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PARAMETERS MEASUREMENT AND IDENTIFICATION EQUIPMENT FOR ON-LINE TESTING OF THE ELECTRIC PANELS

Valentin NAVRAPESCU[1], Cristian Mircea MUSCAI[2]

The equipment performs interactive measurements in order to validate the characteristics of the electrical panels, in relation to the field nomenclature and the design's requirements. The equipment consists of the software verification structure, in various available scenarios, and related to the panel's design type, which allows step-validation. The hardware side perfor ms the electrical parameters measurement, sending their values by a wireless protocol. Each software scenario includes three verification stages: mechanical, placement of the internal electric devices and the electric parameters values. The last stage is validated by involving the hardware side of the equipment. Also, every verification stage has a result, operator's identification number and timestamp. If all the verification stages are passed, the application generates the final report and a certificate of conformity.

Keywords: electric panel, electric design verification, interactive measurements, step-validation, wireless data transfer

1. Introduction

Despite the technological advance the electrical panels keep their place in the distribution of the electric current at all the voltage levels and in all the applications. The electrical panels nowadays consist of many parameter monitoring devices added to the classical structure of electric current distribution and protection [1]. These features allow predictive maintenance and early damage detection of the panel's components by real-time monitoring [2].

Also, the design of the electrical panels has an important evolution in order to meet the main requirements of the actual applications. Thus, a complex algorithm was designed to combine the function modeling with the axiomatic design and the design structure matrix to automatically develop the layout of the electrical panel allowing the computer-aided design implementation in the detailed design stage [3].

At the level of low-voltage panels, their assembly and quality testing raised up numerous improvements regarding the design algorithm for panel size, included components and wiring diagrams [4,5].

[1] Prof., Electrical Engineering Faculty, University POLITEHNICA Bucharest, and associate member of AOSR, Romania

[2] PhD Stud., Electrical Engineering Faculty, University POLITEHNICA of Bucharest, Romania, e-mail: muscaicristian@yahoo.com

For various applications, there were developed dedicated electrical panels, which are included in guidelines with special requirements for customers [6]. These panels include *Intelligent Electronic Smart* devices and are parts of the *Remote Terminal Units* and *Supervisory Control and Data Acquisition* [7].

The electrical panels must answer to a large area of requirements, for quality and durability, and for that they need to be tested even from the accomplishment stage. Classic inspection consists of four typical sections: visual and mechanical, electrical, values of visual and mechanical and values for electrical [8]. For electrical installations with special requirements, there are other tests to perform in order to prove all the features [9].

This paper presents another modern method of testing, using a PC and a mobile electronic equipment (MEE) consisting of an electronic measuring device (EMD) and a bar-code reader (B-CR), that successfully replace the classical methods of testing the electrical panels. It allows a record keeping of type and specific checks of the manufactured switchboards, using a new software that integrates electrical measurements performed by qualified persons. The software also generates the necessary certificates of conformity once all the necessary electrical and visual checks have been successfully completed. If irregularities are detected, a detailed report is provided. The information of the equipment's operation is saved in a database, allowing save and restore strategy and updates for the checking algorithm.

2. Structure of the proposed equipment

The proposed Parameters Measurement and Identification Equipment (PMIE) consists of three distinct components: Electronic Measuring Device (EMD), a PC with the dedicated software and Bar-Code Reader (B-Cr) for QR or simple bar-codes, the interaction between components is presented in Fig. 1.

