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

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19-21 OCTOBER, 2021

TECHNICAL SCIENCES APPLIED IN ECONOMY, EDUCATION AND INDUSTRY

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ЕЛЕКТРОТЕХНИЧКИ ФАКУЛТЕТ

UNIVERSITY „GOCE DELCHEV” - SHTIP
FACULTY OF ELECTRICAL ENGINEERING

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FIRST INTERNATIONAL CONFERECE

ЕТИМА / ETIMA 2021

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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 живееењето. 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

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MEASUREMENT ON COMPENSATION CAPACITANCE IN INDUCTIVE NETWORK BY MICROCONTROLLER

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Abstract
In the paper are presents the results of a practically realized prototype on an microcontroller circuit for determined on the compensation capacitance in inductive network. In energy networks with high inductive load the reactive energy is high and therefore these networks operate with a low power factor. In such networks to reduce the reactive energy are installed compensating capacitors. The solution in the paper determines the required capacitance in inductive networks to reduce reactive energy and increase the power factor to one unit. The realized measuring circuit, in addition to determining the value of the compensation capacitor, determines the current, voltage, active power, active energy and reactive energy. The circuit is based on Atmega 328 microcontroller and smart power meter PZEM004. The capacitance value is visualized on an LCD display, and the values of current, voltage, active power, compensation capacitance and power factor are displayed on a serial monitor on the computer.

Key words
Power meter, Microcontroller, Measurement capacitance.

1. Introduction

In power industrial plants, AC and DC motors are mainly used as actuators. They are inductive consumers and contribute to increasing reactive power (energy). The increase of reactive power is related to the decrease of the power factor and thus the decrease of the active power at the same apparent power. In power plants with AC or DC motors connected directly to the power network, the reason for the reduction of the power factor is the increase of the phase angle between the voltage and the current. This increase is caused by the inductive nature of electric motors.

The situation is similar at actuators supply by converters. Due to the change in the inductance of the load leads to a reduction of the power transfer from the converter to the load.

From interest is the power transferred from the power network (or converter) on the load be maximal. Often due to the change in the parameters of the output circuit of the converter, this power is not always maximal [1], [2], [3]. To maintain maximum transferred power from the converter to the load, is needed knowledge of the parameters that affect the power. Independent of the type of process controlled by the converter, motor drive or induction device, etc., causes leading to a reduction in the transferred power are related to increasing the phase difference between the voltage and the current of the converter as well the deviation of duty cycle of value 0.5. The change in the phase difference is caused by the change of parameters (inductance, resistance, and capacitance) of the output circuit of the converter. To changing the duty cycle on the output voltage of the converter comes as a result of the need to change the effective value of the output voltage, with target to controlling the output power of the converter. The change on the phase difference leads to an increase in reactive power and a reduction in the active power of the converter. And reduction of the duty cycle from 0.5 increases the harmonic distortion of the output voltage and current of the converter. Both reasons reduced the output active power and efficiency of the converter [4], [5], [6] [7].

In Fig. 1 is shown the electrical scheme of inductive actuators which is supply from full bridge converter. A typical inductive actuator is a device for induction heating of metal materials. The nominal initial values of the actuator parameters are: $R = 0.24\ \Omega$, $C = 26{,}6\ \mu F$ and $L = 26{,}5\ \mu H$ [8].

