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CONTROL SOFTWARE FOR A RECONFIGURABLE CONTROL SYSTEM FOR A SET OF TESTING DEVICES

Key words

Control system, testing device, hardware structure, procedure, PLC.

Summary

The article presents the PLC control software for a reconfigurable control system, implemented in a series of testing devices, executing durability tests of electronically secured documents. A general methodology of design of a reconfigurable control system is shown. The objective of tasks undertaken was to develop a structure of the software system, and a method of selection of procedures for a PLC programme, to create a full PLC software for each testing device, and the objective was to develop a structure of the user interface for a series of devices. In the article, apparatus for documenting durability testing, using applications of a developed reconfigurable control system are presented, and an example of the configuration of the control system of one of the devices is discussed.

Introduction

The execution of fatigue resistance tests for electronically secured documents requires the application of specialised test apparatus. The article presents an original solution concerning the development of a reconfigurable control system for a document fatigue resistance-testing device. One of the main foundations for the developed system was the maintenance of the unification of the solutions of a series of testing devices.

The main objective of the investigations was to develop a complex reconfigurable control system (a reconfigurable hardware structure and reconfigurable software) common for a series of devices intended for the following tests:

- Repeated spherical bending stress,
- Sheet turning and pulling stress,
- Repeated alternate spatial torsion stress,
- Repeated one-sided transverse bending stress,
- Repeated alternate two-sided bending stress,
- Repeated stamping stress,
- Pen stress, and
- Abrasion.

The execution of the assumed objective was sequential, and the works were conducted according to a predefined methodology [1, 2, 3], starting from the definition of the test object, which in the case of the designed reconfigurable control system for a set of test devices, were the electronically secured documents in the following formats:

- ID-000 (e.g. SIM card size) [4],
- ID-1 (e.g. ID card size) [4],
- ID-2 (e.g. Visa size) [4],
- ID-3 (e.g. Passport book size) [4], and
- Non-standard formats (with the maximum dimensions up to 125 [mm] x 176 [mm]).

Next, the test requirements were defined. Sample requirements include, for instance, the execution of tests consisting the following: the multiple pressing of a test object against a flexible base with the force of 350 [N], which is maintained in ten cycles for 5 [s] and then released; the multiple alternate spatial torsion of a test object in the angular range ±15 [º] and the torque of 0.3 [Nm] during 500 test cycles; the cyclical abrasion tests with the surface load of 14 000 [N/m2] ±5 [%], the amplitude of the abrasive motion at least 20 [mm], the speed of the sliding movement in the range of 0.025–0.25 [m/s], and the number of abrasion cycles 500.

Following the above, an analysis of the requirements and their decomposition were conducted in order to define individual test functions; the examples of which included, i.e., the exertion of force and the measurement of the force and the moment of force, the exertion of impact loads, or the movement and its measurement.

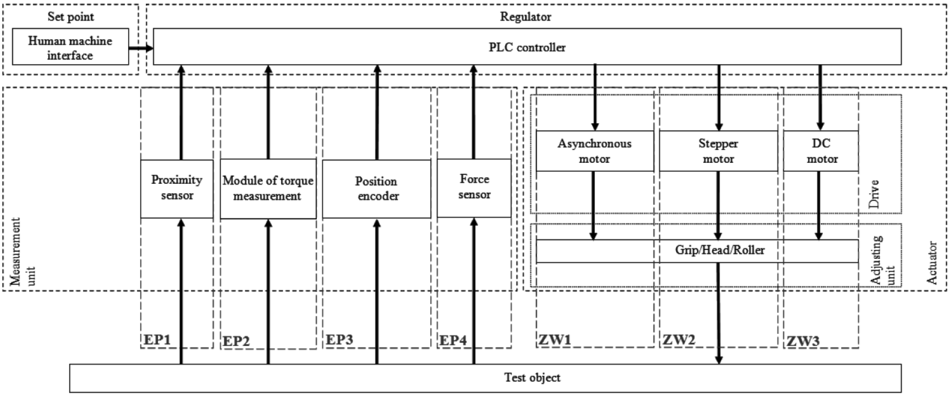


Fig. 1. Draft of the reconfigurable control system: EP1, EP2, EP3, EP4 – module of the measurement unit; ZW1, ZW2, ZW3 – modules of the actuator unit

The next step in the design of the proposed system concerned the allocation of functions performed in the hardware structure, which led to the design of hardware solutions for testing devices (Fig. 1).

