GOCE DELCEV UNIVERSITY, SHTIP, NORTH MACEDONIA
FACULTY OF ELECTRICAL ENGINEERING

ETIMA 2021

FIRST INTERNATIONAL CONFERENCE

19-21 OCTOBER, 2021

TECHNICAL SCIENCES APPLIED IN ECONOMY, EDUCATION AND INDUSTRY

УНИВЕРЗИТЕТ „ГОЦЕ ДЕЛЧЕВ" - ШТИП
ЕЛЕКТРОТЕХНИЧКИ ФАКУЛТЕТ

UNIVERSITY „GOCE DELCHEV" - SHTIP
FACULTY OF ELECTRICAL ENGINEERING

ПРВА МЕЃУНАРОДНА КОНФЕРЕНЦИЈА
FIRST INTERNATIONAL CONFERENCE

ЕТИМА / ETIMA 2021

ЗБОРНИК НА ТРУДОВИ
CONFERENCE PROCEEDINGS

19-21 Октомври 2021| 19-21 October 2021

Главен и одговорен уредник / Editor in Chief
Проф.д-р Сашо Гелев
Prof.d-r Saso Gelev

Јазично уредување / Language Editor
Весна Ристова (Македонски) / Vesna Ristova (Macedonian)

Техничко уредување / Technical Editing
Доц.д-р Далибор Серафимовски / d-r Dalibor Serafimovski

Издавач / Publisher
Универзитет „Гоце Делчев" - Штип / University Goce Delchev - Stip
Електротехнички факултет / Faculty of Electrical Engineering

Адреса на организационен комитет / Adress of the organizational committee
Универзитет „Гоце Делчев" – Штип / University Goce Delchev - Stip
Електротехнички факултет / Faculty of Electrical Engineering
Адреса: ул. „Крсте Мисирков" бр. 10-А / Adress: Krste Misirkov, 10 - A
Пош. фах 201, Штип - 2000, С.Македонија / PO BOX 201, Stip 2000, North Macedonia
E-mail: conf.etf@ugd.edu.mk

CIP - Каталогизација во публикација
Национална и универзитетска библиотека "Св. Климент Охридски", Скопје

62-049.8(062)
004-049.8(062)

МЕЃУНАРОДНА конференција ЕТИМА (1 ; 2021)
Зборник на трудови [Електронски извор] / Прва меѓународна конференција ЕТИМА 2021, 19-21 Октомври 2021 = Conference proceedings / First international conferece ETIMA 2021, 19-21 October 2021 ; [главен и одговорен уредник Сашо Гелев]. - Штип: Универзитет "Гоце Делчев", Електротехнички факултет = Shtip: University "Goce Delchev", Faculty of Electrical Engineering, 2021

Начин на пристапување (URL): https://js.ugd.edu.mk/index.php/etima. - Текст во PDF формат, содржи 358 стр.илустр. - Наслов преземен од екранот. - Опис на изворот на ден 15.10.2021. - Трудови на мак. и англ. јазик. - Библиографија кон трудовите

ISBN 978-608-244-823-7

1. Напор. ств. насл.
а) Електротехника -- Примена -- Собири б) Машинство -- Примена -- Собири в) Автоматика -- Примена -- Собири г) Информатика -- Примена -- Собири

COBISS.MK-ID 55209989

ОРГАНИЗАЦИОНЕН ОДБОР
ORGANIZING COMMITTEE

Василија Шарац / Vasilija Sarac
Електротехнички факултет,
Универзитет „Гоце Делчев" - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

Сашо Гелев / Saso Gelev
Електротехнички факултет,
Универзитет „Гоце Делчев" - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

Тодор Чекеровски / Todor Cekerovski
Електротехнички факултет,
Универзитет „Гоце Делчев" - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

Далибор Серафимовски / Dalibor Serafimovski
Електротехнички факултет,
Универзитет „Гоце Делчев" - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

Маја Кукушева Панева / Maja Kukuseva Paneva
Електротехнички факултет,
Универзитет „Гоце Делчев" - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

Билјана Читкушева Димитровска / Biljana Citkuseva Dimitrovska
Електротехнички факултет,
Универзитет „Гоце Делчев" - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

Весна Конзулова / Vesna Konzulova
Електротехнички факултет,
Универзитет „Гоце Делчев" - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

ПРОГРАМСКИ И НАУЧЕН ОДБОР
SCIENTIFIC COMMITTEE

Влатко Чингоски / Vlatko Cingoski
Електротехнички факултет,
Универзитет „Гоце Делчев” - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

Божо Крстајиќ / Bozo Krstajic
Електротехнички факултет
Универзитет во Црна Гора, Црна Гора
Faculty of Electrical Engineering,
University in Montenegro, Montenegro

Милован Радуловиќ / Milovan Radulovic
Електротехнички факултет
Универзитет во Црна Гора, Црна Гора
Faculty of Electrical Engineering,
University in Montenegro, Montenegro

