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EXPLORING
THE DIGITAL LANDSCAPE:
INTERDISCIPLINARY PERSPECTIVES

EXPLORING THE DIGITAL LANDSCAPE: INTERDISCIPLINARY PERSPECTIVES

Monograph

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1.3. Control software by electronic load of the household

Informatization of society is aimed at the creation of new information technologies for all branches of science, education, production andprovision of services in the field of energy supply.

Automation and robotization of technological processes, the latest information technologies, the development of smart grids (Smart Grids), artificial intelligence (Artificial intelligence) and innovative digital platforms allow effective management of electricity supply and consumption modes (Суходоля, 2022). INthe use of digital technologies helps increase the flexibility of responding to consumer needs, reveals new models of organization and provision of service.

Using the capabilities of various digital platforms for information processing and control of household peak electrical load is a kind of technological transition to a new quality of service provision in the field of energy supply.

The specificity of the provision of energy supply services, namely the need to process, in real time, large volumes of information on forecasting weather conditions, energy consumption and production volumes, equipment condition, operation modes of power transmission lines, etc., paves the way for the application of artificial intelligence in the energy sector (Івасюк, 2023).

The article is devoted to the development and research of the system of automated control of peak energy load in households with autonomous energy supply. The system uses modern information technologies, hardware, and software to monitor and control energy consumption, allowing automatically adjust the load and turn off non-critical electrical appliances to prevent overloads.

In the context of the energy challenges that Ukraine has faced in recent years during a full-scale invasion, ensuring the reliability and efficiency of autonomous energy supply systems has become especially important. Large-scale blackouts caused by war, natural disasters, technical failures, or other external factors have highlighted the critical need for independent sources of electricity to ensure the stability of life. This applies not only to industrial enterprises, but also to private households striving for self-sufficiency and energy independence.

For example, one of the main advantages of intelligent buildings is the comfort they provide to their residents. Controlling the lighting of the house and the surrounding infrastructure allows you to create different options of light scenes, any combinations, depending on the time of day and mood, with one click of a button (Антонюк, 2017).

In this context, generators, inverters, and solar energy systems play a major role, allowing households to meet their electricity needs independently of centralized networks. However, the use of these systems is accompanied by an important challenge – the need for effective control of peak loads to avoid overloading and ensure reliable operation of the equipment.

Overloading can lead not only to wear and damage to equipment, but also to serious consequences, such as loss of energy necessary for life, or even a fire. This is especially relevant for systems operating in offline mode, where network capacity is limited.

Peak load control requires a comprehensive approach that includes both technical solutions and changes in consumer behavior. On the one hand, this can be realized through the use of modern intelligent energy management systems that allow monitoring the level of consumption in real time and automatically adjust the load to prevent overloads. On the other hand, informing consumers about the need for rational use of electricity, especially during peak periods, plays a significant role.

The second case is characterized by the implementation of energy efficiency measures, in particular, the use of energy-saving technologies and materials in the construction and reconstruction of buildings, the use of energy-efficient household equipment, as well as the optimization of heating, ventilation, and air conditioning schemes.

For the first – ensuring effective management of peak loads is the integration of autonomous load control devices. It is this case that is particularly interesting from the point of view of practical research. Because it requires the construction of specialized devices that will monitor the state of the power supply network and will not allow the inclusion of new devices in the network in case of exceeding the limits on the total power. The creation of an information system that does not contain overly complex elements will be relevant at the present time and will have a wide demand in households.

Determining the technical and technological requirements for the system is a fundamental step in the development of an information system. In the process of creating a system for controlling the peak energy load in the household, the authors were guided by key principles and considerations of stable uninterrupted operation of the energy source. The basis of the system being created is the Wemos D1 Mini controller with a Wi-Fi module, which is responsible for collecting data from the current sensor, processing this information, and controlling electromagnetic relays to regulate the load in the network (Fig. 1). The use of a non-invasive current sensor allows you to monitor electricity consumption without the need to interfere with the power grid, which makes the system safe and easy to install.