The individual hardware solution for a control system for a testing device is created by the selection and the assembly of an actuator and measurement modules, in accordance with the developed matrix for the selection of the system's hardware structure (Table 1).

The developed hardware structure of the system enables the hardware execution of the operator communication functions, and the actuator and measurement functions. The hardware structure of the reconfigurable control system is discussed in more detail in the authors' publication [5].

Table 1. Matrix for the selection of the system's hardware elements

	Type of device	Actuator unit			Measurement unit			
		ZW1	ZW2	ZW3	EP1	EP2	EP3	EP4
1	Repeated spherical bending stress tester	-	X	-	X	-	-	X
2	Sheet turning and pulling stress tester	X	-	-	X	-	-	X
3	Repeated alternate spatial torsion stress tester	X	-	X	X	X	-	-
4	Repeated one-sided bending stress tester	X	-	-	X	-	-	-
5	Repeated alternate bending stress tester	X	-	-	X	-	-	-
6	Multifunctional tester	-	X	X	X	-	X	-

1. Software structure

Test functions were divided into separate procedures, which are used to form the main programme of the PLC responsible for the execution of a given test. The software procedure development process was divided into two stages; the first concerned the development of the basic procedure, while the second concerned the maintenance procedures for individual modules of the control system. The developed basic procedure executes the general diagnostics tasks, and enables communication with the user (using Modbus interface) and implements the objectives of the external security of the hardware solution.

In the next stage of the procedure development process, procedures necessary for the operation of measurement and actuator modules of the control system were described. The description consisted in the definition of procedures responsible for the exchange of control signals for the hardware module, with the basic procedure at the core of the main programme of the PLC controller. The selected hardware structure for the execution of a given group of tests consists of three actuator modules and four modules of the measurement unit. To operate each of the modules, the following dedicated programme procedures were designed:

- The asynchronous motor operation procedure (P1) for the maintenance of hardware modules ZW1 and EP1 of the control system was developed. The procedure is intended for the execution of tasks connected with the work of the asynchronous motor and the measurement of its position using proximity sensors. The design of procedures was connected with the programming of the software of the frequency converter, and the identification and programming of the necessary interfaces for the transmission of data between the PLC controller and individual modules. The next task concerned the design of functional blocks of the procedure's subprogram, such as the homing of the motor (Fig. 2), the positioning of the drive at certain speed in any direction, the movement of the motor to a predetermined position in any direction, the positioning of the drive to a given measurement sensor, the manual movement of the motor in any direction, and the stopping the drive and the reading of the sensors. The next step concerned the implementation of the modules' diagnostics blocks and the handling of alerts.
- The stepper motor operation procedure (P2) supports modules EP3 ZW2 of the control system. This procedure is responsible for the proper operation of the stepper motor and its communication with the PLC. The development of the procedure consisted in the programming of the controller of the stepper motor responsible for the operation of the motor and the measurement of its position and then the selection and programming of the communication interfaces of the modules. After that, the following functional blocks were

implemented: the homing of the motor, the positioning of the drive at given speed in any direction, the movement of the motor in an absolute and relative mode, the manual positioning of the drive in any direction, and the stopping of the motor. The drive position and data processing measurement blocks were also designed. The next stage of the procedure design concerned the development of a subprogram, a local diagnostics block, and an alert handling block.

- The DC motor operation procedure (P2) supports modules ZW3 and EP1 of the control system. The procedure is responsible for the proper operation of the DC motor and the measurement of its position using proximity sensors. The development of the procedure consisted in the programming of the communication interfaces integrated with these modules. After that, the following functional blocks were made: the positioning of the motor in any direction, the positioning of the drive to a given sensor, the manual movement of the motor in any direction, the stopping of the drive, and the reading of sensors. Within this procedure, the motor position and data processing measurement blocks were also implemented. Finally, the following blocks of the subprogram were designed: a local diagnostics block and an alert handling block.