Гоце Стефанов / Goce Stefanov
Електротехнички факултет,
Универзитет „Гоце Делчев” - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

Мирјана Периќ / Mirjana Peric
Електронски факултет
Универзитет во Ниш, Србија
Faculty of Electronic Engineerig,
University of Nis, Serbia

Ана Вучковиќ / Ana Vuckovic
Електронски факултет
Универзитет во Ниш, Србија
Faculty of Electronic Engineerig,
University of Nis, Serbia

Тодор Чекеровски / Todor Cekerovski
Електротехнички факултет,
Универзитет „Гоце Делчев” - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

Далибор Серафимовски / Dalibor Serafimovski
Електротехнички факултет,
Универзитет „Гоце Делчев” - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

Мирослава Фаркаш Смиткова / Miroslava Farkas Smitková
Факултет за електротехника и информациони технологии
Словачки Технички Универзитет во Братислава, Словачка
Faculty of Electrical Engineering and Information Technology
Slovak Technical University in Bratislava, Slovakia

Петер Јанига / Peter Janiga
Факултет за електротехника и информациони технологии
Словачки Технички Универзитет во Братислава, Словачка
Faculty of Electrical Engineering and Information Technology
Slovak Technical University in Bratislava, Slovakia

Јана Радичова / Jana Raditschová,
Факултет за електротехника и информациони технологии
Словачки Технички Универзитет во Братислава, Словачка
Faculty of Electrical Engineering and Information Technology
Slovak Technical University in Bratislava, Slovakia

Драган Миновски / Dragan Minovski
Електротехнички факултет,
Универзитет „Гоце Делчев” - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

Василија Шарац / Vasilija Sarac
Електротехнички факултет,
Универзитет „Гоце Делчев” - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

Александар Туџаров / Aleksandar Tudzarov
Електротехнички факултет,
Универзитет „Гоце Делчев” - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

Владимир Талевски / Vladimir Talevski
Електротехнички факултет,
Универзитет „Гоце Делчев” - Штип, Северна Македонија
Faculty of Electrical Engineering,
Goce Delchev University - Stip, North Macedonia

PREFACE

The Faculty of Electrical Engineering at University Goce Delcev (UGD), has organized the International Conference ***Electrical Engineering, Informatics, Machinery and Automation - Technical Sciences applied in Economy, Education and Industry-ETIMA*.**
ETIMA has a goal to gather the scientists, professors, experts and professionals from the field of technical sciences in one place as a forum for exchange of ideas, to strengthen the multidisciplinary research and cooperation and to promote the achievements of technology and its impact on every aspect of living. We hope that this conference will continue to be a venue for presenting the latest research results and developments on the field of technology.
Conference ETIMA was held as online conference where contributed more than sixty colleagues, from six different countries with forty papers.
We would like to express our gratitude to all the colleagues, who contributed to the success of ETIMA'21 by presenting the results of their current research activities and by launching the new ideas through many fruitful discussions.
We invite you and your colleagues also to attend ETIMA Conference in the future. One should believe that next time we will have opportunity to meet each other and exchange ideas, scientific knowledge and useful information in direct contact, as well as to enjoy the social events together.

The Organizing Committee of the Conference

ПРЕДГОВОР

Меѓународната конференција ***Електротехника, Технологија, Информатика, Машинство и Автоматика-технички науки во служба на економија, образование и индустрија-ЕТИМА*** е организирана од страна на Електротехничкиот факултет при Универзитетот Гоце Делчев.
ЕТИМА има за цел да ги собере на едно место научниците, професорите, експертите и професионалците од полето на техничките науки и да претставува форум за размена на идеи, да го зајканува мултидисциплинарното истражување и соработка и да ги промовира технолошките достигнувања и нивното влијание врз секој аспект од живеењето. Се надеваме дека оваа конференција ќе продолжи да биде настан на кој ќе се презентираат најновите резултати од истражувањата и развојот на полето на технологијата.
Конференцијата ЕТИМА се одржа online и на неа дадоа свој допринос повеќе од шеесет автори од шест различни земји со четириесет труда.
Сакаме да ја искажеме нашата благодарност до сите колеги кои допринесоа за успехот на ЕТИМА'21 со презентирање на резултати од нивните тековни истражувања и со лансирање на нови идеи преку многу плодни дискусии.

Ве покануваме Вие и Вашите колеги да земете учество на ЕТИМА и во иднина. Веруваме дека следниот пат ќе имаме можност да се сретнеме, да размениме идеи, знаење и корисни информации во директен контакт, но исто така да уживаме заедно и во друштвените настани.