Fig. 1. Appearance of Wemos D1 Mini

The task of the created system is to detect the peak load in the power grid and the automated response to reduce it. This allows the system to independently, without human intervention, turn on or off powerful electrical appliances and adjust the power consumption to avoid system overload and ensure the stability of autonomous power supply. Thanks to Wi-Fi communication, the system can provide users with real-time current consumption data via a mobile app, allowing them to take additional measures to optimize energy consumption.

The controller software must be designed in such a way that it provides high accuracy of current monitoring and effective control of the relay, with minimal response delays to changes in power consumption. The developed algorithms can analyze the collected data and manage the load based on user-defined criteria and priorities. Also, the system must be able to adapt to changing operating conditions, such as a change in the number and type of connected electrical appliances, as well as provide the possibility of manual control for the user.

The user interface is clear and provides full access to information about the system status, consumption history, current loads, and the status of connected electrical appliances. Users can configure the parameters of the system, set thresholds for peak loads and control the modes of disconnection and connection of devices.

To ensure reliability and safety, the system includes mechanisms to protect against overload, short circuit, and other potential hazards. This can be implemented with the help of additional sensors that monitor temperature and other critical parameters of the system, as well as through the implementation of software algorithms for emergency shutdown in case of detection of anomalies.

Based on the technical requirements, the following components were selected for the system, which together form a reliable and efficient system for controlling the peak energy load in the household. The central element of the system is the Wemos D1 mini controller, which provides basic calculations and wireless communication through a built-in Wi-Fi module. Its choice is due to a wide range of development opportunities and extensive technical support, which simplifies development and integration with other system components.

A 4-channel relay module is used to control electrical loads, which allows you to switch high loads and ensures reliable disconnection or connection of electrical appliances depending on the needs of the system (Fig. 2). This is important for the automation of peak load control and management processes, especially at critical moments of electricity consumption.

Fig. 2. Scheme of the 4-channel relay module to the microcontroller

The non-invasive current sensor TA12-100 is used to monitor current consumption without the need for direct connection to the power grid, which ensures safe measurement and high data accuracy (Fig. 3). This sensor allows the system to accurately detect peak load times and respond accordingly, reducing the overall load by controlling the relay module.

In addition to the main components, the system provides for the use of additional elements, such as buttons for manual control of the system, resistors for current limitation and protection of LEDs and other sensitive components, as well as LEDs for visual indication of the system's operating status, Wi-Fi connection and other critical work parameters. The use of these components allows not only to ensure the efficiency and reliability of the system, but also to make it convenient and intuitive for the end user.

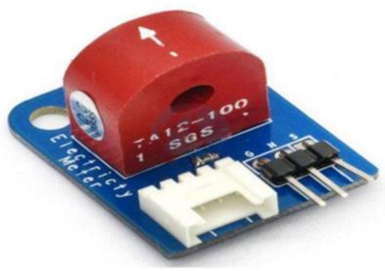

Fig. 3. Appearance of TA12-100

Regarding these components, the following scheme of the developed system was constructed (Fig. 4).

