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The Education of Marine Engineers in Control Engineering in Accordance with the IMO Requirements Contained in the STCW'95 Convention*

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This paper describes and discusses the purpose and range of the education of marine engineers in control engineering within the context of international requirements. It introduces the concept of a three level system of education and formulates concise characteristics of particular subjects. The practical aspects have been presented through two representative examples. The conclusions are drawn in the light of ever-developing shipbuilding technologies, reliability of shipboard equipment, costs of servicing and continually increasing requirements concerning the safety of shipping.

INTRODUCTION

The aim of education in this area of marine engineering is to convey knowledge of the construction and operation of the automation systems of ships in accordance with the requirements of the International Maritime Organisation as formulated in the STCW '95 Convention. The range of courses includes electrical, electronic, and control engineering distributed over the operational and management levels, comprising a theoretical knowledge (fundamentals of automation, instrumentation and control systems) and a practical knowledge (operation, testing and maintenance of electrical and electronic control equipment including fault diagnostics) [1].

Educational activities are carried out with both full-time and part-time students of the Gdynia Maritime Academy (GMA), studying in the Faculties of Navigation, Marine Engineering and Marine Electrical Engineering. The education of GMA students is undertaken by the Department of Ship Automation; GMA graduates continue their education in this respect through specialist courses conducted by the Officer Training Centre (OTC) to obtain successive officer's degrees. In addition, curricula are currently being designed for candidates wishing to obtain the degrees of PhD and DSc in ship control engineering [2].

* A revised and expanded version of a paper presented in Wismar

SHIP CONTROL ENGINEERING WITHIN THE CONTEXT OF INTERNATIONAL LAW AND SHIP OWNER'S RULES

The International Convention on Standards of Training Certification and Watchkeeping for Seafarers (STCW '95) requires officers serving on board merchant ships to have specialist knowledge and competence in control engineering. The requirements concerning the officers have been distributed over two levels of competence:

- Operational Level, concerning all shipboard officers.
- Management Level, concerning Chief Officers and Masters.

Details are specified in the STCW Code separately for navigators and marine engineers in the form of *minimum standards of competence for officers in charge*. For navigators at the Operational Level the provisions covering the requirements read as follows: *knowledge of steering control systems, operational procedures and change-over from manual to automatic control and vice versa. Adjustment of controls for optimum performance* (STCW Code A/29).

For navigators at Management Level the provisions covering the requirements read as follows: *maintain safe navigation through the use of modern navigation systems* (STCW Code A/45).

For marine engineers the requirements are grouped in functions covering electrical, electronic and control engineering distributed over both Operational and Management Levels. At the Operational Level they include the ability to operate:

- main and auxiliary machinery and associated control systems (STCW Code A/75);
- main marine engineering systems, including control systems (STCW Code A/77).

While at the Management Level they include:

- operation, testing and maintenance of control systems (STCW '95 Code A/83);
- test, detect faults, maintain, restore electrical and electronic control equipment to operating condition (STCW '95 Code A/85).

The STCW '95 Convention does not make a distinction between the requirements expected of electrical officers and mechanical engineers, although many shipowners establish separate positions for an electrical officer or auto-electrical officer, excluding them from the umbrella term of an engineering officer. A good example may be the Hanseatic Shipping Company that provides the following ranks:

- Electrical Engineer for standard vessels.
- Auto Electrician, Senior Electrician, Electrician, Gas Engineer Electrician and Assistant Electrician.

The Norwegian Maritime Administration distinguishes two ranks with respect to electrical aspects: Marine Engineer Officer Class 1 or 2 in the area of machinery or electro-automation.

The extent of requirements for electrical officers established by the shipowners is much wider than that specified by the Convention, especially with regard to fault detection and repair of ship control systems [3].

THE EDUCATION SYSTEM

Instruction in control engineering at the Gdynia Maritime Academy is conducted in the three Faculties of Navigation, Marine Engineering and Marine Electrical Engineering. The extent of curricula in each of the Faculties is differentiated and takes into consideration both specific duties to be performed on board a ship by the graduates and the requirements of the STCW '95 Convention [4-6].