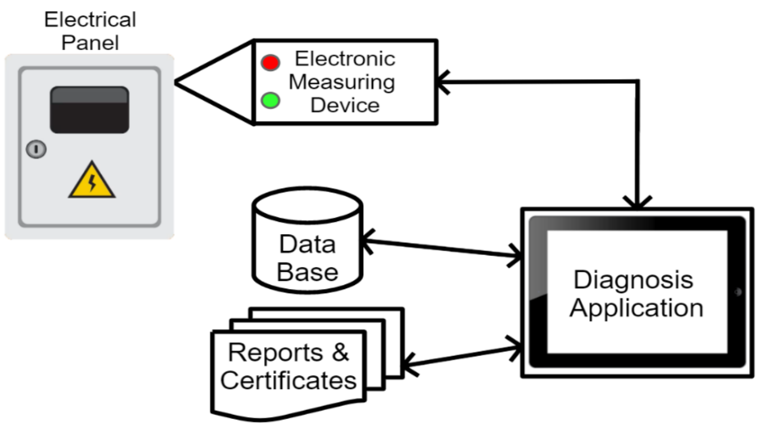

Fig. 1. Block diagram of PMIE.

A SQLite database was used to allow saving / restoring, and also the portability of the application, which can be moved from a computer running Microsoft Windows, to Linux, or even Mac OS X unmodified. The application database file can be placed on the testing PC or a dedicated server, according to internal rules.

The diagnosis application from the PC sends commands to EMD, which sends back to the PC the answer about the measured parameters and the state of the measuring device. The operator follows the steps indicated by the application. At the end of the test, if all steps are passed, the application generates the report and the required certificates.

2.1. The PC application software

The Live Code programming environment is widely used to implement different applications in engineering. Other popular programming language, used to create in house application for different practical purposes, is the Visual Basic Language, it draws up AutoCAD or Office Applications as the most used scripting language [10-11].

The programming environment allows the programmer to create a functional graphical user interface with a minimum number of line-code, using the high level integration of scripting methods and graphical user interface. The manufacturer calls the Live Code as being the Very High Level Language, placing it over the traditional programming languages, such as Visual Basic, Delphi or Java [12-13].

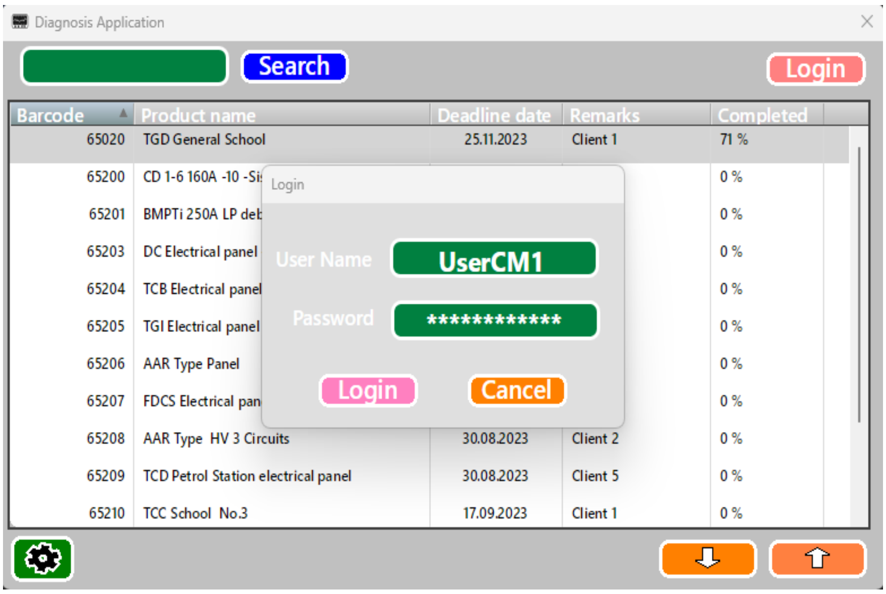

Fig. 2. Main and login window.

The designed application allows navigation and settings to be made, using a touchscreen PC or tablet, without mouse and keyboard, or other pointing devices. The use of interface and navigation among multiple objects is performed by the up-down buttons.