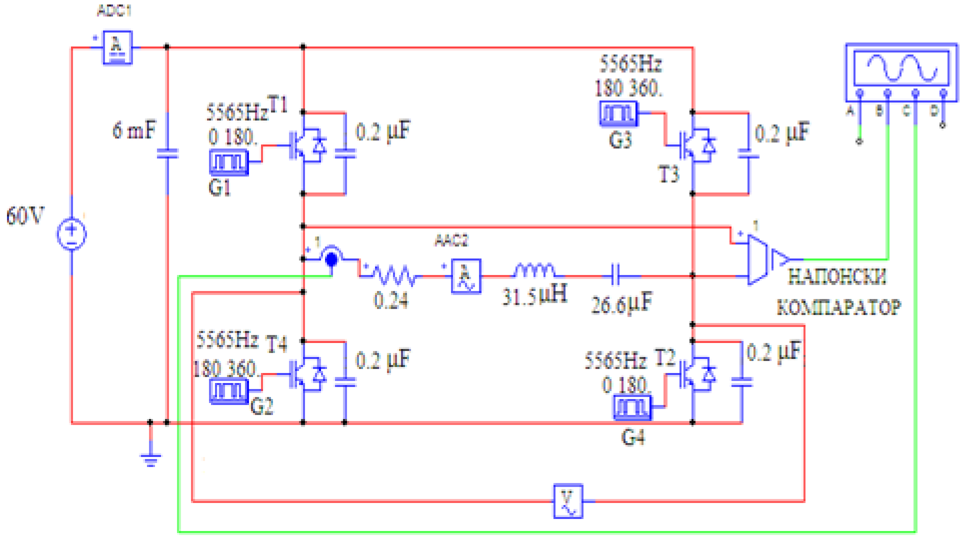


Fig. 1. Electrical scheme of inductive actuators which is supply from full bridge converter.

In Fig. 2 shows the output voltage and current waveforms on the converter from Fig. 1. In induction heating/melting and similar applications the heated workpiece equivalent electrical parameters are part of the resonant circuit. As the work-piece temperature increases, its equivalent resistance and inductance change, thus changing the circuit resonant frequency. Consequently, the deviation of the switching frequency from the resonant one is also changed, which results in undesired change of output power. The typical R and L change during metal-piece induction melting is in the range of 50%. These real values are used as an example in the following investigation giving the values for the resonant frequency ω_0 = 37665 rad/s, f_0 = 5998 Hz [9], [10].

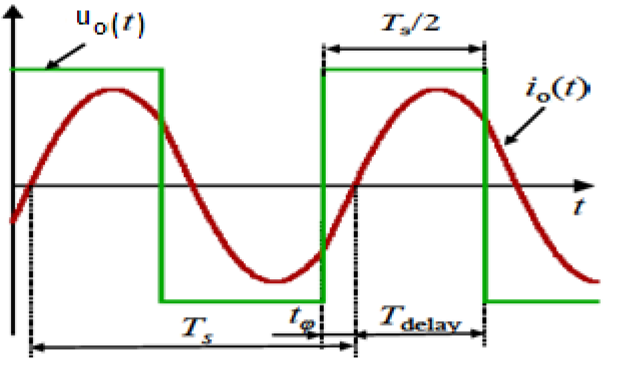


Fig. 2. Output voltage and current waveforms on full bridge converter loading with inductive load.

The mode of induction heating changes the value of the resistance and inductance of the resonant circuit of the converter. This leads to a change in the phase difference between the current and the voltage of the converter and the change of the output power. In Table I are given the values on the switching frequency f_{sw} , output voltage U_o, output current I_o, output power P_o and phase difference φ for chance the inductance for 20 %, i.e.: change on L from

26.5 μH on 31.5 μH.

TABLE I: VALUE ON OUTPUT CONVERTER PARAMETERS FOR CHANGE ON INDUCTANCE FROM 20%

L [μH]	R [Ω]	φ_i [°]	f_{sw} [kHz]	I_o [A]	U_o [V]	P_o [kVA]
26,5	0,24	5,00	6.27	208	56	10,7
31,5	0,29	31,34	6.27	145	56	6,16

From Table I it can be seen that a change of R and L by 20% causes a change of the phase angle for 63 % and change on the power for 58 %. In the Table II is given value on compensation capacitance which is needed to compensate for the change in inductance and the phase angle φ and the power Po to remain unchanged.

TABLE I: VALUE ON COMPENSATION CAPACITANCE AND POWER

L [μH]	R [Ω]	C [μF]	φ_i [°]	f_{sw} [kHz]	I_o [A]	U_o [V]	P_o [kVA]
26,5	0,24	26.6	5.00	6.27	208	56	10,7
31,5	0,24	21.28	5.00	6.27	208	56	10.7

From Table II it can be seen that if a capacitor is installed in the circuit whose value is changed by 20 %, it will compensate for the change in inductance and the circuit will operate with constant power.

2. Design on microcontroller circuit for measurement on compensation capacitance

In this part an microcontroller (microcomputer) power meter is designed. The designed solution will collect data for the current from current transformer and the voltage on which is connected device in industrial power process. In the Fig. 3 is shown block diagram of the specific microcontroller circuit, [8], [9], [10] [11].