The greatest extent of knowledge is provided for students of the Marine Electrical Engineering Faculty for the reason that the graduates undertaking shipboard positions not only have to operate the control systems but also, and above all, to diagnose and repair them. The very heart of the education system is to equip students with the theoretical knowledge that would enable them to face the challenges posed by the control systems that will be installed in the future.

The educational activities covering control engineering in the Marine Electrical Engineering Faculty are conducted within a two step system of studies at three levels of advancement (Figure 1).

The aspects of control engineering are included in the subjects numbered from 1 to 11, conducted in the form of lectures, classes, laboratory exercises, seminars and practical placements on board a ship.

All students within the engineering step (BSc) study the first two levels, ie basic and intermediate. The third level, ie advanced, is conducted at the Master's degree step of studies (MSc). Some lectures in control engineering are conducted on a facultative attendance basis [7-10].

Instruction in control engineering for students of the Marine Engineering Faculty covers the subjects numbered 1, 2, 5, 7, while instruction of the Navigation Faculty covers the subjects numbered 1, 2, 5, 8 [11].

CURRICULUM OF CONTROL ENGINEERING

The sections below synthetically present a range of each of the 11 subjects shown in Figure 1. The presentation reveals the range of specific aspects of instruction offered to future officers of merchant marine [3][4].

Fundamentals of automation

This subject covers the following: mathematical models, transfer functions and state space equations, stability analysis; object identification; time domain analysis and design; frequency domain analysis and design; discrete time system analysis and design; non-linear control systems; discrete time control systems; process control system design.

The subject also covers specialist laboratory exercises in industrial controllers and their co-operation with the measuring and effecting systems.

Fundamentals of electronics and power electronics

This subject covers the following: semiconductor elements: diodes, bipolar transistors, IFET'S and