The application consists of the main and the secondary stack, the main being the working interface and the secondary is a small utility that allows setting and testing the communication parameters with EMD. This utility searches and lists all serial, real and virtual, ports that can be opened and used on the platform, and populates a Combo Box control with all these available ports, from which the user can select the desired one based on its name [14]. It also allows commands sent to the electronic terminal, to identify electronic or connection problems due to wrong settings or device’s defects. The main stack contains four Card objects, each being a self-contained interface that can be accessed using the programming environment's card traversal commands, depending on the application's state at the time.

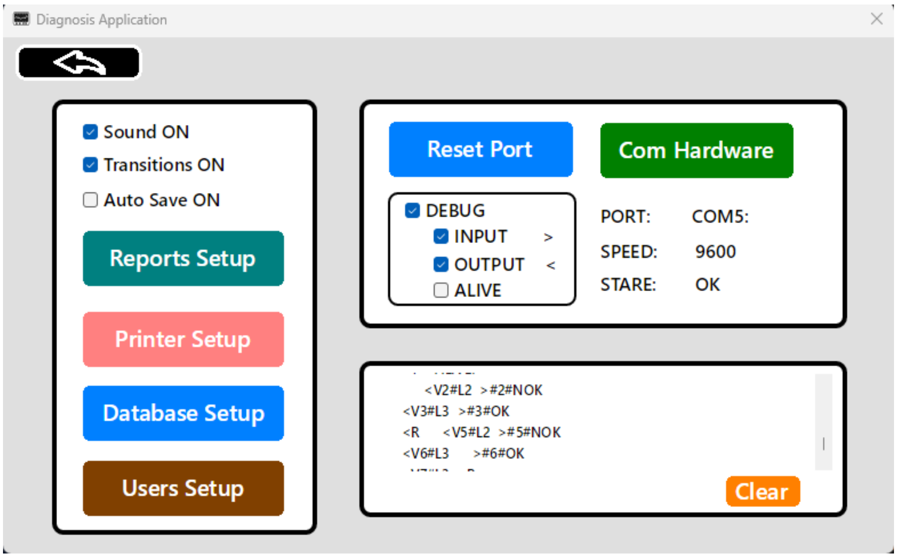

Fig. 3. Setup window.

The main window allows the search and navigation among projects under review, in order to retrieve, resume or complete a previously interrupted process. Once a project is completed it cannot be modified and becomes read only.

The completion or non-completion of a project can be found out from the column next to the product under verification, as percentage, which must reach 100% to be considered completed. The percentage is the sum of all checks of the product divided by the total number of checks to be performed. If there are checks that did not pass the test, they are not quantified and thus the product cannot be considered as completed.

To setup various options related to the operation and functioning, a setting card is needed, Fig. 3. By the card, the selection of database location, printer's type, report formatting and the user's management can be performed. The setup is granted just for administrator level, the other users do not have permission. A *Debug* option can be accessed to view in real-time the commands sent to, and responses from, the device during checks.

In order to facilitate the tracking process of the communication protocol used, the application allows disabling the signals transmitted to the measuring device or those received by the PC. The proposed communication protocol tests the communication with the measuring device by means of a type signal transmitted every 10 seconds. If two successive responses are not received from the measuring equipment, then communication with the equipment is considered lost and the measurement process ends until communication is restored