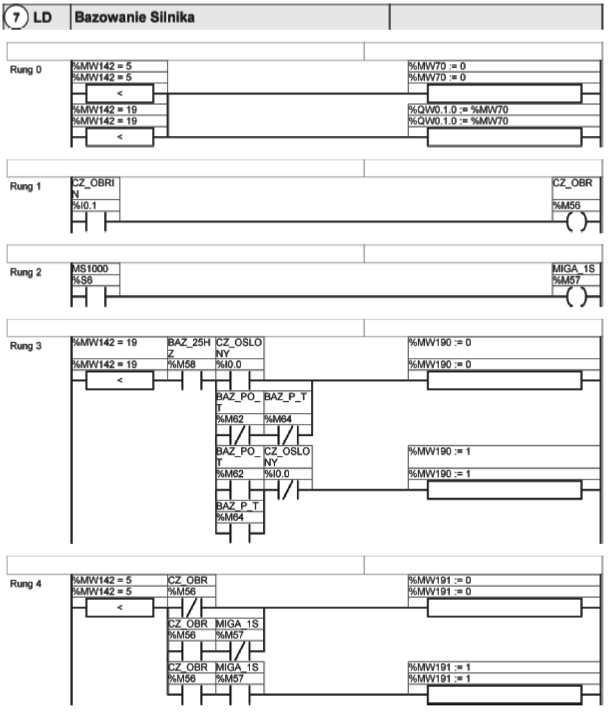


Fig. 2. Part of the subprogram for the motor positioning in procedure P1

- The torque measurement procedure (P4) supports the measurement unit EP2 of the control system. The procedure is responsible for the measurement of the DC motor load, based on the measurement of the value of the current of the motor. The procedure development process consisted in the programming of communication modules connected with the module. The next step concerned the development of the block for the reading of the moment of force exerted by the DC motor and the measurement data conversion block. Then, the block of the subprogram of the diagnostics module was developed.
- The force measurement procedure (P5) is responsible for the operation of the measurement module EP4 of the control system. The procedure supports the measurement of force using a strain gauge and a dedicated measurement amplifier. The development of the procedure was connected with the programming of the module's communication interface. The next step concerned the development of the subprogram of the force measurement data reading block and the measurement data conversion block. Finally, the module's diagnostics block was developed.

Table 2. Procedure selection matrix

	Type of device	Base procedure	Dedicated procedures				
			P1	P2	P3	P4	P5
1	Repeated spherical bending stress tester	X	-	X	-	-	X
2	Sheet turning and pulling stress tester	X	X	-	-	-	X
3	Repeated alternate spatial torsion stress tester	X	X	-	X	X	-
4	Repeated one-sided bending stress tester	X	X	-	-	-	-
5	Repeated alternate bending stress tester	X	X	-	-	-	-
6	Multifunctional tester	X	-	X	X	-	-

The reconfigurability of the developed control system stems from the possibility to configure the hardware of the system and the software of the PLC, as a result of which, a new type of a testing device is created. The developed configurable software of the control system is the result of including all of the programme procedures (basic and dedicated) in the main programme of the PLC. The implementation of a selected testing device within configurable software of the system consists in the activation, in the main programme of the PLC controller, of the procedures and the blocks of the subprograms that concern the operation and maintenance of selected modules of the control system, according to the developed matrix for procedure selection (Table 2), in the range specified by the functional requirements of a given type of a testing device.

The developed system also allows its further extension, both in terms of hardware, and software.

2. User interface structure

Another element producing the unification of the developed reconfigurable software for the control system was the development of a common core of the user interface (Fig. 3).

