PS-11 HIL SIMULATOR OF PROPULSION ENGINE AND MICROPROCESSOR GOVERNOR

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1. Introduction

The contemporary stage of ship propulsion plant automation is characterised by the intensive introduction of microprocessor-based controllers to govern the main propulsion engines. Furthermore, modern marine engines combine various technologies to achieve superior efficiency and complex dynamic interaction between the engine elements imposes challenging control and dynamic optimisation problems. Since access to the engine test benches as well as engines on ships is limited, the development and excessive testing of the control systems to tackle these tasks are restricted. Moreover, possible faults should be detected as early as possible as well as a safe and reliable operation of the controller has to be ensured. Another way of accomplishing these tasks is to use a software simulation. Although it is widely applied, the tests are limited to the constraints of the simulation environment. A more complex and real testing environment is given by the usage of a hardware-in-the-loop (HIL) setup. In HIL applications, the controller connects to a virtual plant executed on a real-time simulator, instead of to a physical plant. Virtual plants provide a constant environment allowing for more repeatable results and provide for testing conditions that are unavailable on real hardware, such as extreme conditions or faults testing.

2. Overview of HIL Setup

The HIL test bench has been designed to facilitate the development and optimisation of power management strategy of a ship propulsion plant at the system level. The virtual propulsion plant is implemented on a system controlled by the real-time operating system (RTOS) using open-source software Scicos/RTAI-Lab[1]. The simulator is modular and consists of a propeller model, engine model and disturbance model representing actual sea behaviour. The simulator communicates with the real world using an analog-to-digital converter from National Instruments (NI PCI-6221). The microprocessor controller, based on a MicroDAQ platform[2], is interfaced with the simulator forming the closed loop HIL test bench as shown in Fg.1.

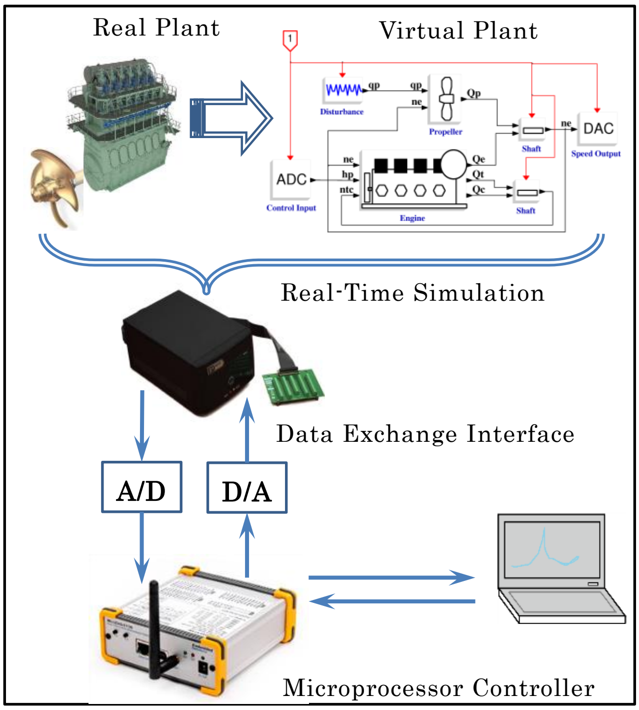

Fig.1 HIL simulator framework

3. Virtual Plant Model

The first challenge faced then developing the simulator is the components model that should meet the specific requirements. The key requirements are a) the time constant of the fastest element to be simulated, which in turn dictates the time-step, and b) the complexity of the system to simulate, which along with the time-step, dictates the computing power required.

3.1 Engine model

The main purpose of engine simulator is to capture the major dynamics intrinsic to the real engine. Cycle mean-value engine model provides capturing most of the physic phenomena in the engine system components, except for the combustion cycle which is simplified such as to produce average torque and mass/energy flow of combustion gas. The main elements of the model are a turbocharger, an intercooler, an air/exhaust gas receivers and simplified engine cylinder.

3.2 Propeller and disturbance model

In the present plant configuration, a fixed pitch propeller is directly connected to the engine. The open-water characteristic is used to calculate the torque of the propeller. The ship hull dynamics is neglected, and the operating point of the propeller is determined by arbitrary shaft rotational speed. The hull-propeller and wave-propeller interactions are indirectly included in the precomputed spectrum of propeller inflow velocity, from which the time-series are then obtained. In this way, the real-like propeller load fluctuation is simulated.