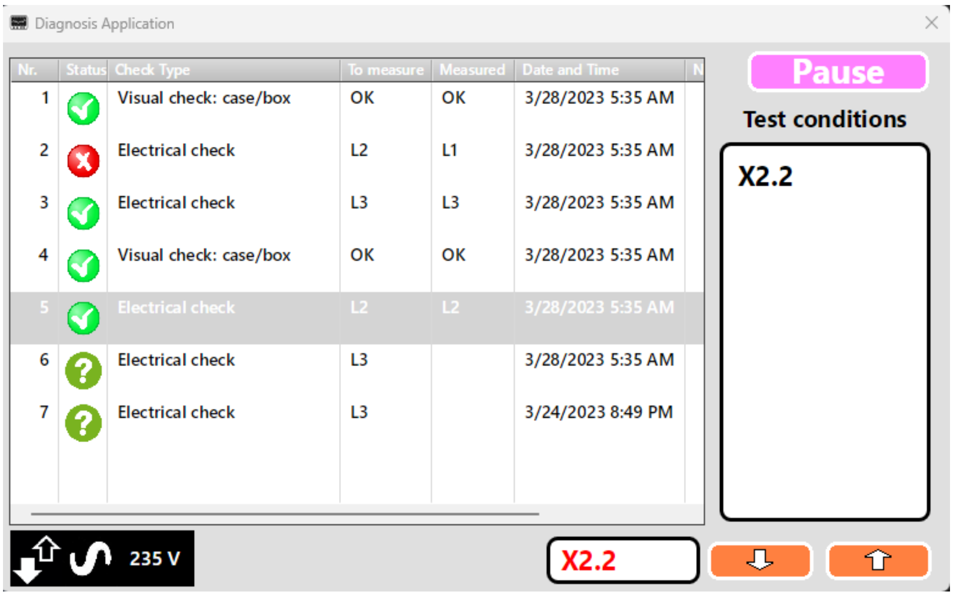

Fig. 4. The verification card.

The most used window should be the Verification card, it is presented in Fig. 4. Here, a DataGrid-like is listed, with all the requirements for the checked panel. The process supposes two scenarios: electrical checking and non-electrical, related to the compliance of the labeling, clamping system, or enclosure and its various mechanical and fastening type. During the non-electrical checking, the automatic operation can be interrupted, and the operator must press OK or NOK button, depending on the compliance or non-compliance of the checked items. The purpose of the non-electrical check is to impose a certain verification route, avoiding to omit certain steps or aspects.

Electrical check requires the exclusive use of MDE. The measuring points and any additional observation are indicated on the user interface, according to the notation of the switchboard. The need of additional information is due to the possibility of testing more complex switchboards, containing control and management components that operate just under certain conditions.

When designing the verification method, more complex steps can be added, which require extensive information about the operation of the switchboard that will be checked. A well-developed scenario can drastically reduce the number of steps, simplifying the testing process and shorting the time [15-16].

2.2. Electronic measuring device

The electronic measuring device (MDE), presented in Fig. 5, consists of two important parts: the input and measuring circuit, which ensure the galvanic isolation, and the programmable intelligent device that allows the connection to the PC.

This method of using general purpose electronic components in technical applications to create special electrical equipment used in electrical measurements is a method often used in engineering practice. [17-18].

MDE simultaneously performs four electrical measurements: between the tip of the device and the ground point, and between the tip and the 3 phases of the mains voltage. By taking the measurements at the same time, the identification of the switchboard outputs and the phases are determined [19]. In this way, faults of the circuits or affected components can be quickly identified.