Организационен одбор на конференцијата

Содржина / Table of Contents

ASSESSING DIGITAL SKILLS AND COMPETENCIES OF PUBLIC ADMINISTRATION AND DEFINING THEIR PROFICIENCY LEVEL 12

PWM OPERATION OF SYNCHRONOUS PERMANENT MAGNET MOTOR 21

SPEED REGULATION OF INDUCTION MOTOR WITH PWM INVERTER 30

WI-FI SMART POWER METER 42

RF SENSOR SMART NETWORK.. 50

FREQUENCY SINUS SOURCE.. 62

MEASUREMENT ON COMPENSATION CAPACITANCE IN INDUCTIVE NETWORK BY MICROCONTROLLER 70

ИЗРАБОТКА НА ВЕШТ НАОД И МИСЛЕЊЕ ОД ОБЛАСТА НА ЕЛЕКТРОТЕХНИЧКИТЕ НАУКИ 79

SIMULATION OF AN INDUSTRIAL ROBOT WITH THE HELP OF THE MATLAB SOFTWARE PACKAGE... 86

BATTERY ENERGY STORAGE SYSTEMS AND TECHNOLOGIES:A REVIEW .. 95

POWER-TO-X TECHNOLOGIES.. 105

NEW INNOVATIVE TOURISM PRODUCT FOR REANIMATING RURAL AREAS 115

PROPOSED MODEL FOR BETTER ENGLISH LANGUAGE ACQUISITION, BASED ON WEARABLE DEVICES.. 123

OPEN SOURCE LEARNING PLATFORM – MOODLE 132

СПОРЕДБЕНА ТЕХНО-ЕКОНОМСКА АНАЛИЗА ПОМЕЃУ ТЕРМИЧКИ ИЗОЛИРАН И ТЕРМИЧКИ НЕИЗОЛИРАН СТАНБЕН ОБЈЕКТ 139

COMPARISON OF PERT AND MONTE CARLO SIMULATION 149

E-LEARNING – CYBER SECURITY CHALLENGES AND PROTECTION MECHANISMS 156

SECURITY AND PRIVACY WITH E-LEARNING SOFTWARE 164

ROOTKITS – CYBER SECURITY CHALLENGES AND MECHANISMS FOR PROTECTION 174

TOOLS AND TECHNIQUES FOR MITIGATION AND PROTECTION AGAINST SQL INJECTION ATACKS 182

INFLUENCE OF ROTATION ANGLE OF LUMINAIRES WITH ASYMMETRICAL LUMINOUS INTENSITY DISTRIBUTION CURVE ON CALCULATED PHOTOMETRIC PARAMETERS.. 189

PHOTOMETRIC PARAMETERS OF LED LUMINAIRES WITH SWITCHABLE CORRELATED COLOUR TEMPERATURE 197

ENERGY-EFFICIENT STREET LIGHTING SYSTEM OF THE CITY OF SHTIP USING SOLAR ENERGY AND LED TECHNOLOGY 204

NANOTECHNOLOGY–BASED BIOSENSORS IN DRUG DELIVERY SYSTEMS: A REVIEW 212

IOT SYSTEM FOR SHORT-CIRCUIT DETECTION OF DC MOTOR AT EKG-15 EXCAVATOR 222

DESIGN OF A PHOTOVOLTAIC POWER PLANT 231

DEVELOPMENT OF COMPUTER SOFTWARE FOR CREATING CHOREOGRAPHY 241

AUTOMATED SYSTEM FOR SMART METER TESTING 249

INFLUENCE DIMING OF LED LAMPS TO ELECTRICAL PARAMETERS 255

INRUSH CURRENT OF LAMP 261

COMPLEX EVALUATION MODEL OF A SMALL-SCALE PHOTOVOLTAIC INSTALLATION PROFITABILITY 269

IMPACT OF FAULTS IN TRANSMISSION AND DISTRIBUTION NETWORK ON VOLTAGE SAGS 278

ON APPLICABILITY OF BLACK-SCHOLES MODEL TO MSE 290

ACOUSTIC SIGNAL DENOISING BASED ON ROBUST PRINCIPAL COMPONENT ANALYSIS 300

INVESTIGATION OF EFFICIENCY ASPECTS IN 3×3 PHOTOVOLTAIC PLANT USING MODEL OF SHADING 309

PROGRESS OF NO-INSULATION HTS MAGNET DEVELOPMENT TOWARDS ULTRA-HIGH MAGNETIC FIELD GENERATION 319

GRID-CONNECTED HYBRID PV SYSTEM WITH BATTERY STORAGE 326

INVESTIGATION ON STABILITY OF PANCAKE COILS WOUND WITH BUNDLED MULTIPLE REBCO CONDUCTORS 336

ON-LINE МУЛТИМЕДИСКИ ОБРАЗОВНИ КАРТИЧКИ 343

АЛГОРИТАМОТ „ВЕШТАЧКА КОЛОНИЈА НА ПЧЕЛИ“ 352

UDC: 004.77:621.38.049.77]:621.313:622.23.05

IOT SYSTEM FOR SHORT-CIRCUIT DETECTION OF DC MOTOR AT EKG-15 EXCAVATOR

Milutin Radonjić[1], Božo Krstajić[2], Žarko Zečević[3]
[1]University of Montenegro, Faculty of Electrical Engineering, Podgorica, Montenegro, email: mico@ucg.ac.me
[2]University of Montenegro, Faculty of Electrical Engineering, Podgorica, Montenegro, email: bozok@ucg.ac.me
[3]University of Montenegro, Faculty of Electrical Engineering, Podgorica, Montenegro, email: zarkoz@ucg.ac.me