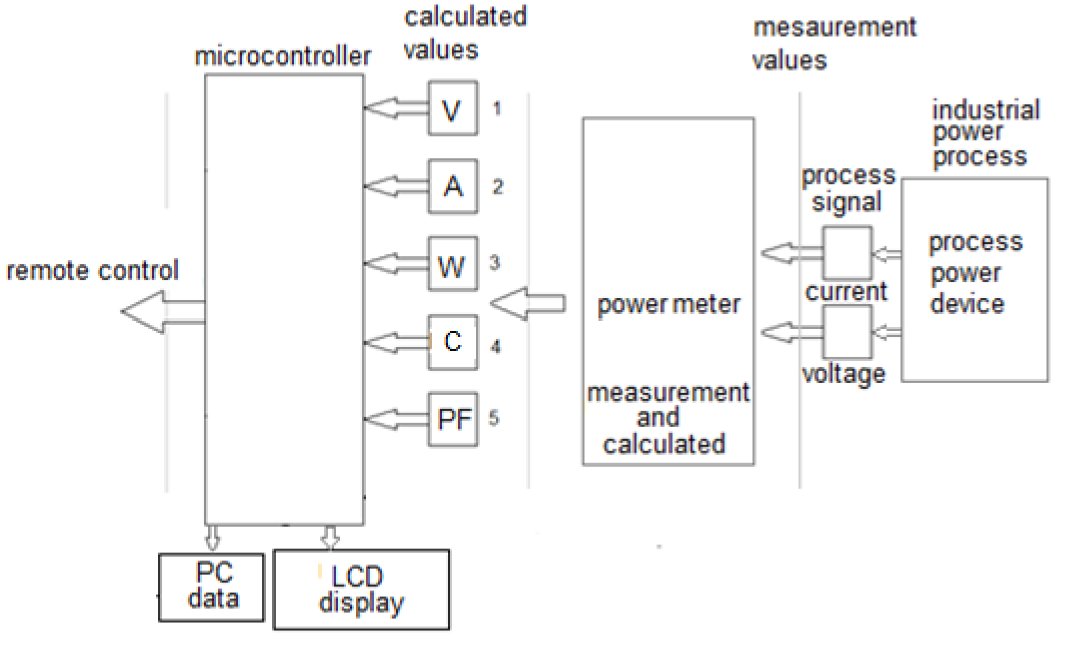


Fig. 3. Block diagram of the specific solution of an microcontroller power meter.

The main part of this power meter is the microcomputer. In the solution is selected the microcontroller Atmega 328P [12]. Microcontroller power meter takes data on the current and

the voltage from the power device. The current data is taken with a current transformer. The voltage data is obtained from the voltage of the device terminals. Based on the current and voltage, the power meter calculates power, capactance and power factor and sends it to the microcomputer together with the current and voltage data. In the Fig. 3 calculated values are marked as: 1 is the data for voltage marked as V, 2 is the data for current marked as A, 3 is the data for power marked as W, 4 is the data for capacitance marked as C, and 5 is the data for power factor marked as PF. The power meter is connected to the microcomputer with the serial port. Based on the values of these parameters, the microcontroller according to the developed algorithm calculates the value of the compensation capacitance and displays it on the LCD display. Also the microcontroller sends data on the current values of the quantities, on a personal computer in serial monitor.
In the Fig. 4 is shown the connection diagram of the realized solution.