4. Use Case

In the framework of the present study, the application of observer theory to the engine was investigated. The main goal of the observer is to provide an estimation of internal variables of the process using limited measurements and a dynamic model. The Extended Kalman Filter (EKF) is a state estimator which produces an optimal estimate in a least-mean-square sense then the estimation errors gets a minimal value. Moreover, the Jacobian matrices of the system model are updated after every state estimation step, providing more precise tracking of the nonlinear process. The observer requires the same inputs as the real process receives. However, among the engine inputs, the propeller disturbance cannot be measured and thus is considered as an unknown perturbation. This unknown variable can also be made identifiable by including it as additional “dummy” state variable in the original system. In the last analysis, the virtual propulsion plant including speed governor was executed on the RTOS, whereas the observer was run on the microprocessor. The engine rotational speed and governor output were only the measured variables. The Fig. 2 illustrates a comparison of the simulated and observed states. The moment of the observer actuation is also clearly seen in the plots.

5. Conclusion

The developed HIL test bench enables the model based design approach for control development and system integration. Also, as was shown, the EKF observer could be implemented on the microprocessor with a hard real-time setting. The EKF observer provides estimation not only the internal engine states but also typically unmeasured propeller disturbance associated with the water inflow velocity fluctuation.

References

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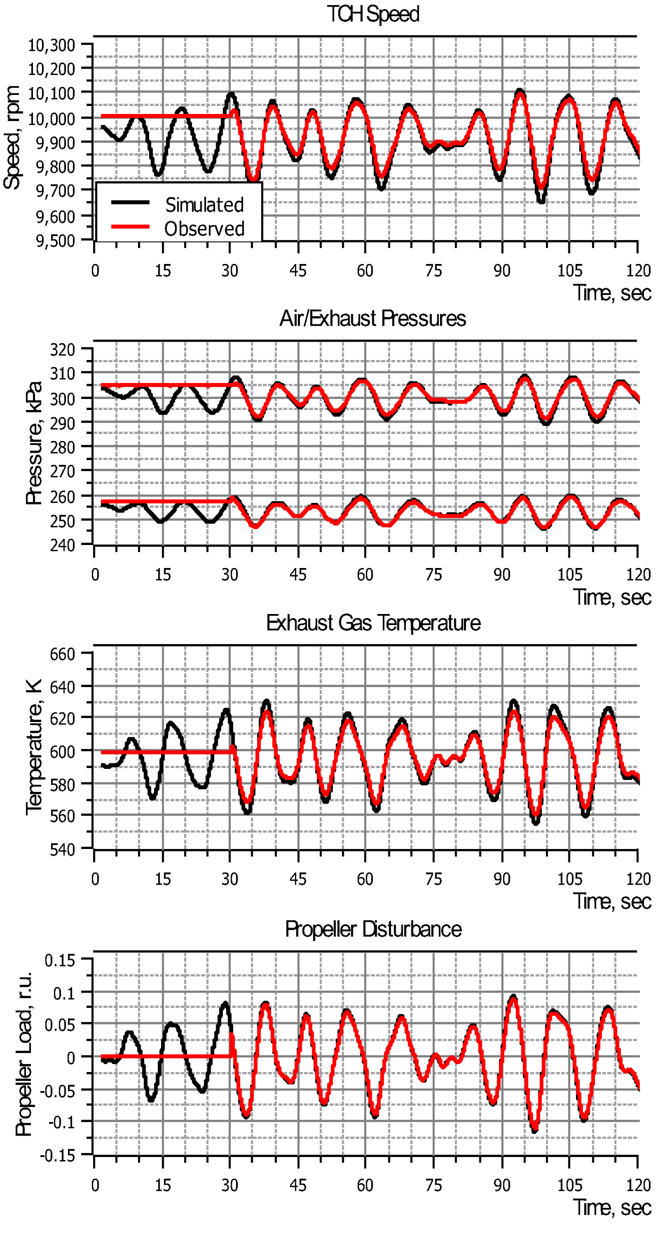

Fig.2 Simulated and Observed states comparison