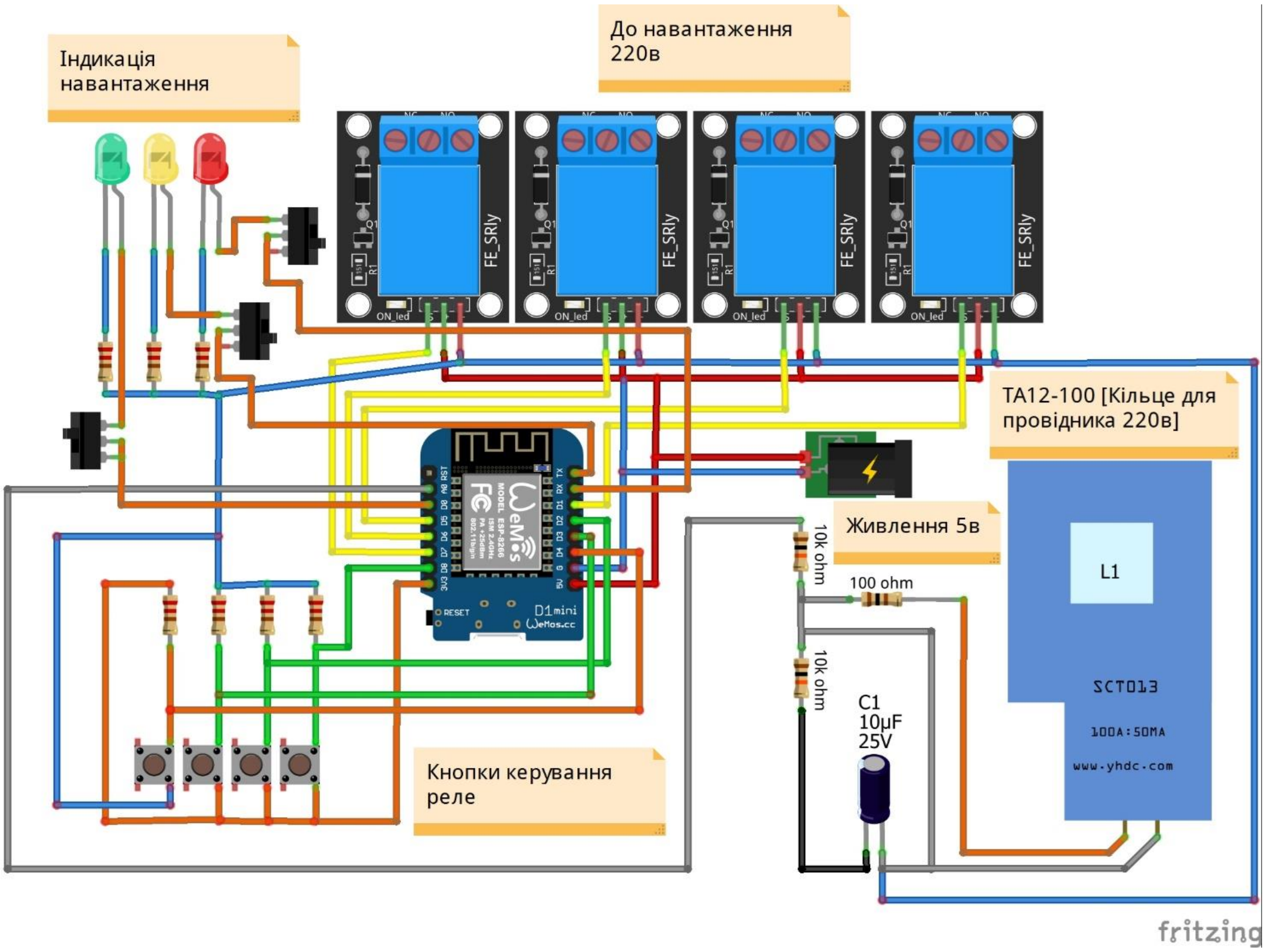

Fig. 4. Scheme of the developed system

Let's take a closer look at the circuit shown in Figure 4. The four-channel relay is connected to the Wemos D1 Mini through GPIO pins D1, D5, D6 and D7. Each relay channel is controlled by a separate GPIO pin, which allows the system to independently control various electrical devices. The relay is powered by 5V, which can be provided by an external power supply or directly from the Wemos D1 Mini if it supports such a load.

The three buttons are connected to pins D2, D3 and D8 by the direct method. This means that when the button is pressed, a high logic level (3.3V) appears on the corresponding pin, and when the button is released, a low logic level (0V) appears. These pins are pulled to ground via built-in resistors on the Wemos D1 Mini board, providing a stable low logic level in the absence of a push button. The buttons themselves are connected to the 3.3V output on the Wemos D1 Mini.

The fourth button is connected to pin D4 in reverse order. At rest, this pin has a high logic level due to the pull-up to 3.3V through the resistor. When the button is pressed, pin D4 is connected to the ground, which causes the logic level to decrease to 0. This circuit allows you to use this button to activate certain functions in the system that are associated with the decrease of the logic level.

The TA12-100 current sensor is used to monitor the current in electrical circuits. The sensor output signal (0-1V) is connected directly to analog input A0 on the Wemos D1 Mini. This allows the system to measure current intensity and use this information to control relays or perform other tasks.