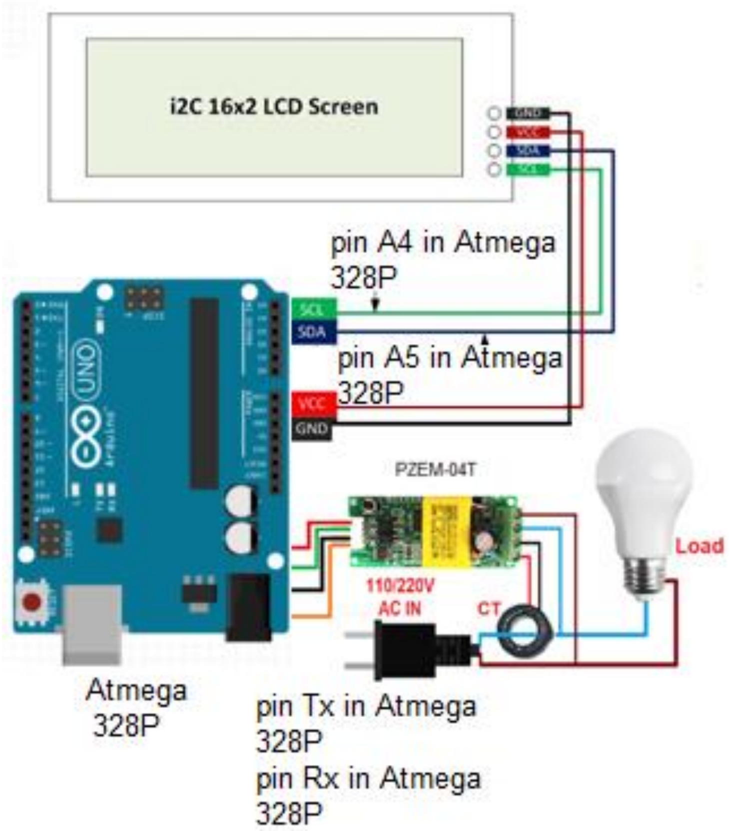


Fig. 4. Connection diagram of the realized solution.

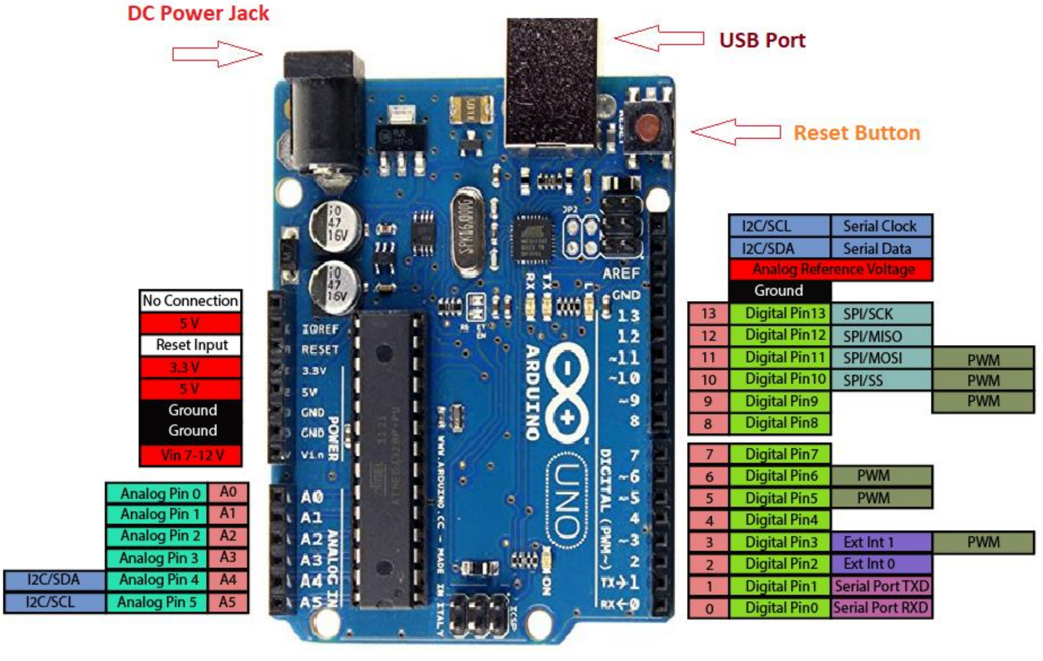
Figure 4 shows that the solution was realized using Arduino Uno Atmega 328P and a power meter PZEM 004T, [13] .

2.1 Features of the used hardware

a.)Microcomputer Atmega 3238P

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts. The word "uno" means "one" in Italian and was chosen to mark the initial release of Arduino Software.[1] The Uno board is the first in a series of USB-based Arduino boards; it and version 1.0 of the Arduino IDE were the reference versions of Arduino, which have now evolved to newer releases. The ATmega328 on the board comes preprogrammed with a bootloader that allows uploading new code to it without the use of an external hardware programmer. In the Fig. 5a is shown electronic board on Arduino Uno with build Atmega 328P mictrocontroller, and Fig. 5b is shown his pinoout.

a.)



b.)