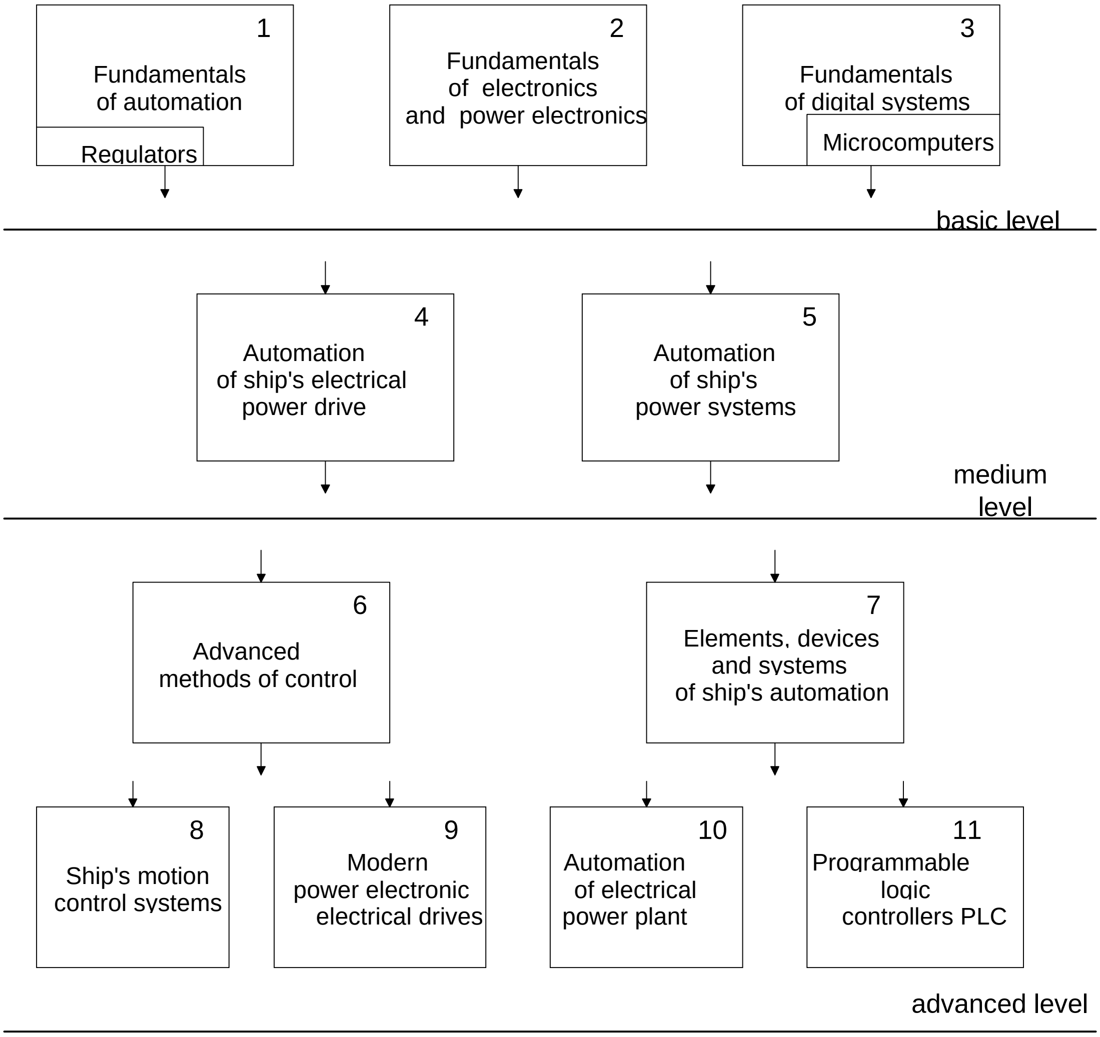

Figure 1: The structure of the educational system in control engineering in the Faculty of Marine Electrical Engineering.

MOSFET'S; diagnostics, construction, method of assembly; analogue devices: amplifiers, power supplies, oscillators; discrete time electronic devices flip-flops, comparators, logic devices; selected devices in marine automation; power electronics elements: thyristors, power transistors IGBT; rectifiers, current controllers, inverters; protections of power electronic systems.

Fundamentals of digital systems

The following topics are taught to students within this subject: types of digital systems and mathematical tools applied in their analysis; digital elements and systems together with basic applications of arithmetical, commutation and sequential blocks; transfer of digital signals; design of combination and sequential systems; measuring devices, registers, time related systems; co-operation between analogue and digital systems.

A separate subject relating to digital technology is control microcomputer systems. This subject covers theoretical problems connected with the structure of microcomputers and their use with special regard to an independent programming of microcomputer controllers [5].

Automation of ship's electrical power drive

The coverage of this subject is as follows: possibilities of controlling dc and ac motors: starting up, stopping and reverse; parallel operation of motors; selection of motors with respect to types of load, heating, static characteristics; mathematical models of electrical motors and power supply systems; analysis and synthesis of adjustment systems of electrical motors; converter drives; microprocessor systems for motors control; ship's main electrical drives.

Automation of ship's power systems

The coverage of this subject is as follows: range of automation found on board vessels, requirements of the classification societies; automation of the ship's main engine, auxiliary systems of the engine room and the ship's power plants; modern control systems used in ship's engine room; integrated control-measuring systems; algorithms for controlling power electrical equipment, development trends in ship's engine room control.

Advanced methods of control

This subject is a continuation of subject 1 and covers the following: multidimensional control systems; optimal control; adaptive control; expert systems; fuzzy control; game control; neural networks; genetic algorithms.

Elements, devices and systems of ship's automation

This subject covers the following: energy saving systems for the generation of electrical power; microprocessor systems for steering ship's internal combustion engines, selection of governors, clutching arrangements; application of modern control methods to selected systems of the engine room; development trends in automation of ship's engine room plants.

Ship's motion control systems

Within this subject the following topics are taught: integrated navigation systems; course and trajectory keeping; dynamic ship positioning; roll compensation; precise ship control with tunnel thrusters; safe ship steering for avoidance of collision risk; optimalisation of ship's route [11].

Modern power electronic and electrical drives

This subject deals with the following: frequency converters of medium and high power; power supply systems for ac motors, including control through magnetic stream; induction machines with two-sided power supply used on board ships as shaft generators; measurements in propulsion systems powered from converters; methods for minimisation of distortions in the *soft* ship's network.

Automation of electrical power plant

This subject covers the following topics: synchronic generator as an object of adjustments, mathematical models, induction systems in ship's synchronic generators; local and global stability of the ship's electrical power system, parallel operation of generators, co-operation with shore-based networks; specific features of the ship's *soft* network, transitory states during starting up of high power engines, elimination of distortions in network; mathematical models for internal combustion engines of low and medium rotating speeds, frequency adjustment systems.