Abstract
In this paper, we present a concept of an IoT system that monitors the DC motor at the EKG-15 excavator. The proposed system is designed for the coal mine "Rudnik uglja Pljevlja", which uses this type of excavator for surface mining. Due to the type of excavation and the work procedures of the excavator, it often happens that the DC motors that drive the bucket of the excavator are in the so-called short circuit. During that time, a large current flow through the motor, which is electronically limited to a value of 2kA. However, there is no limitation in the time domain, which means that this current can flow for an unlimited time. If the operator keeps the excavator control lever in the active position for too long, during a short circuit, the DC motor will burn out. In that case, large repair costs are generated, and the excavator is out of order for a long time. Therefore, there is a need to alarm the operator that the motor is short-circuited, as well as to keep records of such events, to determine the causes of motor burnout and liability. The proposed system is based on a microprocessor hardware platform for short-circuit detection of DC motor and perform the mentioned functions. Experimental and implementation results showed that this IoT platform provides the collection of data that can be useful in the process of analyzing the operation and predictive maintenance of the excavator.

Keywords
DC motor, Excavator, IoT.

Introduction

Working on the surface mine of a coal mine is a challenging job, both for the people and the machines. In the winter, the temperature drops far below 0°C, while in the summer, tropical heat is a common case. There is no shelter from the cold or heat on the surface mine, so the workers are exposed to the extreme ambient conditions. It is similar to the machines that these workers use or operate. Therefore, predictive maintenance becomes a very important task, to cut maintenance costs of an ordinary industrial plant [1] – [4]. A proactive approach can save a lot of effort, especially by avoiding unnecessary delays in the production and use of human resources. However, such prediction is not an easy task and is possible only by continuous observation of the machine's parameters. We are dealing with this very important and challenging topic within the framework of the international project Faster [5]. The focus of this project is predictive maintenance of the rotating machines. Working on this topic in the coal mine "Rudnik uglja Pljevlja" (RUP) [6] we found some more important and challenging aspects to be considered about maintenance of machines. For this purpose, a modification and adjustment of the device that was already developed within the Faster project were performed.

One of the key machines for working on the surface mine of coal mines is a suitable excavator. The EKG-15 excavator is used for this purpose in the "Rudnik uglja Pljevlja" (Fig. 1). It is a machine in which the loading bucket is controlled by a high-power DC motor. In normal operation, these motors are designed to provide a long excavator life. However, when the loading bucket gets stuck due to the extremely hard terrain, the motor can be overloaded. Namely, if the operator does not release the lever that controls the movement of the loading bucket, the motor still tries to move the bucket. In these moments, a so-called short circuit occurs, when a high amount of current passes through the motor. If the operator does not react quickly and releases the lever, the short-circuit current threatens to damage the motor. If this happens, the motor will be out of use, and so will the excavator. Repair of these motors is very expensive and cannot be performed in a very short time. It is clear what this means for the surface mining process in the mine.

For these reasons, there is a need to solve the problem of short circuit current flow through the motors. In the case of excavators located in the company "Rudnik uglja Pljevlja", the manufacturer limited the short-circuit current to an amount of 2kA, as prevention. This means that the current flowing through the motor windings will not exceed this value. However, there is no protection provided concerning the duration of the short-circuit condition. In other words, a current of 2kA will flow through the motor windings as long as the operator activates the bucket control lever. If the operator keeps the motor active for a long time, the conductor will heat up and the motor will burn out.

Less experienced operators can unintentionally cause a condition that leads to a short-circuit current on the motors and often do not recognize in time that such a situation has occurred. This inevitably leads to motor burnout. However, since there is no protection, nor control, or records of the excavator's working mode, the operator can also intentionally cause a short-circuit current and consequently the motor to burn out for some of its reasons.

Therefore, there was a need to find a solution that would prevent the occurrence of a short-circuit current or at least reduce its probability. When designing a system that would lead to solving this problem, the requirement was that the original operation mode of the excavator is not affected in any way, nor that its control electronics are changed. In other words, a clear warning to the operator should be activated when a short-circuit current occurs. Also, it is necessary to record and store for later processing information related to the occurrence of the short-circuit current. Based on this information, the behavior of the operator can be determined, and errors can be pointed out to him if they are found. This provides prevention and extends motor life. In addition, this information can be used to analyze the cause of motor burnout, when it occurs.

Since the funds for the design of a prototype device that would perform described function were not planned in the company's budget, the device had to be inexpensive. Therefore, we decided to base this IoT system on the widely known Arduino open hardware platform [7], [8]. For authorities to have an immediate overview of the situation regarding the short-circuit current of the excavator motors, the data collected by the Arduino platform is immediately sent to the cloud platform. We used the open LiveGate platform for this purpose [9].