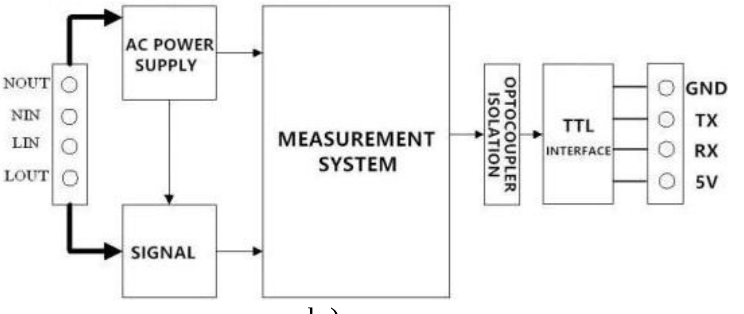
Fig. 5. a.) Arduino Uno and b.) his pinout

b.)Power meter PZEM-004T

The power meter is mainly used for measuring AC voltage, current, active power, frequency, power factor and active energy, the module is without display function, the data is read through the TTL interface. PZEM-004T-10A built-in shunt have measuring range 10A, and PZEM-004T-100Awith external transformer have measuring range 100A, [13] . In the fig. 6a is shown the board on PZEM-004T power meter, and Fig. 6b is shown block diagram on this module.

The current signal is connected to power meter on the terminals NIN and NOUT, and the voltage is connected on the terminals LIN and LOUT. The power meter is supply with 5 VDC voltage. The terminals TX and RX are for serial communication.

a.)



b.)

Fig. 6. a.) The board on PZEM-004T power meter, and b.) block diagram on this module.

Function description

Voltage measuring range is 80～260V.
Current measuring range is 0～10A(PZEM-004T-10A); 0～100A(PZEM-004T-100A)
Active power measuring range is 0～2.3kW(PZEM-004T-10A); 0～23kW(PZEM-004T-100A)
Starting measure power is 0.4W. Resolution is 0.1W.
Display format: ＜1000W, it display one decimal, such as: 999.9W. ≥1000W, it display only integer, such as: 1000W. Power factor measuring range is 0.00～1.00 , resolution is 0.01.
Frequency measuring range is 45Hz～65Hz, resolution is 0.1Hz.
Active energy measuring range is 0～9999.99kWh, resolution is 1Wh.
Display format: ＜10kWh, the display unit is Wh(1kWh=1000Wh), such as: 9999Wh
≥10kWh, the display unit is kWh, such as: 9999.99kWh
Over power alarm
Active power threshold can be set, when the measured active power exceeds the threshold, it can alarm. Communication interface is RS485 interface.

Communication protocol

Physical layer use UART to RS485 communication interface. Baud rate is 9600, 8 data bits, 1 stop bit, no parity. The application layer use the Modbus-RTU protocol to communicate. At present, it only supports function codes such as 0x03 (Read Holding Register), 0x04 (Read Input Register), 0x06 (Write Single Register), 0x41 (Calibration), 0x42 (Reset energy).etc.
0x41 function code is only for internal use (address can be only 0xF8), used for factory calibration and return to factory maintenance occasions, after the function code to increase 16-bit password, the default password is 0x3721.
The address range of the slave is 0x01 ~ 0xF7. The address 0x00 is used as the broadcast address, the slave does not need to reply the master. The address 0xF8 is used as the general

address, this address can be only used in single-slave environment and can be used for calibration etc.operation.
The command format of the master reads the measurement result is(total of 8 bytes): Slave Address + 0x04 + Register Address High Byte + Register Address Low Byte + Number of Registers High Byte + Number of Registers Low Byte + CRC Check High Byte + CRC Check Low Byte.
The command format of the reply from the slave is divided into two kinds: Correct Reply: Slave Address + 0x04 + Number of Bytes + Register 1 Data High Byte + Register 1 Data Low Byte + ... + CRC Check High Byte + CRC Check Low Byte Error Reply: Slave address + 0x84 + Abnormal code + CRC check high byte + CRC check low byte.

