MINISTRY OF EDUCATION AND SCIENCE
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NATIONAL RESEARCH
TOMSK POLYTECHNIC UNIVERSITY

Institute of Cybernetics
Department of Automatics and Computer Systems

COMPUTER-AIDED SYSTEM SOFTWARE

Course Program, Methodological Instructions, Test Assignments

Semester	8
Lecture hours	22
Laboratory hours	22
Self-study hours	44
Type of assessment	Examination

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This course program, methodological instructions and test assignments are examined and recommended for edition by Department of automation and computer systems.

Head of Department, G.P. Tsapko, Professor,
Doctor of Engineering Science

Abstract

Purpose: to conceptualize students' knowledge in theory and practice of software design for automatic control including software for microprocessor controllers and operator control station.

Contents: CAM software concepts and classifications; software design technologies and standards for CAM; IEC – 61131 languages, SCADA systems, operator station design, data exchange.

4^{th} Academic Year (8^{th} term, form of assessment – pass-fail test).
Total 88 hrs, incl. lectures.- 22 hrs, lab. practice - 22 hrs.

COMPUTER-AIDED SYSTEM SOFTWARE

Program, Methodological Instructions, Test Assignments

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TEACHING PURPOSES

The purpose is to conceptualize students' knowledge in theory and practice of software design for automatic control including software for microprocessor controllers and operator control station. This course of lectures is intended to form the students' knowledge about current technologies in automatic system programming.

The subject study is based on the courses in object- oriented programming, automatic control theory, automated management information systems.

OBJECTIVE OF STUDYING

As a result of studying the subject students should have knowledge and practical skills in following areas:

- building principles of automatic control systems, system composition and structure, controller software standards and their interrelations;
- algorithm support and hardware and software structure;
- synthesizing the algorithm support and software for automatic control of technological processes;
- selecting the proper language to solve the control problems;
- functionality of specified program packages (SCADA) and their implementing;
- progress trends in computer-aided system development.

1. COURSE CONTENTS

UNIT 1. CONCEPT AND CLASSIFICATION OF AUTOMATIC CONTROL SYSTEMS

Automatic control system concept (ACS). ACS classification. Information systems. Control systems. ACS types. Automatic process control systems (APCS). Computer-aided manufacturing systems (CAM). Information automatic control systems (IACS).

CAM classification. Classification by operating mode, functional development, information capacity, time-nature of current controlled process.

UNIT 2. ACS ARCHITECTURE

ACS architecture. Architecture requirements to the developed ACS. Methods of ACS building. Architecture varieties. Information flows.

UNIT 3. FUNCTIONS OF AUTOMATIC PROCESS CONTROL SYSTEMS

APCS functions. Data-computing and control functions. Direct and indirect measurements, parameter deviation monitoring, locking and protection analysis, diagnosis, forecasting. Control of certain parameters, multivariable and cascade control, logic control, program control, optimal process control by steady-state and transient process with adaptation and without it.

Characteristics of technological processes as control objects. Control, disturbing and output parameters. Examples of simple processes as control objects. Automatic process control systems, basic concepts of hierarchical automatic control.

APCS support types. Purpose of hardware, algorithm, software, information and organization supports. Principles of software interactions.

UNIT 4. BASIC FUNCTIONS OF PROGRAMMABLE LOGIC CONTROLLERS AND OPERATOR CONTROL STATIONS

Functions and purpose of programmable logic controllers (PLC). Functions and purpose of operator control stations (OCS). Interaction and data exchange between PLC and OCS.

UNIT 5. APCS SOFTWARE AND INFORMATION SUPPORT

Software structure. General and application software. Programming system and languages of industrial microprocessor controllers.

The IEC-61131-3 programming languages: IL, LDFBD, ST, CFC. Representative application of standard languages. Function block diagrams: monitoring and alarm signaling, engine and valve control, analog control. Function sequence diagrams: start – stop control, periodical process control. Structured text: loop operations, programs for complex calculations, addition to complex logic.

UNIT 6. ALGORITHMICAL SUPPORT OF APCS

Algorithm support of APCS. Basic concepts and definitions.

Sampling interval assessment of continuous parameters. Primary processing the information input into microprocessor control devices. Algorithms for sensor calibration, extra- and interpolation of measurable values. Filtering algorithms. Difference equations of low-frequency digital filters. Exponential smoothing filters and average moving filters. Robust, high-frequency, band- pass and band – rejection filters. Discrete differencing, integrating and averaging the measurable values. Data validation. Methods of data validation increasing. Control algorithms of process parameters and equipment.

Digital control algorithms. Structure of digital control system. Difference equations of parametric adaptive controllers (P, PI, PID) in recurrence and non-recurrence forms.

UNIT 7. APCS HIGH-LEVEL SOFTWARE

SCADA - systems. Purpose, structure and basic functions. General information about MasterSCADA. Project structure. Information channel in MasterSCADA. Channel types. Channel values and their processing. Connection with actual input – output information channels.

Real-time monitor structure (RTM) and peculiarities of real-time starting. Performance prioritizing. Time characteristics of the system and system settings. Current state control and error monitoring by working the operator control stations. Parameter auto save by reset. Unauthorized access security.

Data exchange with WINDOWS applications.

Archiving and filing. MasterSCADA archive system. Operation with project archives. Backup data revision. Report generation. Data export from MasterSCADA to WINDOWS applications.

2. CONTENTS OF LABORATORY PRACTICE

1. Introduction into the CoDeSys software product , 2 hours.

2. Algorithm realizing of digital filtering the input analog signals: exponential smoothing filter, average moving and median filters in theCoDeSys software product, 4 hours.