Three LEDs are used to indicate different system states: green, yellow, and red. The green LED is connected to pin D0 and signals the normal working state of the system. A yellow LED is connected to the TX pin and can indicate an intermediate state or the execution of certain processes. A red LED connected to the RX pin signals critical conditions in the electrical network or failures in the information system.

It is important to note that when programming the Wemos D1 Mini, the LEDs connected to the TX and RX pins must be turned off with physical switches to avoid conflicts with the serial communication. This ensures seamless programming and maintains stable LED operation after the program is loaded onto the board.

For effective system management, a computer program has been developed for the microcontroller, which reads the state of the buttons, controls relays, LEDs, and processes the signal from the current sensor. The software code includes logic to interpret the sensor measurements, control the light indication, and respond accordingly to button presses by activating or deactivating relays and changing the state of the LEDs according to the current state of the system.

The description of the control model of the built system is based on the implementation of a specific algorithm that is programmed for the Wemos D1 mini microcontroller. This algorithm is responsible for monitoring the current consumption of electricity, detecting moments of peak loads and corresponding control of electromagnetic relays to regulate the load in the system. The system uses data from the TA12-100 analog sensor to estimate current consumption and analyzes this data to detect peak load values.

The system is controlled via software written for the Wemos D1 mini controller. This software reads data from the current sensor, analyzes it and controls the state of the relay depending on the received data. The program also provides remote monitoring and control over Wi-Fi, allowing users to monitor system status and make changes to settings in real time.

The main goal of the system is to ensure efficient energy consumption, reduce the risk of grid overload and optimize the use of electricity. The system reacts to peak loads by turning off or limiting the energy consumption of certain devices or groups of devices, which reduces the overall load on the network and helps avoid overloads.

To implement this algorithm, the system first initiates the process of monitoring current consumption using the TA12-100 sensor. Current consumption data is read and analyzed by the controller for exceeding user-defined or default thresholds. In the case of detection of a peak load, the system activates the load management algorithm, which can disconnect individual powerful consumers using a relay.

Let’s consider the key onesprogram modules for Wemos D1 Mini: data collection from sensors, relay control, web interface creation, remote system control. Let's consider the following key modules of the program.

Data collection from sensors. To collect data from the TA12-100 current sensor, you need to read the analog value from the A0 pin and convert it to a physical current value using conversion factors. The following code snippet does this:

```
int currentSensorValue = analogRead(A0);
float current = (currentSensorValue * (5.0 / 1023.0)) / 1000.0; // Conversion to physical units
```

*Relay control.*Relay control can be implemented by setting pins D1, D5, D6, and D7 to a high (HIGH) or low (LOW) logic state. The function that implements this can have the following form:

```
void controlRelay(int relayPin, bool state) {
```

```
digitalWrite(relayPin, state ? HIGH : LOW);
}
```

The development of the web interface for the peak power control system is carried out using the ESP8266WiFi and ESP8266WebServer libraries, which allows you to create a simple web server on the Wemos D1 Mini. This web server provides users with an interface to remotely monitor and manage the system through any web browser. The following functions are used to start the web server and configure routes:

```
#include <ESP8266WiFi.h>
#include <ESP8266WebServer.h>

// Declaration of the web server object
ESP8266WebServer server(80);

void setup() {
Serial.begin(115200);
// Connecting to the WiFi network
WiFi.begin(ssid, password);
while (WiFi.status() != WL_CONNECTED) {
delay(500);
Serial.print(".");
}
Serial.println("\nWiFi connected");

// Setting up route handlers
server.on("/", handleRoot);
server.on("/control", handleControl);
// Start the web server
server.begin();
Serial.println("HTTP server started");
```

```
// other microcontroller settings

}

void loop() {
// Processing requests to the web server
server.handleClient();
// Handle button clicks
//Processing display through diodes
//Check the state of the power grid

}

// Function for processing the main page
void handleRoot() {
String html = "<html><body><h1>Control Panel</h1>";
// Display the current current consumption
html += "<p>Current: " + String(current) + " A</p>";
// Reference for relay control
html += "<a href=\"/control?relay=1&state=1\">Turn On Relay 1</a><br>";
html += "<a href=\"/control?relay=1&state=0\">Turn Off Relay 1</a><br>";
// Similar links for other relays
html += "</body></html>";
server.send(200, "text/html", html);
}
// Function for relay control
void handleControl() {
int relay = server.arg("relay").toInt();
bool state = server.arg("state").toInt();
// Call the relay control function
```

```
controlRelay(relay, state);
// Redirect the user to the main page
server.sendHeader("Location", String("/"), true);
server.send(302, "text/plain", "");
}
```