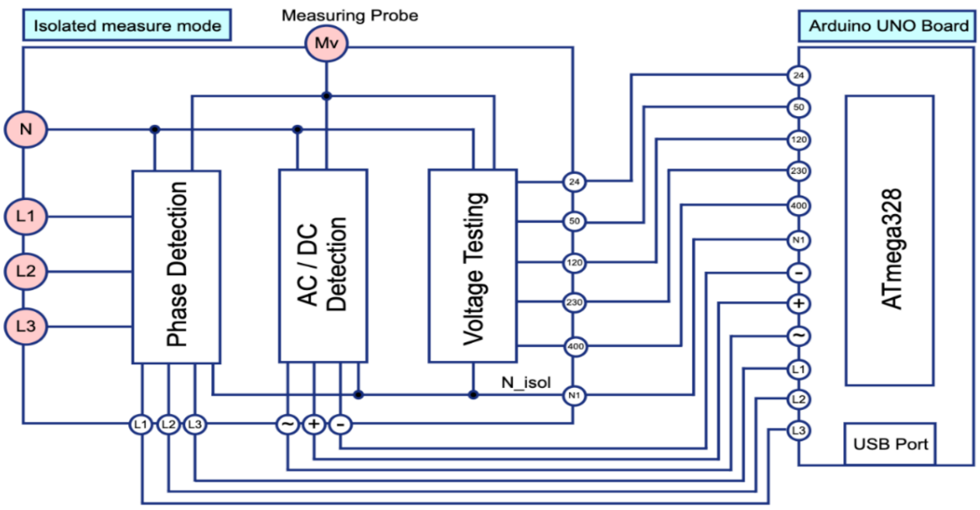

Fig. 5. Schematic diagram of MDE.

MDE is made by an Arduino Uno development board, a series of resistive dividers and a set of PC 719 optocouplers. Only the digital inputs are used in this application, the analog inputs remaining for future developments. Communication with the PC and the supply are ensured via the serial port emulated on the USB interface of the device [20].

MDE allows fast, accurate and safe handling, without requiring laborious commissioning or calibration steps, because the presence or absence of a phase is detected by a voltage or phase level detection circuit, not requiring the adjustment of voltage levels. The actual measured value is used to establish the measurement thresholds and identify the voltage range. The electric diagram of the MDE's input is presented in Fig. 5. Thus, the panel's output voltage is measured, not just phase identification

The MDE's voltage testing side is based on the voltage divider, consisting in a set of series resistors, each representing one of the measurable electrical voltages. In parallel with these resistors the optocouplers inputs are connected. Each of the optocoupler outputs are connected to an Arduino Uno digital input in the D3-D7 range, see Fig. 6.

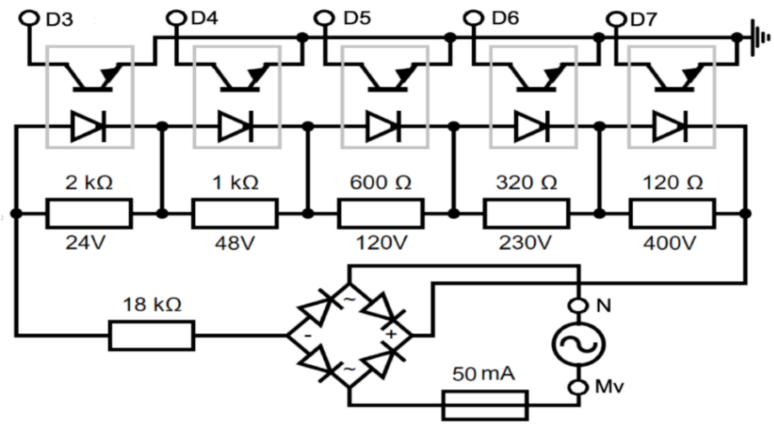

Fig. 6. MDE voltage testing side.

The phase detection side can be seen in Fig. 7, and it is based on the voltage detection, filtering and sensing via a digital input.

$$R = \frac{U_{Main} - U_{Led}}{I_{Led}} = \frac{400 - 1.2}{0.01} = 39.8k \qquad (1)$$

Voltage detection is made using a rectifying bridge, a limiting resistor and an optocoupler. The resistor value is calculated to limit the current through the optocoupler input to a maximum of 10 mA in case of 400 V, and a minimum 3-5 mA for 230V.

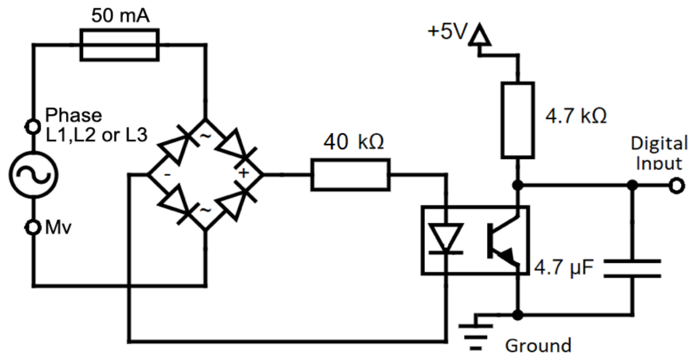

Fig. 7. MDE phase detection side.