Programmable Logic Controllers (PLC)

This subject covers the following: classification of logic controllers; methods for programming controllers; co-operation of controllers with the computer system; designing a control system with the use of a logic controller.

PRACTICAL FORMS OF EDUCATION

Instruction is conducted in the form of lectures, classes and laboratory exercises, of which the latter play a crucial role in terms of the prospective employment of a graduate as an operator of control systems on board a ship. It should be underlined here that these specific features of ship's control arrangements are already focused upon within the subjects placed at the basic level.

Control of a physical model of a ship

A testing stand for course-keeping by a physical model of a ship has been designed and constructed in the Department of Ship's Automation at the GMA (Figure 2). The stand consists of three units: a PC computer, a water tank containing a ship's model, together with hydraulic equipment and a connecting unit.

The purpose of the exercise is to monitor features of the course stability system of a ship using PID digital controllers in any configuration. These controllers are constructed in the form of blocks on the computer screen, defining, at the same time, the quantitative values of the parameters, integration step, sampling period of analogue signals, etc. The analogue signals of the ship's course and a predetermined rudder angle are supplied through A/C converters.

The physical model of the vessel is *moving* on the surface of the water container, but since the model is in a restricted space, the vessel is immobile while the water is flowing. The movement of the water is forced in a closed circulation system by pumps of an adjustable output. There is also the possibility to steer the vessel manually and to make comparisons. The characteristics of the selected physical values, ie course deviations, rudder angle, etc are displayed on the computer screen (Figure 3).

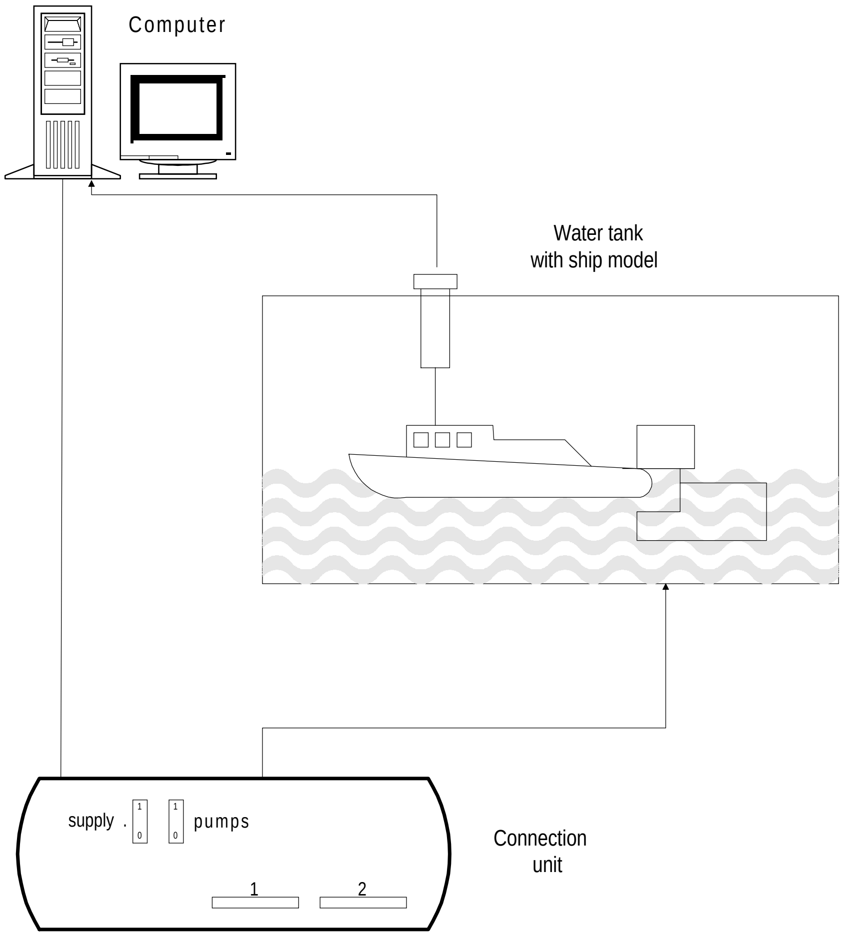

Figure 2: Testing stand for the control of the ship's physical model.