Fig. 1 Excavator EKG-15
Source: https://uralmash-kartex.ru/en/electric-rope-shovels#&gid=1&pid=1

The paper is organized as follows. In Section 1, we analyze the control of the excavator's DC motors and discuss possible techniques for short-circuit detection. Section 2 describes the proposed architecture of the system for detection and indication of the short-circuit current. Preliminary results of the system testing through laboratory simulations are presented in Section 3. Finally, in the conclusion, we summarize important aspects of this paper.

1. Analysis of the short-circuit detection of DC motor

To monitor the motor load in the excavator, the manufacturer implemented the system that allows the operator to have information about the current flowing through the DC motor windings. Namely, in the circuit of each of the two DC motors, there is one resistor, the so-called shunt. A voltage of 75mV is generated on this resistor during a short circuit current of 2kA. The voltage from the shunt is brought to an analog voltmeter with a symmetrical scale since the motor can move in both directions, so the current can also flow in both directions. One such voltmeter is in the machine part and another in the operator cabin of the excavator. Of course, the scale is calibrated in (kilo)amperes since the strength of the current flowing through the motor is important. This means that the operator, in addition to the mine surface where he works, should also continuously observe an analog instrument. This is inconvenient both from the point of safety or from the point of work efficiency. Therefore, it would be convenient for the operator to be somehow warned when the motor overloads.

The electronics that manage and control the excavator is a closed system that we did not have insight into. Therefore, the modification on the control electronics itself, to protect against overload, i.e., to prevent long-term short-circuit current, was not possible. Also, the maintenance engineers in RUP requested that the manufacturer's electronics of the excavator should not be modified or influenced in any way. Therefore, the only way to prevent frequent motor overload, and thus its burnout, was to warn the operator clearly and reliably that an undesirable situation had occurred, and that motor activity should be stopped.

The motor short-circuits current detection system, which is the subject of this paper, aims to continuously monitor the voltage from the shunt located in the motor circuit. As long as the current flowing through the motor does not exceed the critical value, i.e., the voltage on the shunt does not exceed the predefined value, the system does not take any action. When the voltage on the shunt above the critical value is detected (in the current version of the prototype it is set to 65mV), the timer that measures the duration of the excessive current is started. There is some time during which it is considered that the current flow of about 2kA is not dangerous for motor failure (in the current version of the prototype it is set to 3 seconds). If this time elapses, actions are taken to warn the operator and to store information about critical event.

2. Architecture of the proposed IoT system

After consulting with the engineers in charge of machine maintenance in RUP, we decided that the system for short-circuit detection of DC motor at EKG-15 excavator has a principal scheme shown in Fig. 2. Instead of messing up with the control electronics of the excavator, the warning signal to the operators will be generated by a strong siren (alarm). It will serve not only as a warning but also as an incentive for the operator to stop the overcurrent motor mode. The sound intensity and frequency have been chosen to be an inconvenience to the operator when exposed even for a short time. Since this siren is supplied with electricity taken from the power supply unit of the excavator, its activation is performed utilizing a common relay.