The outputs of the optocouplers used to identify the measured voltages are connected to the digital input circuits of a microcontroller. The supply of the transistorized outputs of the used optocouplers is realized by means of pull-up Resistors and a small capacitor used also to obtain a consistent signal from the pulsating voltage.

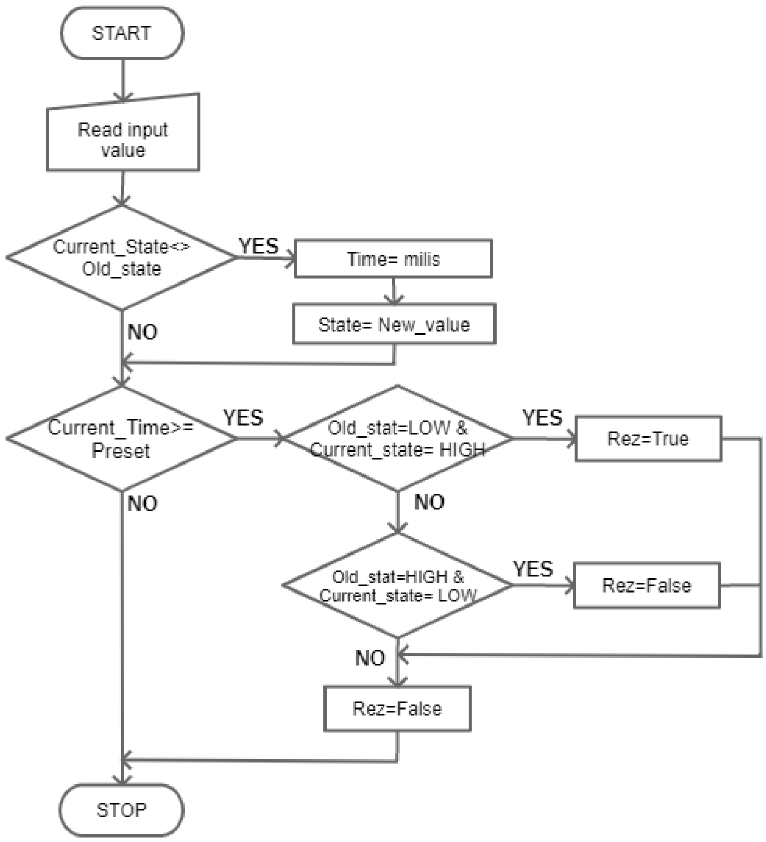

Fig. 8. PMIE debouncing routine's flowchart.

The AC / DC detection module provides the identification of the current flow direction, resulting in the identification of current type: AC – alternating or DC – direct.

The logic diagram of the PMIE is based on an asynchronous reading loop of the measurements, everyone being compared to the requested value.

Each sent command is identified and syntactically tested within the Process String function, the simplest ones are immediately processed and executed.

The measurement requires placing the probe of the MDE on the circuit indicated by the application. The debouncing routine checks the accuracy of the measured value over a period of 500 ms, the routine is given in the Fig. 8.

If the type, value, or phase of the voltage does not match the requested one, then the equipment returns a message to the PC showing the measured value, the NOK message and the measurement number. This number allows the identification of the row in the measurement.

3. Results and Discussions

PMIE identifies via MDE the type of electric current, AC or DC, the number of the phase, L1 to L3, and certain voltage levels: 24, 48, 120, 230 and 400. The operator is notified for the measuring start, by the simultaneously lighting of the red and green lamps, and the result of the measurement, by green light if it is right, or red light if it is not. Thus, the voltage levels were tested, and the starting voltage value for each level has been determined, they being listed in Table 1.