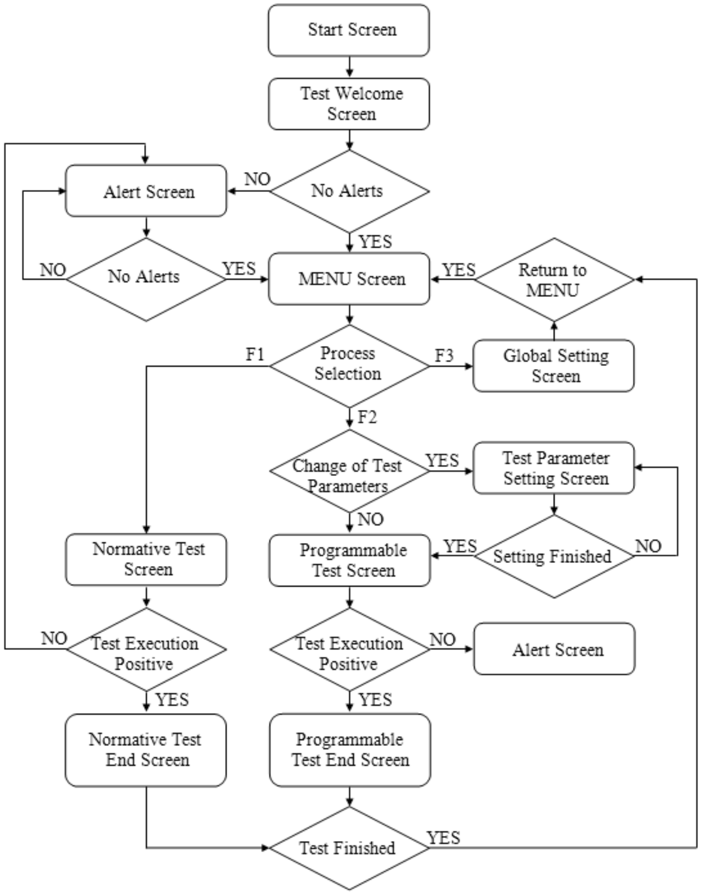


Fig. 3. Diagram of the structure of the user interface

Once the operator makes himself familiar with a single testing device, this interface enables a free passage and operation of another testing device intended for the execution of different tests, but developed within the common reconfigurable control system.

The developed structure of the user interface software was used for the development of the user panel responsible for the communication of the user with the central unit of the testing device. The developed structure of the user interface shows general dependencies between individual screens of the user panel, and it is designed for the entire series of the developed testing devices.

Within this structure of the user interface and each testing device, two types of tests, i.e. normative (Fig. 4a) and programmable tests can be performed – the global parameters of the device set (Fig. 4b) and the alerts handled.

a) b)

Fig. 4. Examples of screens of user interface; a) screen of the normative test, b) screen of the menu

3. Examples of devices for document durability tests

The development of the reconfigurable control system enabled the design of a series of testing devices intended for durability tests for electronically secured documents. Each type of a testing device was made by connecting proper hardware modules of the control system and the programme procedures for the PLC, while maintaining the uniform structure of the user interface. The selection of the hardware structure and the structure of the software of the control system for a given testing device depended on the requirements for a particular test.

The process of designing the control system of the testing device, executed within the developed control system, is presented based on a repeated spherical document bending stress test as follows:

- The test object is determined, which is an electronically secured document in ID-1, ID-3 format.
- The requirements and technical foundations are developed. The device should execute the test consisting in a repeated multiple pressing of a test object against a flexible base with a force of 350 [N], which is maintained in

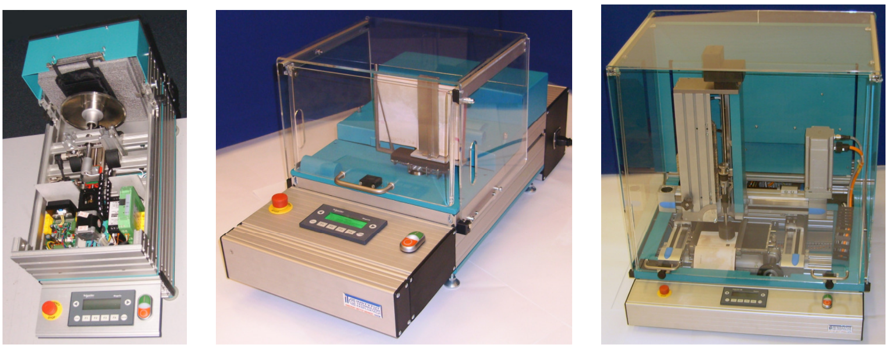
ten cycles for 5 [s], and then released. The test procedure assumes the execution of 10 load cycles on both sides of the document.