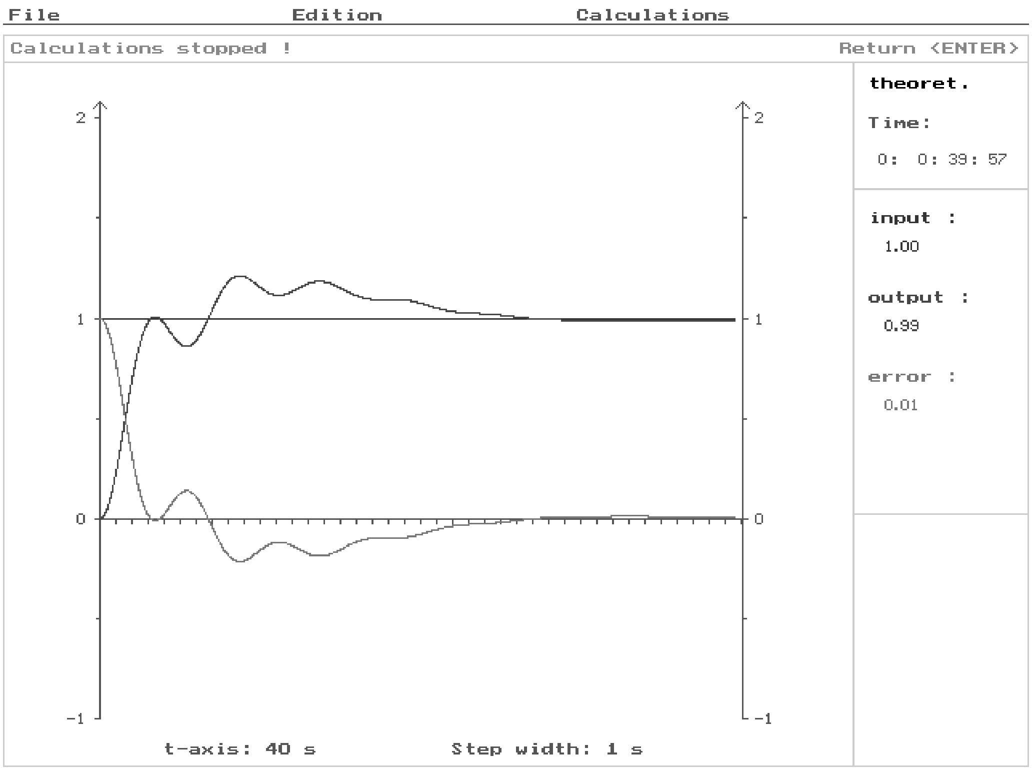

Figure 3: Presentation of system output (above) and system error (below) during control of ship's model. The right-hand window shows temporary time and values of the qualities presented.

After completion of the exercise the quality of steering may be analysed on an off-line basis using special support software together with Excel 5.0. An additional didactic focus is the possibility of digital simulation of the model vessel and comparison of the steering of the physical model vessel and the digital model vessel by using the same controllers.

Relay temperature stabilisation systems for main engines

The purpose of this exercise is to acquaint students with the specific operation of the three-setting point controller used to stabilise the temperature of the water that cools the cylinder liners of the main engine. This exercise has been designed in the form of a digital simulation with the use of the Matlab-Simulink special supporting package. Familiarity with this universal programme for the analysis, simulation and synthesis of the modern control systems became an additional element in our education.

A mathematical object of the cooling water system in the main engine of a trawler under construction in a Polish shipyard has been selected as an object of our control. A block diagram of the two versions of the testing arrangement has been presented in Figure 4.

The task assigned to students is to select and combine the parameters for the three-setting point controller which would ensure the best controlling quality of steering, with differences in the dynamics of the arrangement being a result of different measuring points for the adjusted value. An additional element of the exercise is the analysis of the operation of the arrangement on the phase plane (Figure 5).

