engine model is a dynamic model, including the limiting effect of the turbocharger. The engine model is based the model in [7], while the turbocharger model is based on the model presented by [8]. For the generator, and electrical system, a steady state model is used. The generator model is derived from the steady state model presented by [5]. For the electrical system, the equivalent Thevenin circuit is used to calculate the system parameters. The genset active power and frequency, are controlled by the governor, while the genset reactive power and voltage, are controlled by the Automatic Voltage Regulator (AVR). For both the governor and AVR, droop mode and PID-control are used. In order to prepare the simulator for fault detection, six different failure modes are implemented in the model.

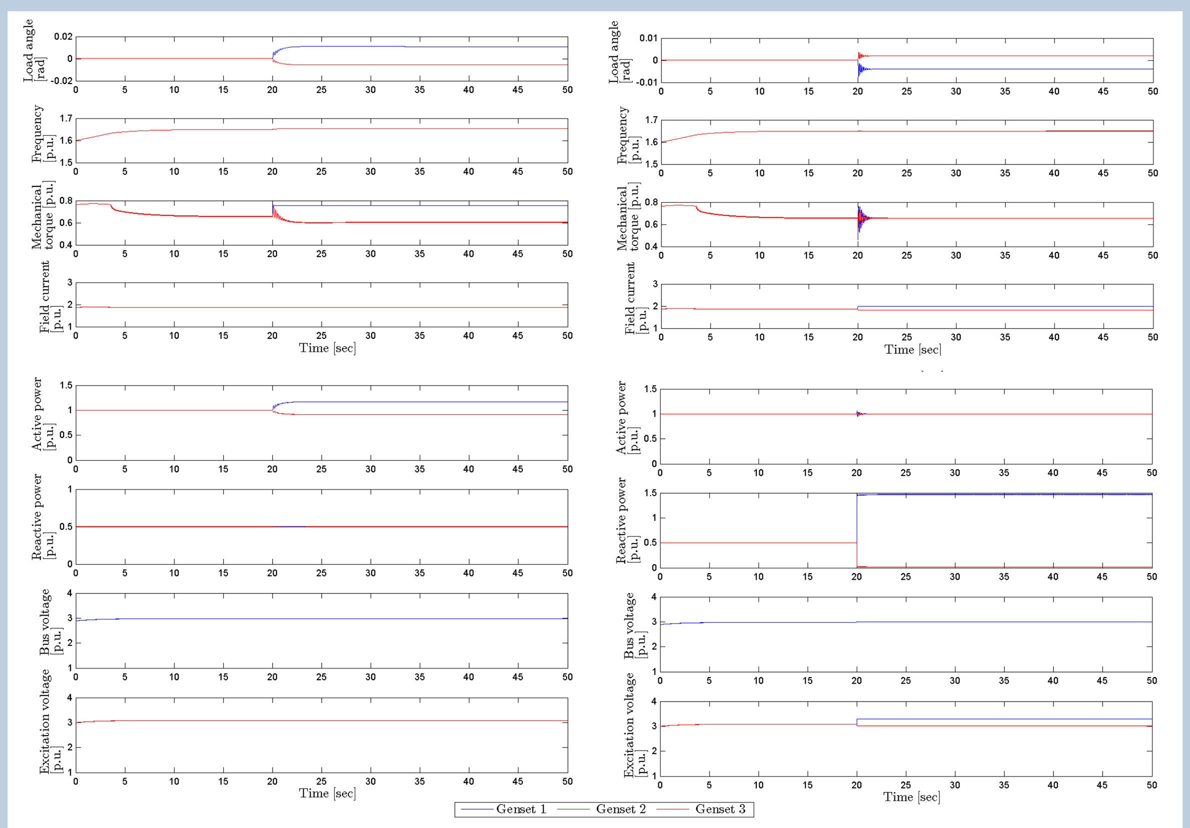
Three different fault detection systems are developed. The first one is a non-model based, but commonly used commercial system, namely Advanced Generator Protection (AGP) [3] [4]. Further, an analytical redundancy relation, based on a simplified, nonlinear model of the simulation plant model, is developed, in accordance with [2]. The same model is partly linearized, and used to develop a fault detection system, based on a nonlinear Luenberger-type observer, based on the observer design described by [1].