Table 1

Starting voltage values tested for each voltage value detected by the MDE

Voltage level (V)	Starting Value (V)
24	20
48	41
120	90
230	200
400	350

In Fig. 9 a real testing scenario is depicted.

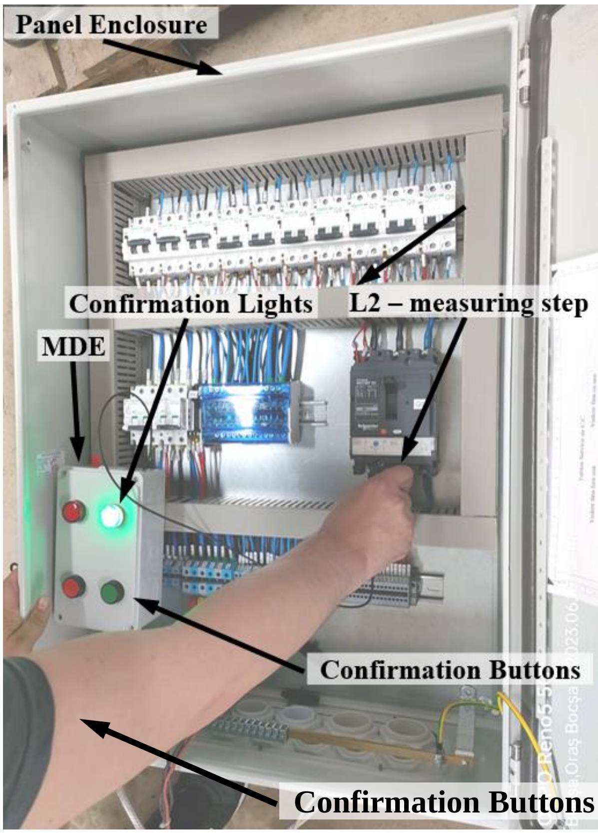

Fig. 9. Performing tests on an electric panel.

Before the electric measurements, the operator must check the visual aspects, as the labeling, the enclosure type, the mechanical and dimensional features, the internal placing of the panel's components, each of these steps are confirmed by buttons for okay-green or not okay-red. The time consumed to check up these aspects was in about 3 min. In the image, the measurement step corresponds to the second phase, L2, it being highlighted as step in Fig. 4. An electric measuring time period can take maximum 5 s for each one, the average value in this testing scenario was 2.5 s. For the entire electric measurement stage a 75 s time has been spent.

If something goes wrong for an electric measuring step, the software marks the mistake, it indicates the wrong value, and pass forward. At the end of measurement, the generated report clearly indicates the wrong steps, and the troubleshooting will be easily performed by the repairing team.

In this way, it has been confirmed that the electrical panel's checking is faster performed, the results are more detailed and accurate, than in the case of classic verification strategy.

As possible improvement resulted by testing, an acoustic signal added to the existent should produce more comfort in the MDE operation. Also, the wireless communication between MDE and the PC would be more desirable, increasing the MDE physical manipulation flexibility.

4. Conclusion

The designed testing equipment avoids most of the problems encountered by the operator, allowing a structured checking of the electric panel, the process can be interrupted and resumed any time. The testing process automatically produces as a result the quality certificate for the tested panel. Also, an important feature of this application is the saving of date and time, actual testing step and the operator's name. Thus, the testing process can be continued even if it was started by someone else.

The testing equipment main advantages:

- A general feature - all types of the low-voltage electrical panels can be tested without changing the assembly in any way.
- Easy operation - testing speed and accuracy are increased more than five times comparing to the classic testing procedures.
- High reliability - it does not require special configuration or adjustment procedures.
- Easy maintenance - due to the reduced number of components and the simple schematic.
- Low cost - the components are cheap and easy to purchase.

In order to easily perform testing on complex automation panels, future version of the testing equipment will provide analog and digital outputs, in order to simulate the real conditions.

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