CONCLUSIONS

The analysis of the education of marine engineers within the area of control engineering allows us to formulate the following conclusions:

- The selection of an optimum educational programme constitutes, on the one hand, an appropriate compromise between the maritime requirements set up by the International Maritime Organisation and the educational requirements determined by the Ministry of National Education, and, on the other, the duration of studies and theoretical and practical level to be represented by the graduates undertaking their marine careers.
- It is not possible to satisfy all the requirements in the course of the four-year system of studies in marine engineering.
- The optimum model for the education of shipboard engineers is a five-year MSc oriented system of study that would satisfy both the requirements of the maritime convention and the minimum educa-

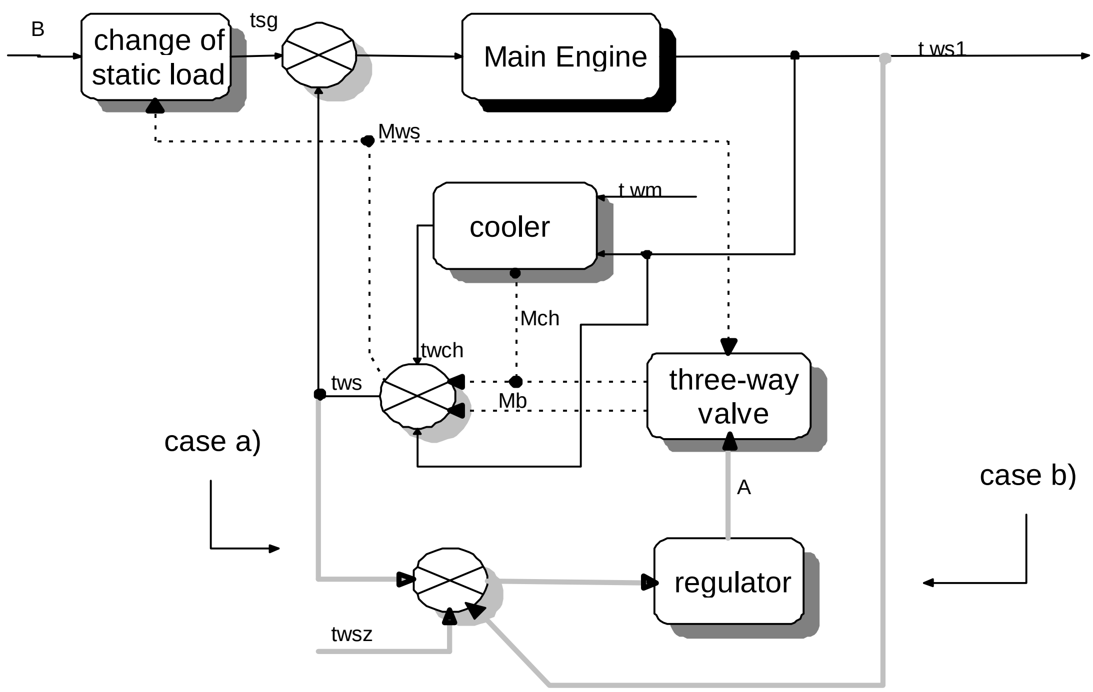

Figure 4: A block diagram of the arrangement for the control of the temperature of the water that cools the ship's main engine with temperatures measured.