3. Experimental results

The design of an microcontroller power meter are consists of hardware design and software design.

Hardvare design
According to the description of the characteristics of the hardware components given above and the main purpose of the paper, in the Fig. 4 is shows the electrical circuit of the WI-FI smart power meter. The circuit consists of Arduino Uno, PZEM-004T power meter and LCD display.

Software design
The software is written in micro C. Arduino Uno software is compatible with the Arduino IDE platform. The software ensures that the microcomputer receives the signals from the power meter and, after processing, displays the current values on the voltage, current, power, energy, frequency and power factor on LCD display, sends them in serial monitor.
According to the above, the software consists of several steps.
Defining on variables and libraries:

```
#include <PZEM004Tv30.h>
#include <SimpleTimer.h>
#include <LiquidCrystal.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
```

Reading data on Serial Monitor:

```
float v = pzem.voltage(ip);
  if (v < 0.0) v = 0.0;
  Serial.print(v);Serial.print("V; ");
  float i = pzem.current(ip);
  if (i < 0.0) i = 0.0;
    Serial.print(i);Serial.print("A; ");
  float p = pzem.power(ip);
   if (p < 0.0) p = 0.0;
 Serial.print(p);Serial.print("W; ");
   Serial.print(Cap);Serial.print("uF ");
  Serial.print("PF= ");Serial.print((p)/(v*i));
```

Building a data log file:

```
Serial.print(value());      // Read value from sensor and send its value to Excel
Serial.print(",");                    // Move to next column
```

Reading data on display:

```
lcd.print("name:");
lcd.print(variable);
lcd.print("unit");
```

In the Fig. 7a is shown the experimental prototype on microcontroller power meter, and the Fig. 7b is shown the complete process microcontroller power meter.

a.) b.)

Fig. 7. Experimental results: a.) prototype on the microcontroller power meter and b.) the complete process microcontroller power meter.

In the Fig. 8 is shown data for voltage, current, power, capacitance and power factor in serial monitor.

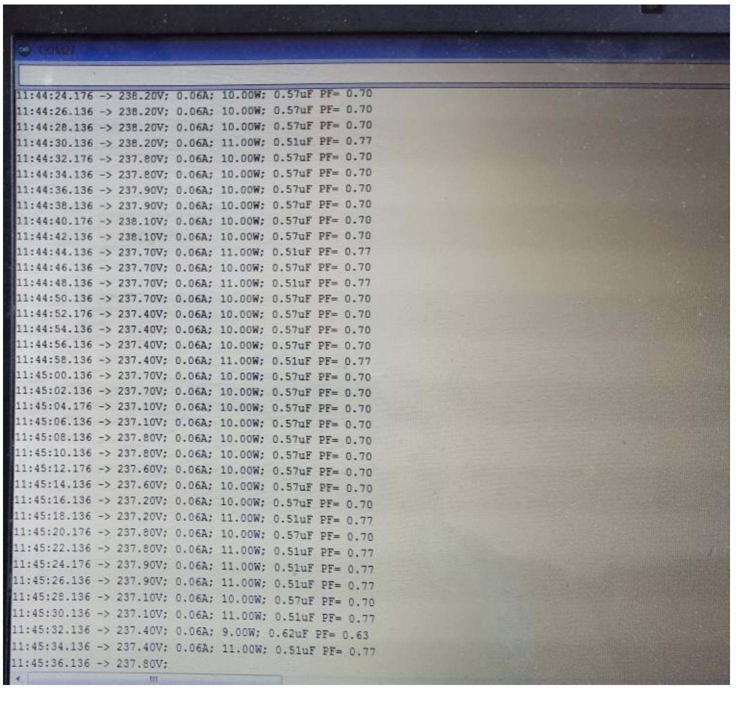


Fig. 8. The data for voltage, current, power, capacitance and power factor in serial monitor.

Conclusions

In the paper with theoretical analysis is designed and practically realized microcontroller power meter. The power meter allows data on power, compensation capacitance and power factor to be obtained only by measuring the voltage and current of a process device. Then these data are processed, the required compensatory capacity is visualized on an LCD screen and data for voltage, current, power, capacitance and power factor are sent in serial monitor. The solution also provides the ability for upgrade to remote control on the process quantities.

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