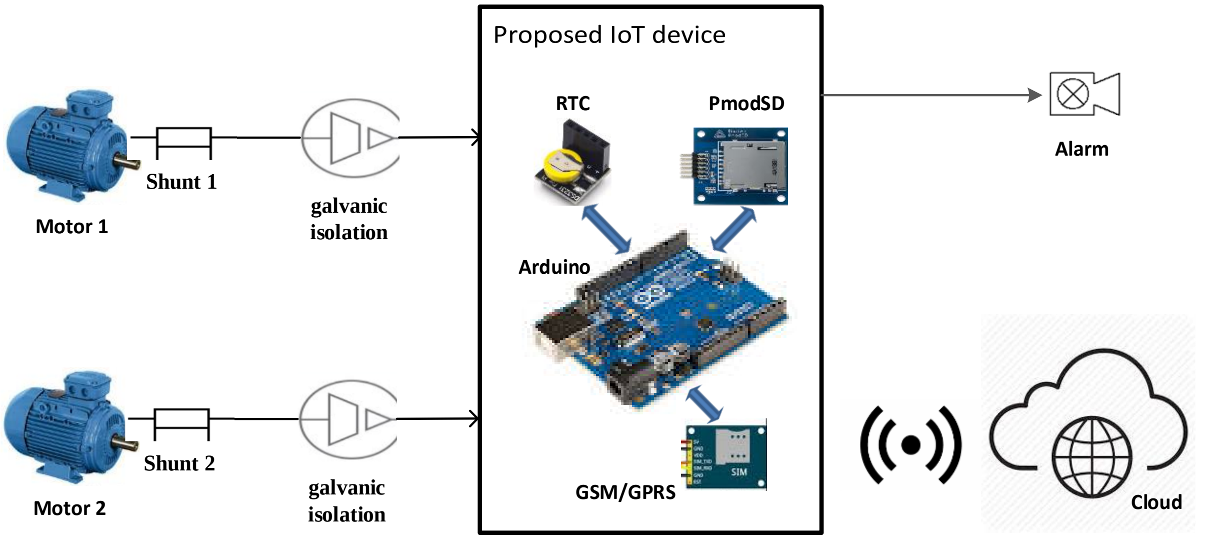

Fig. 2 Block diagram of the proposed solution

2.1 Short-circuit detection of excavator's DC motor

Monitoring the voltage on the shunt in the motor circuit is the most critical part of the designed system. Since we have taken the Arduino microcontroller platform as the basis of the system, voltage monitoring is performed using a built-in A/D converter. Inside each excavator, it is necessary to monitor two DC motors, so an Arduino with at least two A/D converters is needed, to complete the job for the entire excavator with one microcontroller platform.

The voltage on the shunt to be monitored changes polarity during motor operation. When the motor rotates in one direction the voltage has one polarity, and when the motor rotates in the other direction the voltage has the opposite polarity. This is a challenge for the acquisition process because the microcontroller is powered by DC voltage, as well as its A/D converter, Therefore, it is not possible to measure the voltage that is "negative" from the point of the microcontroller. On the other hand, it is mandatorily required for the implementation of the shunt voltage monitoring system to be galvanically isolated from the monitored circuit. This means that it is not possible to directly apply voltage from the shunt to the input of the A/D converter of the microcontroller.

We solved the problem with galvanic isolation by using a TLP7920 optically isolation amplifier from Toshiba Corporation [10]. Voltage from the shunt is applied to the input of TLP7920. A voltage proportional to the input voltage is generated at the output, but galvanically isolated. This output voltage can also be negative from the point of the microcontroller, and its range is quite small. We have experimentally determined that in the case of the maximum voltage on the shunt (± 75mV), i.e., voltage at the input of the TLP7920 circuit, a voltage of about ± 570mV is obtained at its output. This means that output voltage must be translated into a range that will have a single polarity from the point of the microcontroller. It should also be amplified to utilize the entire input range of the A/D converter and thus get a more accurate reading. We performed the translation and the amplification using appropriate operational amplifiers, which is beyond the scope of this paper. Finally, the inputs of the A/D converter receive a voltage in the range of 0.13V to 2.98V when the shunt voltage changes in the range from -80mV to + 80mV. Since the range of acceptable input signal on the A/D converter is from 0V to 3.3V, we considered this design to be appropriate.

2.2 Communication between microcontroller platform and the cloud

As mentioned earlier, at the moment of detecting a critical short-circuit current, in addition to the audible alarm, the system must save information about the event. This information is of multiple importance. On the one hand, maintenance engineers need to have continuous insight into potentially critical situations related to excavator motors, to take preventive actions for better maintenance. This means that it would be convenient to transmit information about the detected event immediately after the event occurred. The simplest way to perform this action is to use a GPRS connection. Namely, the RUP coil mine is covered by the signal of the mobile telephony operator. Therefore, in regular conditions, it is possible to transmit information about the critical event via GPRS. Within our system, a GSM/GPRS module based on the SIM808 chip was used (Fig. 3).

Fig. 3 GSM/GPRS module SIM808

The information transmitted via the GPRS module must be stored somewhere and made easily visible and noticeable for those people who should observe the events on the excavator system. Since it has become common to use cloud services for such purposes, we opted for one such service, called LiveGate [9]. It is a free service developed at the Faculty of Electrical Engineering, University of Montenegro. In addition to providing data storage, this service offers visualization of the stored data.

2.3 Data storage at the platform itself

Although the GPRS connection is quite reliable in the case of good coverage of the mobile operator's signal, it can still fail when trying to transfer data to the cloud. Failure may occur either due to the current unavailability of the mobile operator's signal due to an interruption in its operation, or some other error in the process of establishing or maintaining a GPRS connection. In any case, the data transfer failure may occur when there is an urgent need for the data transfer. If the system relies solely on data transmitted by a GPRS connection, some important data may not be available for later processing. For this reason, we decided that the data of the motor overload are, in addition to the cloud, also stored on the SD memory card, which is an integral part of the device installed in the excavator. For this purpose, we used a PmodSD adapter from Digilent (Fig. 4).

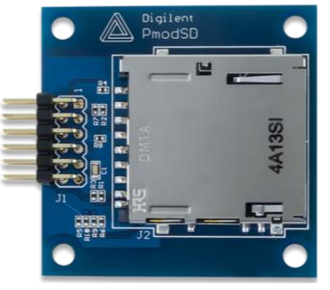

Fig. 4 Digilent PmodSD module
Source: https://store.digilentinc.com/pmod-sd-full-sized-sd-card-slot/

2.3 Real-time clock

When sending data to the cloud via a GPRS connection, the cloud platform keeps track of the time at which the data arrived. This means that the device does not have to take care of the exact time and transmits the timestamp to the cloud platform. However, when it comes to writing data to the SD memory card, things are different. Namely, the information that there was a motor overload does not mean much if it is not known when that overload occurred. Only based on information on the time in which the overload occurred, conclusions can be drawn about the behavior of individual operators or the mode of operation of the excavator in certain parts of the coal mine. Therefore, this means that the designed system must take care of the exact time. The easiest way to deal with the exact time is to use the Real-Time Clock (RTC) circuit. We used the DS3231 chip in our design (Fig. 5).