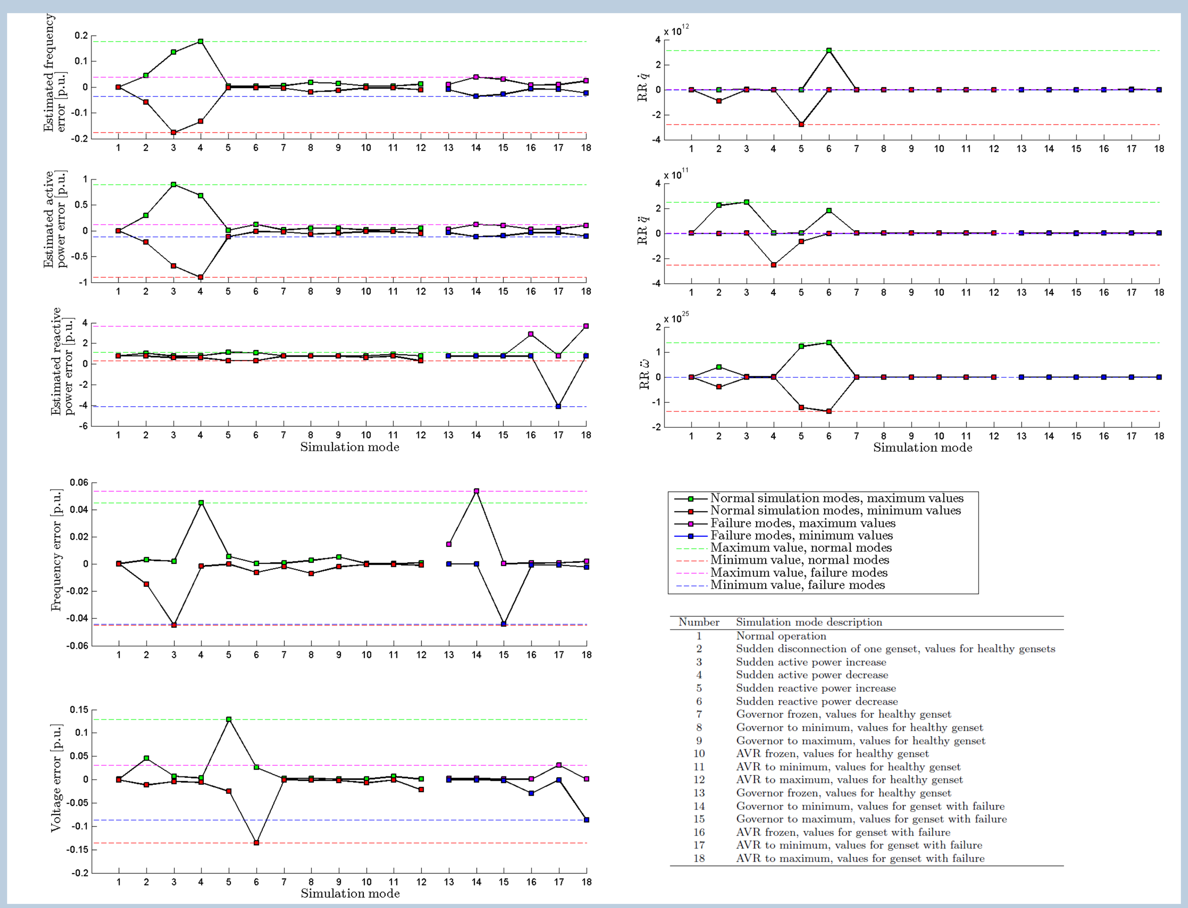
Left: Simulation plant block diagram, with equations and implemented failure modes. **Middle top:** Nonlinear Luenberger-type observer based fault detection system. **Middle below:** AGS with main equations and structure. **Right:** Analytical redundancy relation, fault detection algorithm and system structure.

Simulations

The below figure, shows results for running the simulation plant model with failure modes occurring after 20 seconds. The left part of the figure shows the system response to the fault governor to maximum. The right figure shows the respond to the failure mode AVR to maximum. It is seen that the model behaves as expected.



The below figure shows the maximum and minimum values of the fault detection algorithm **r**. **Bellow left:** AGS. **Above left:** Fault detection system based on nonlinear Luenberger-type observer. **Right:** Analytical redundancy relation.



It can be seen that the AGS and analytical redundancy relation fault detection systems, have a more adverse response to scenarios that are considered normal, than the failure modes. In other words, in the current state, the fault detection algorithms are not suited for fault detection. The observer based fault detection system however, is suitable for fault detection of AVR failure modes.