As you can see from the code example, the function server.handleClient(); is regularly executed as part of a continuous loop void loop(), which ensures continuous processing of incoming HTTP requests received by the web server. This procedure is critical to the functioning of the web server because it allows you to «listen» and respond to user requests, redirecting them to the appropriate handlers specified in the routing settings.

The void handleControl() and void handleRoot() functions are activated automatically by the web server when corresponding requests are received for certain URLs. This is made possible by configuring routes in the void setup() function using the server.on() method, which allows you to define specific handlers for each URL request.

The route to the root address of the web server, " / ", is configured so that when it is called, the handleRoot() function is activated. This function creates an HTML page with a system control panel that displays current power consumption figures and allows the user to control relay status.

The "/control" route is used to handle relay control requests. When a user follows a specially crafted link, such as http://192.168.1.1/control?relay=1&state=1, the web server invokes the handleControl() function, which parses the request parameters to determine the relay number and required state, and then executes command to turn the specified relay on or off.

In addition to the technical aspects of the implementation of control functions and data display, an important role is played by the development of the user interface, which provides convenient access to system management and visualization of important information about energy consumption. The web interface, implemented using simple HTML pages with basic controls, plays a key role in the user's interaction with the system. The central element of this interface is the control panel, which contains information about the current load and allows you to control the relay via hyperlinks.

The integration of LEDs to visualize the load level helps users to quickly assess the system status and effectively manage the load. Green, yellow, and red LEDs indicate low, medium and high load respectively, making system status information easily accessible and intuitive.

The appearance of the device with two active relays and a current sensor is shown in Figure 5.

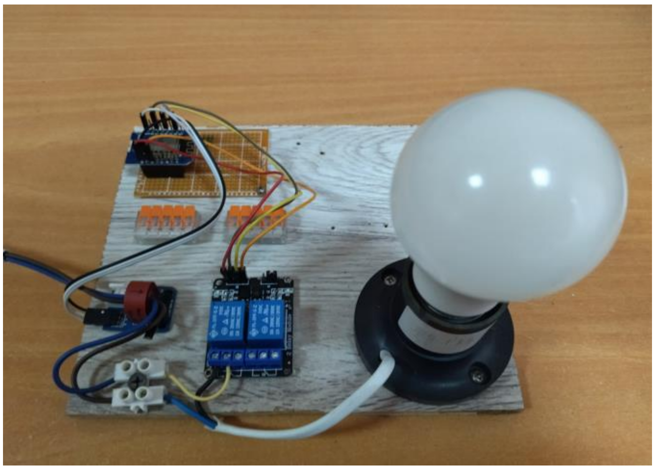

Fig. 5. Appearance of the device

Automated testing of the power consumption management system developed based on Wemos D1 Mini was performed in several stages. The focus was on the hardware, in particular the TA12-100 current sensor, electromagnetic relays, LEDs and pushbuttons, as they are fundamental to the operation of the system. Detailed testing of each component ensured their accuracy, reliability and efficiency in operation.

Software testing includes code validation, checking the logic of the program and its compliance with user requests. Testing of the work algorithm confirmed that all functions are performed in accordance with the technical task, a quick and accurate response of the system to peak loads of the household power grid is ensured.

The developed information system monitors the load in the electricity network of households. It is designed to protect power grids and optimize energy consumption in a home or office space.

In the information society, the process of computerization of the energy supply of households will protect the owners of houses and households from emergency and critical situations in the power grid since the control will be carried out by the developed information system onbased on the Wemos D1 mini controller.

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