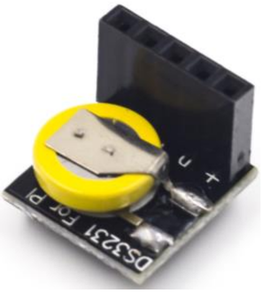

Fig. 5 RTC module DS3231

When a motor overload occurs, the RTC is read, and a file named by the date read from the RTC is created (if it does not already exist). In this way, it is easier to reach the necessary information when it is needed. The duration of the motor overload and the time in which the overload occurred are recorded inside the file. Of course, regardless of the writing to the SD card, the duration of the motor overload is also sent to the cloud.

3. Simulation results

After careful consideration of all aspects of the proposed DC motor short-circuit current detection system, the prototype shown in Fig. 6 was developed. As can be seen from the figure, the current version of the prototype, in addition to the previously mentioned components, also has an LCD. In the development phase, we use this display to show important information about the current operation of the system and thus facilitate the design and development of the system itself. In the final version, this LCD is not required, because the device is mounted in the drive part of the excavator, where the operator does not have access while working with the excavator. Therefore, it is not necessary to show any information on the display, especially since important information is sent to the cloud and saved to the SD memory card.

Before the installation and commissioning of the proposed system on the excavator itself, we performed extensive testing of the device in laboratory conditions. Instead of voltage from the shunt in the DC motor circuit, we applied voltages from galvanically isolated power sources with the voltage regulation to the system inputs. By applying various voltages, we also simulated the events of the short-circuit current, i.e., the corresponding shunt voltage. At that moment, as previously explained, the system saves data to the memory card and sent it to the LiveGate cloud service. Figure 7 depicts diagrams that visualize part of the data received from the designed system.

The diagrams labeled as "duration of overload" show the lengths of the detected overloads expressed in seconds, for each motor individually. These are data that are important for persons who perform the analysis and determine the behavior of the operator regarding the motor overload.

