Simulation Modelling Performance Dynamics of Ship Gas Turbine at the Load of the Ship's Synchronous Generator

Josko Dvornik[1] and Eno Tireli[2]

[1] Faculty of Maritime Studies, University of Split,
Zrinsko frankopanska 38, 21000 Split, Croatia
[2] Faculty of Maritime Studies, University of Rijeka,
Studentska 2, 51000 Rijeka, Croatia

Abstract. Simulation modelling, performed by System Dynamics Modelling Approach-MIT and intensive use of digital computers, which implies the extensive use of, nowadays inexpensive and powerful personal computers (PCs), is one of the most convenient and most successful scientific methods of analysis of performance dynamics of nonlinear and very complex natural technical and organizational systems [1].

The purpose of this work is to demonstrate the successful application of system dynamics simulation modelling at analyzing performance dynamics of a complex system of ship's propulsion system.

Ship turbine generator is a complex nonlinear system which needs to be analysed systematically, i.e. as an entirety composed of a number of sub-systems and elements which are through cause-consequence links (UVP) connected by retroactive circles (KPD), both within the propulsion system and with the corresponding environment.

Indirect procedures of analysis of performance dynamics of turbine generator systems used so far, which procedures are based on the use of standard, usually linear methods, as Laplace's transformation, transfer functions and stability criteria, do not meet the current needs for information about performance dynamics of nonlinear turbine generator systems.

Since the ship turbine generator systems are complex and the efficient application of scientific investigation methods called qualitative and quantitative simulation methodology of System dynamics will be presented in this work. It will enable the production and application of more and varied kinds of simulation models of the observed situations, and enable the continuous computer simulation using high speed and precise digital computers, which will significantly contribute to the acquisition of new information about nonlinear characteristic of performance dynamics of turbine generator systems in the process of designing and education.

Successful realization of this work, or qualitative and quantitative scientific determination of a complex phenomenon of performance dynamics of load of the ship electric network, or ship turbine generator system, will give a significant scientific contribution to the fundamental and applied technical scientific fields, and to interdisciplinary sub-directions of maritime transport, exploitation of ship drive systems, mariners education, automatics, theory of management and regulation, expert systems, intelligent systems, computerization and information systems.

Dvornik J. and Tireli E. (2006).
Simulation Modelling Performance Dynamics of Ship Gas Turbine at the Load of the Ship's Synchronous Generator.
In *Proceedings of the 4th International Workshop on Modelling, Simulation, Verification and Validation of Enterprise Information Systems*, pages 157-162
DOI: 10.5220/0002471301570162

The contribution may also be significant in the process of education of the present and future university mechanic and electric engineers in the field of simulation modelling of complex organisational, natural and technical systems.

1 Introduction

Dynamic investigation of nonlinear engine (especially electric engine) systems is a relatively considerable problem in the area of investigating performance dynamics of ship's propulsion systems.

Ship gas turbine, i.e. the ship turbine synchronous generator (BTSG), belongs, undoubtedly, to a set of linear complex technical systems, which consist of two main subsystems: turbine system and ship synchronous generator.

In this work ship three-phase self-excited synchronous generator (BSG) has been treated as particular sensitive consumer which is driven by ship gas turbine, which means that they are the main source of alternating voltage of ship energy consumers.

Ship turbine generator system will be presented as a set of nonlinear differential equations, or continuous simulation model of upper level, the so called equations of state, so it will simultaneously be a discrete simulation model, because it strictly complies with the selected value of the main computation interaction step DT.

2 System Dynamics Simulating Modelling of Twin Shaft Gas Turbine

2.1 System Dynamics Mathematical Model of Twin Shaft Gas Turbine

Mathematical model of dynamic performance of gas turbine is presented like this [11]:

$$T_1 \dot{\varphi}_\omega + \varphi_\omega = k_G \mu_G - k_b \mu_b - f(t) \tag{1}$$

where:

φ_ω - relative change of angular speed,

ω - turbine angular speed,

μ_G - relative change of fuel consumption,

G_t - absolute fuel consumption

By developing the equation a final differential form in explicit form is reached:

Equations of shaft of turbo compressor with low pressure – consumer:

$$\frac{d\varphi_{\omega 1}}{dt} = \frac{1}{T_{a1}}\left(\mu_G + k_{\omega 2}\varphi_{\omega 2} - f(t) - k_1 \varphi_{\omega 1}\right) \tag{2}$$