3. Digital control circuit and PID controller setting by the example of liquid level control in CoDeSys software product, 6 hours.

4. MasterSCADA package structure. Basic operations. Technological process visualization. Creating of statistical mnemonic diagram and image dynamicizing, 4 hours.

5. Complex software development for liquid level control system, 6 hours.

3. ARRANGMENT OF STUDENTS' SELF-STUDY ACTIVITY

Self-study (extracurricular) students' activity is aimed at learning the lecture course materials, self-preparing to laboratory practice. It is developed for 44 study hours and includes following activities:

1) course self - studying (20 hrs)
2) preparing to laboratory practice (8 hrs)
3) preparing to laboratory practice defense (8 hrs)
4) supplementary tasks in one of the application development systems by order of lecturer (8 hrs).

4. TESTS

A progress test is performed according to rating- plan by results of laboratory practice and progress check. A progress test is performed in following parts of the course:

1. APCS algorithm support and software.
2. High-level software of APCS.

Checklist for the Progress Test

APCS Algorithm Support and Software

1. List the operations of primary information processing.
2. For what purposes is the operation of analytic sensor calibration used by development of mathematical support for automatic system?
3. Filters are divided into following classes by frequency parameters: low-frequency, high- frequency, band – pass and band – rejection filters. Which class is the exponential smoothing filter related to? Justify your answer.
4. Write the difference equation of average moving filter. In what way is the filter setting determined?
5. What is the purpose of robust filters?
6. Write the Pulse transfer function of parametric adaptive digital filter of N^{th} order.
7. Write the difference equation of a PID controller.
8. List the accuracy increasing algorithms applied for determining the technological process parameters.
9. For what purpose are the static characteristics determined by operation of automatic control system?
10. List the basic operations of the secondary information processing.

High-level software of APCS

1. For what purposes are the SCADA packages used by developing the automation systems?
2. List the stages of APCS software development based on MasterSCADA.
3. Dynamic Data Exchange (DDE).
4. Object linking and embedding technology (OLE).
5. Methods of file system building.
6. Primary data processing in MasterSCADA.
7. Data backup and documentation. Archive and report generation.
8. Data import in DBMS and spreadsheet.
9. Real-time system management.
10. Controller data exchange.

5. PROGRESS AND FINAL TESTS

Progress test in the subject is performed according to laboratory practice results. Students who are successful in laboratory practice and progress check are allowed to take the final examination.

Examination Checklist

1. Concepts of ACS, APCS, IACS, CAM and their characteristics.
2. The CAM functions. The CAM structure.
3. IEC 61131. Main parts of IEC 61131. Standard language development.
4. Set of IEC 61131 function. Function blocks. Standard's relevancy.
5. Design complexes of IEC 61131-3. Tools of PLC design.
6. Embedded editors. Text editors. Graphic editors.
7. Project debugging. Project management tools.
8. CoDeSys features.
9. Variables. Identifiers. Variable memory allocation. Direct addressing.
10. Bitwise addressing. Type conversion.
11. POU definition. POU declaration. Formal and current parameters. POU parameters and variables.
12. Functions. Function blocks.
13. Tasks. Resources. Configuration.
14. Instruction language (IL). Function block diagrams (FBD).
15. Structured text (ST). Ladder diagrams (LD).
16. Sequential Function Charts (SFC).
17. Arithmetical operators. Bitwise shift operator. Bitwise logical operators.
18. Selection and delimiter statements. Comparison operators.
19. Mathematical functions. String functions.
20. Timers. Triggers.

21. Pulse detectors. Counters.
22. Bit serial access to integers. Hysterisis. Threshold signal indicator.
23. Limiting the signal changing rate. Integrating. PID controller.
24. The SCADA system concept. The SCADA system functions.
25. Structure, characteristics, and facilities of MasterSCADA.

6. COURSEWARE

Compulsory Required Reading

1. Denisenko, V.V. Computernoye upravleniye technologitcheskim processom,experimentom, oborudovaniyem [Computer- aided Control of Process, Experiment, and Equipment] – M.: Goryatchaya liniya – Telecom, 2009. – 608 p.
2. Aristova, N.I., Korneyeva, A.I. Promashlennyje programmno – apparatnyje sredstva naotetchstvennom rynke ASU TP [Industrial hardware-software in the local APCS market] –M: Nautchtekhlitizdat, 2001.
3. Olsson, G, Piane, D. Tsifrovyje systemy avtomatizatsiyi I upravleniya [Digital automatic control systems] - StPb: Nevskiy Dialect, 2001.
4. Petrov, I.V., Dyiakonov, V.P. Programmiruyemyie controllery. Standartnyje yazyki I instrumenty [Programmabe Controllers. Standard Languages and Tools. – M.: SOLON – Press, 2003.
5. MasterSCADA. Documentation. http://insat.ru.

Supplementary References

1. Avtomatizirovannoye upravleniye technologitcheskimi processami [Automatic control of technological processes]: Study Book / Yakovlev, V.B. – L.: LSU, 1988.
2. Stroganov, R.P. Upravlyayushtchiye machiny i ikh primeneniye [controlling machines and their implementation]. – M.: Vysshaya shkola, 1986.
3. Stefanie, E.P. Osnovy postroyeniya ASU TP [Basics of APCS building]. - M.: Energoizdat, 1982.
4. Eserman, R. Tsifrovyje systemy upravleniya [Digital control systems]: transl. from engl. – M.: Mir, 1984.
5. Kulikovskiy, K.L., Cooper, B.Y. Metody i sredstva izmereniya [Measuring methods and tools]. – M.: Energoatomizdat, 1986.