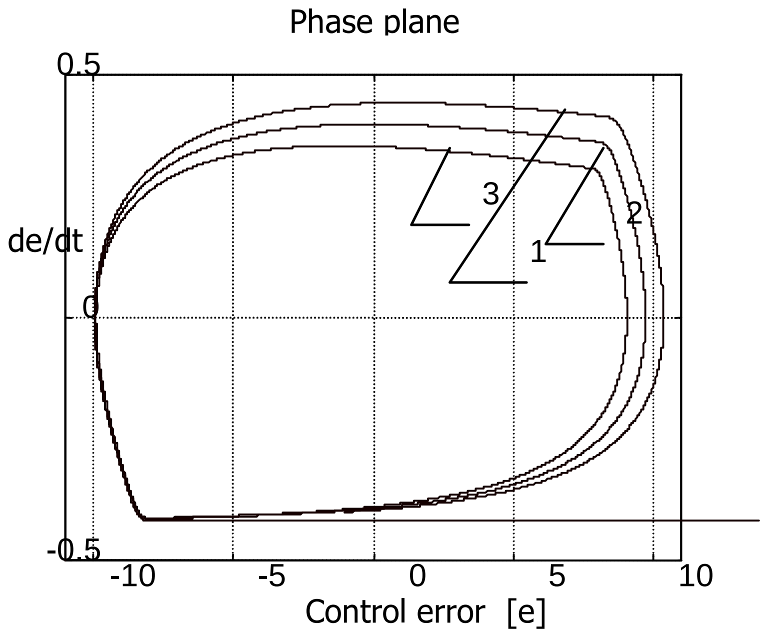

Figure 5: A phase portrait of control error for three values of sea water temperature as a system disturbance sea water temperature: 1-25 °C, 2-15 °C, 3-5 °C.

tional programme obligatory at a particular faculty. This would enable students to obtain the following diplomas: Merchant Marine Officer Class III, MSc Engineer together with the completion of training conducted by the Polish Navy.

- The best preparation of a graduate to undertake a professional career is ensured by a comprehensive system of lectures, laboratory exercises, training on professional simulators and apprenticeship on board instrumentation, sail and cargo vessels.
- The subjects to be taught and their contents must be renewed from time to time with regard to the development of shipbuilding technologies, ships' equipment, reliability of shipboard arrangements, costs of servicing, diagnostic and repair of the shipboard equipment and evermore demanding requirements in the area of safe navigation and environmental protection.

REFERENCES

1. O'Neil, W.A., World Maritime Day 1995, IMO'S achievement and challenges. IMO News, 3 (1995).
2. Catalog 96, Gdynia Maritime Academy. Poland (1996).
3. IMO-STCW 95 - International Convention on Standards of Training, Certification and Watchkeeping for Seefarers. London (1995).
4. Lisowski, J., Merchant Maritime Academy in Gdynia - organisation and activity programme. *Polish Maritime Review*, **6** (1994).
5. Lisowski, J., The engineering education and research for maritime industry - transfer of information and professional development. *Proc. Inter. Cong. of Engng. Deans and Industry Leaders*, Melbourne, Australia, 380-383 (1995).
6. Mindykowski, J. and Rymarz, W., Polish experience concerning maritime education changes in the light of STCW'95 Convention implementation. *Proc. 8th Inter. Cong. on Marine Techn.*, Istanbul, Turkey (1997).
7. Lisowski, J., Automation of ship steering processes. *I Symposium obrazovanje kadrowa u pomorstvu sa aspekta technoloskog rozvoja*. Kotor, Jugoslawia (1988).
8. Lisowski, J. et al, Laboratory of the ship process automation. Gdynia, Poland (1993) (in Polish).
9. Lisowski, J., Gil, A., Kaminski, K., Morawski L. and Wasilewski, L., PC Computers in teaching ship automation. *Proc. 3rd East-West Cong.on Engng. Educ.*, Gdynia, Poland, 376-380 (1996).
10. Lisowski, J., Gil, A., Kaminski, K., Morawski, L. and Wasilewski L., Computer-Based Teaching of Ship Automation. *Global J. of Engng. Educ.*,1, **2**, 151-161 (1997).
11. Minimum programme requirements for technical education. Offical Newspaper of Ministry National Education, Warsaw (1996) (Polish).

BIOGRAPHIES

Witold Gierusz was born in Olsztyn in 1952. He received his Msc degree from the Electrical Engineering Faculty of the Technical University, Gdansk, in 1977 and his PhD degree in Automatic Control from the same university in 1987. From 1977 to 1980 he worked as an assistant in the Institute of Power Systems Automation in Gdansk. Since 1980 he has worked in the Department of Ship Automation in the Gdynia Maritime Academy. From 1988 to 1990 he worked as an Officer-Electrician on seagoing ships. His research interest is automatic steering of ships motion.

Jozef Lisowski is Professor of Automation at the Gdynia Maritime Academy, Poland, and Head of the Department of Ship Automation. He received his MSc, PhD and DSc degrees from the Electrical Engineering Faculty of the Technical University of Gdansk in 1967, 1973 and 1979, respectively. From 1989 to 1996 he was Rector of the Gdynia Maritime Academy. His research interests include control theory applications in shipping: synthesis of optimal, adaptive and safety in ship steering systems. He is now undertaking a research project to develop methods for computer safe ship control.