Equations of shaft of turbo compressor with high pressure:

$$\frac{d\varphi_{\omega 2}}{dt} = \frac{1}{T_{a2}}\left(\mu_G + k_{\omega 1}\varphi_{\omega 1} - \varphi_{\omega 2}\right) \qquad (3)$$

2.2 System Dynamics Qualitative Model of Twin Shaft Gas Turbine

Qualitative simulation models, or mental and verbal, structural model and flow diagram of ship gas turbine for the explicit differential equation (2) will be:

Mental and Verbal Model. When relative variation of fuel consumption μ_G and product $k_2*\varphi_{\omega 2}$ are increasing, relative angular speed variation is also increasing, resulting in positive cause-consequence relation UPV (+).
When relative variation of possible external act of cargo and product $k_1*\varphi_{\omega 1}$ are increasing, relative angular speed variation is decreasing and observed UPV(-) is negative.
Further, when time of shaft running T_{a1} is increasing, relative angular speed variation is decreasing, resulting in negative sign UPV (-).

Structural Model and Flow Diagram. In accordance to the developed mental and verbal model, structural model and flow diagram in DYNAMO symbols [2] of the equation of the state (2) follow:

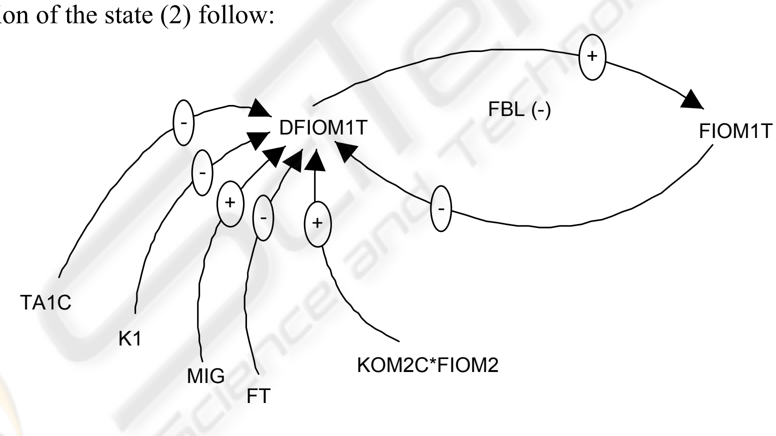

Fig. 1. Structural diagram of turbo compressor with low pressure.

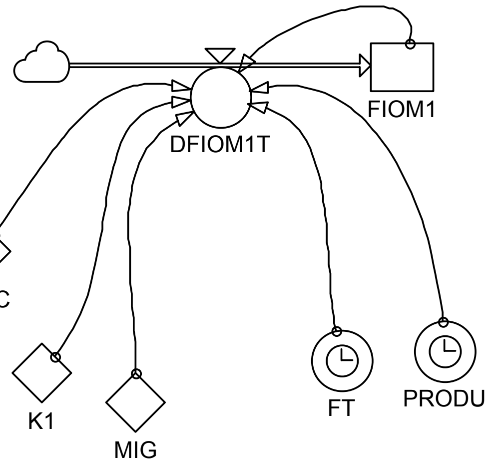

Fig. 2. Flow diagram of turbo compressor with low pressure.

In observed system there is one feed back loop (FBL):

FBL1(-): FIOM1=>(-) DFIOM1T=>(+)DFIOM1T=>(+)FIOM1; with self regulating dynamic character (-), because the addition of negative sign is odd number.

3 System Dynamics Simulating Modelling of Ship Synchronous Generator

In this short paper, it is impossible to give a complete model; complete model (30 equations) has been presented in IASTED, Pittsburgh, 1998, 372-375, (7).

4 Computing Simulating Model of the Gas-turbo Generator

Simulation Scenario. Run of the turbine is triple-stage, which means that in TIME=1 second the turbine was accelerated by bringing the fuel. At 10% of the nominal number of revolution in TIME=5 seconds fuel consumption was increased to the 35% of the nominal number of revolution, and in TIME=10 fuel supply was increased, and in that way "uniform" heating of turbine i.e. nominal number of revolution is obtained. In TIME=20 PID regulator is involved, and in TIME=30 exciting of the generator started. In TIME=30 stochastic load occurs.