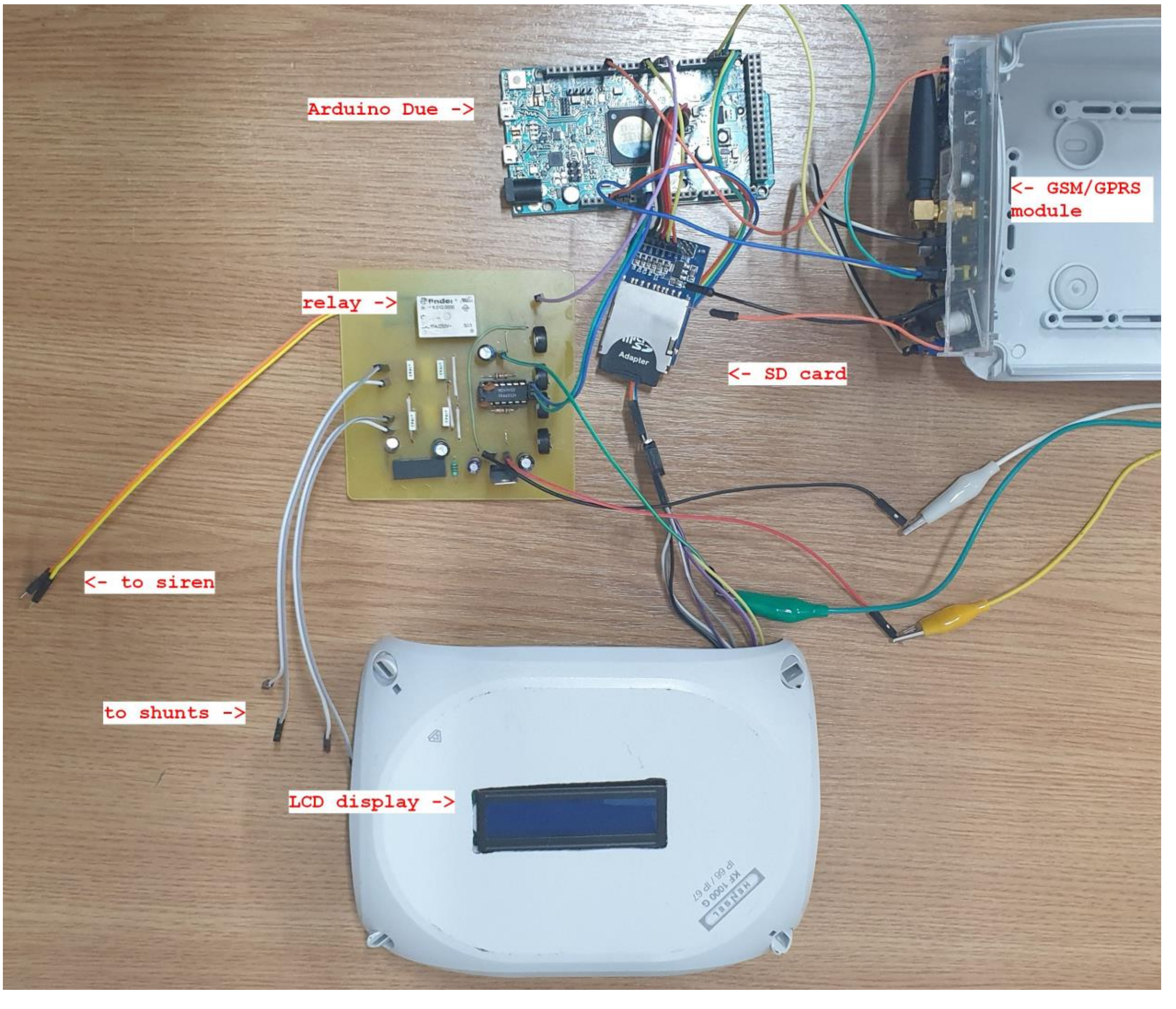

Fig. 6 Prototype of an excavator's DC motor short-circuit detection system

However, in addition to this data, we decided to send two more pieces of information to the cloud. The first of them is the information that the device has started (diagram labeled as "Power on"). Namely, when the microcontroller platform is powered on (or restarted), one data is sent (an arbitrary number - in our case '1') to the cloud to register that event and append the time stamp. The information about restarting the device can be significant in many ways. If a reboot occurs frequently, this may indicate various problems with the system. In any case, from the moment the device shuts down until it responds to the cloud again, the system does not perform its function of detecting the short-circuit current of the motor.

Another additional information that we send to the cloud is the indicator that the device is active, i.e. that it performs its function. We send this information every hour in the form of the current time read from the RTC. If it is noticed that the device has not sent this data for more than an hour, it is necessary to check its functionality.

Fig. 7 Data visualization within LiveGate cloud service

Conclusions

The paper presents an IoT system that was implemented within the FASTER project, to solve one of the challenges of predictive maintenance in the coal mine "Rudnik uglja Pljevlja". This system upgraded and improved the closed control system of the considered industrial machine with the microcontroller-based device described in the paper.

The simulation results show that the developed prototype works following the functional requirements, and additional adjustments will be performed based on the results in real operation conditions. Testing of this device on the considered excavator in real operating conditions is in progress. After that, we will analyse collected data and, if necessary, upgrade the device. In addition to the functional requirements, the ambient and other conditions in which the IoT device will work will be considered in the final design phase.

This solution is an example of the wide use of IoT systems in various industrial and home applications that enable the development of new or improvement of existing devices and systems. Modifications or upgrades of this device are feasible and simple, both in the existing application or some similar implementation, which is an added value of this solution. This confirms that the availability, openness, and interoperability of such systems are the main advantages that nominate them for the already proven wide application.

References

[1] Radonjic, M., Kvascev, G., Radulovic, M. and Krstajic, B., "One Example of Mobile Hardware Platform for Sound Acquisition in Industrial Environment", Proc. 24th Conference on Information Technologies IT 20, Žabljak, Montenegro, February 2020.
[2] R. K. Mobley. An introduction to predictive maintenance (2nd ed.), Amsterdam: Butterworth-Heinemann, 2002.
[3] G. Vachtsevanos, F. Lewis, M. Roemer, A. Hess, and B. Wu. Intelligent fault diagnosis and prognosis for engineering systems, Hoboken, NJ, USA: Wiley, 2006.
[4] S. Vujnovic, Z. Djurovic, and G. Kvascev, "Fan mill state estimation based on acoustic signature analysis," Control Engineering Practice, vol. 57, pp. 29 – 38, 2016.
[5] Faster project home page, http://www.faster.ucg.ac.me/eng/index.php (accessed on 01.05.2021.)
[6] Web page of "Rudnik uglja Pljevlja", https://www.rupv.me/en (accessed on 01.05.2021.)
[7] Gardašević, G., Veletić, M., Maletić, N. et al. The IoT Architectural Framework, Design Issues and Application Domains. Wireless Pers Commun 92, 127–148 (2017). https://doi.org/10.1007/s11277-016-3842-3
[8] Arduino, https://www.arduino.cc/, (accessed on 12.05.2021).
[9] LiveGate, Cloud platform, http://www.livegate.ac.me/ (accessed on 12.05.2021.)
[10] TLP 7920 datasheet, Toshiba Electronic Devices & Storage Corporation, https://toshiba.semicon-storage.com/ap-en/semiconductor/product/optoelectronics/isolation-amplifiers-isolated-delta-sigma-modulators/detail.TLP7920.html (accessed on 12.05.2021.)