- The test functions and selection of procedures of the main control system are determined. In this test, force exertion and measurement functions are executed and, based on the procedure selection matrix (Table 2), a basic procedure and procedures P2 and P5 are activated in the main programme of the PLC of the control device. In the basic procedure, the following features and parameters were determined: the number of screens of the user panel, the method of their presentation and protection, and the means and the number of external security elements for the testing device. In the developed subprogram (communication with the user) of the basic procedure, 13 information screens (in the range of 1 to 64,999 screens) were activated and programmed.
- In the dedicated procedure P2, which enables the operation of both the stepper motor and the set (a motor and a stepper motor controller), the application of the subprogram operating the stepper motor was activated, particularly for the spherical bending stress test. Within the application, several general blocks, such as the homing of the motor, or its movement at a given speed in any direction, were activated. For example, in the motor movement block, the possibility of the determination of border speed for a given stepper motor, the possibility to set the speed, and the direction of the movement were attributed.
- Procedure P5 enables the activation of a required communication interface (out of Modbus, RS232, Ethernet interfaces, or analogue inputs/outputs) with a dedicated measurement module. For the spherical bending stress test, a block for the operation of the interface of analogue inputs/ outputs was activated, together with the measurement data reading, conversion and record blocks, which make use of a predefined range of measurement records in the memory of the central control unit. The general subprogram of measurement data conversion also has a specified maximum memory area for measurement records; and for a given application, there also is a possibility for its declaration within this area.
- The hardware structure for the execution of the test is selected. This includes the selection of a PLC, a user panel, dedicated actuator and measurement modules (ZW2 and EP4) complying with the test requirements.
- The device is constructed.
- Verification tests on a real test object (spherical bending stress tester) (Fig. 5a) [6] are made.

The development of the reconfigurable control system formed the basis for the development of the following testing devices:

- Repeated spherical bending stress tester,

- Sheet turning and pulling stress tester (Fig. 5b) [7],
- Repeated alternate spatial torsion stress tester [7],
- Repeated one-sided bending stress tester,
- Repeated alternate bending stress tester [7], and
- Multifunctional tester (Fig. 5c) [8].



a) b) c)

Fig. 5. Examples of devices for document durability tests: a) repeated spherical bending stress tester, b) sheet turning and pulling stress tester, c) multifunctional tester

Summary

The developed reconfigurable hardware and software structure of the control system enables the modification, selection and assembly of suitable actuator and measurement modules, the selection of relevant programme procedures for the PLC controller of the system, maintaining the unification of the structure of the user interface, and creating an unique type of a testing device with the work parameters set. The development of the reconfigurable software of the PLC controller enables the use of general basic procedures for the operation of different kinds of measurement and actuator elements, the activation of required full procedures, or the selection of blocks of procedures in the main programme. The developed reconfigurable control system allows further extension, both in terms of hardware and software structure. The development of the system enabled the construction of a series of testing devices for document durability tests. Additionally, the solution also enabled the unification of the user interface, guaranteeing uniform standards of operation and functioning of individual testing devices. The development of the reconfigurable control system significantly increased the speed of the design of each type of a testing device and concurrently reduced the costs of the development of the series of testing devices.

A different area of the application of the developed solution may include other quasi-static and low cycle systems of precise exertion and small load tests.

Scientific work executed within the Strategic Project "Innovative Systems of Technical Support for Sustainable Development of Economy" within Innovative Economy Operational Programme.

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Oprogramowanie sterujące rekonfigurowalnego systemu sterowania zestawu urządzeń testujących

Słowa kluczowe

System sterowania, urządzenie testujące, struktura sprzętowa, procedura, sterownik PLC.

Streszczenie

W artykule przedstawiono oprogramowanie sterujące rekonfigurowalnego systemu sterowania zestawem urządzeń realizujących badania trwałości dokumentów z zabezpieczeniem elektronicznym. Przytoczono ogólną metodykę projektowania rekonfigurowalnego systemu sterowania. Przedstawiono strukturę oprogramowania systemu oraz metodę doboru procedur programu przy tworzeniu pełnego oprogramowania sterownika PLC dla poszczególnych urządzeń testujących. Opisano strukturę interfejsu użytkownika typoszeregu urządzeń. Zaprezentowano urządzenia do badania trwałości dokumentów, w których zastosowano aplikacje opracowanego rekonfigurowalnego systemu sterowania oraz omówiono przykładowy proces konfiguracji systemu sterowania jednego z urządzeń.