Graphics results of the simulation:

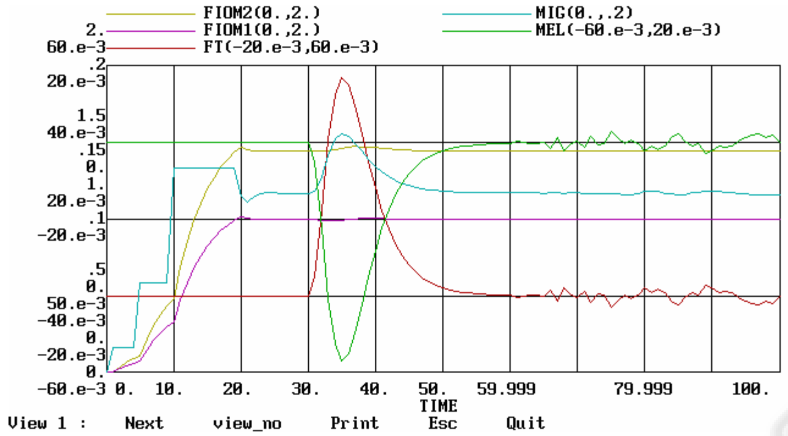

Fig. 3. Relative angular speed variation, relative angular speed variation of second shaft, generator electromagnetic moment, relative variation of fuel consumption.

After turn of the turbine in idling PID regulator is involved. PID regulator acts on fuel supply and with this act brings number of revolution of turbine on nominal value. Fuel consumption increases with switching on the synchronous generator, while the number of revolution of both shafts varies relatively little. In regime of stochastic load (we simulate alternating switch on and off of electric consumer generating random number) attempt to stabilise output voltage with self-excited according to the phase compounding scheme was not effective enough. After replacing this part of assembly with electrical PID regulator, which is visible from the diagram, those output voltages vary in permissible limits, although variations of load are extremely unfavourable.

5 Conclusion

The application of System Dynamics Simulation Modelling Approach of the complex marine dynamic processes revealed the following facts:

1. System Dynamics Modelling Approach is a very suitable software education tool for marine students and engineers.
2. System Dynamics Computer Simulation Models of marine systems or processes are very effective and successfully implemented in simulation and training courses as part of the marine education process.

References

1 Forrester, Jay W., *Principles of Systems*, MIT Press, Cambridge Massachusetts,USA, (1973).,

2 Richardson, George P. and Aleksander L., *Introduction to System Dymanics Modelling with Dynamo*, MIT Press, Cambridge, Massachusetts, USA, (1981),

3. Munitic, A., *Computer Simulation with Help of System Dynamics*, Croatia, BIS Split, p. 297., (1989),

4. Munitic, A., Milic L. and Milikovic M., *System Dynamics Computer Simulation Model of the Marine Diesel-Drive Generation Set*, Automatic Control System." IMACS World Congress on Scientific Computation, Modelling and Applied Matematichs, vol.5, Wiessenschaft & Technik Verlag, Berlin, (1997),

5. Munitic, A., *Application Possibilities of System Dynamics Modelling*, System Dynamics, Proceedings of the SCS Western Multiconference, San Diego, California, A, San Diego, USA, (1989),

6. Byrknes, A. H., *Run-Time User's Guide and Reference Manual*, Powersim 2.5, Powersim Corporation, Powersim AS, 12007 Sunrise Valley Drive, Reston Virginia 22091 USA.

7 Munitic, A., Kuzmanic, I., Krcum, M., *System Dynamic Simulation Modelling of the Marine Synchronous Generator*, Modelling and Simulation, IASTED, Pittsburgh, 372-375, (1998),

8. Isakov, L.I., Kutljin, L.I., *Kompleksnaja avtomatizacija sudovljlh dizeljnih I gazoturbinmljih ustanovok*, in Russian, Leningrad, Sudostreonnie, (1984),

9. Suprun, G.F.*,Sintezsistem elektroenergetiki sudov,* in Russian; Leningrad, Sudostroenie, (1972),

10. Hind, A., *Automation in merchant ships,* London, (1968)

11. R. A. Nalepin, O.P. Demeenko, *Avtomatizacija sudovljih energetskih ustanovok*, Sudostroennie-, in Russian, (1975),