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# Design and simulation of a programmable electric energy meter, integrating a backup power system and a communication interface GSM

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## Abstract

The present work details the design and simulation of a state-of-the-art programmable electric energy meter. The system under consideration incorporates a backup power module aimed at ensuring operational continuity in the event of a power outage, as well as a GSM (Global System for Mobile Communications) communication interface allowing for remote transmission of consumption-related data. The study focuses on the selection of hardware components, software modeling, as well as the validation method thru simulation. The empirical results attest to the reliability of the meter under real operating conditions, highlighting the efficiency of the backup power system and the relevance of integrating GSM technology for optimized energy management.

**Keywords:** Design; Simulation; Electric energy meter; GSM communication interface

## 1. Introduction

Precise and real-time regulation of energy consumption is essential to optimize energy efficiency and reduce costs. Traditional meters, frequently limited to manual readings, no longer meet current requirements for monitoring and consumption analysis [5]. The incorporation of a programmable system communicating via the GSM network constitutes an appropriate solution for telemetry and remote management. Moreover, the integration of an auxiliary power supply ensures continuity of measurements, which is essential to ensure data reliability, especially during power outages that can skew readings or interrupt monitoring [3].

The present project aims to design, simulate, and analyze an innovative device integrating these features with optimal accuracy. Context: The present project aims to design, simulate, and analyze an innovative device integrating these functionalities with optimal accuracy.

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## 2. Materials and Methods

### 2.1. Materials

*2.1.1. Programmable board*

It is recommended to select a low-power board, equipped with analog and digital measurement capabilities, such as an Arduino UNO in our case, to ensure the management of the meter and the performance of energy calculations. Figure 1 shows the physical appearance of the Arduino UNO board.

**Figure 1** Programmable Arduino UNO Board [1]

*2.1.2. Energy measurement module*

Hall effect current sensors and high-precision voltage sensors allow for the simultaneous acquisition of the required electrical quantities, namely voltage and current. Figure 2 below represents the different energy measurement sensors used in this work.

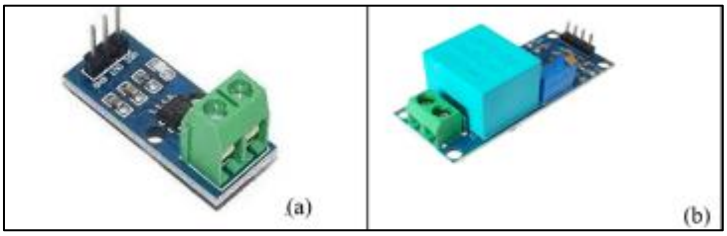


**Figure 2** Current sensor (a) and voltage sensor (b) [1]

*2.1.3. Emergency power system*

Rechargeable Li-ion batteries associated with a power management circuit (Battery Management System, BMS) ensuring autonomy in case of power outages.

The integration of DC-DC converters is being considered to ensure a stable power supply for the system.

*2.1.4. GSM Module*

The GSM/GPRS communication module (SIM800L) designed for data transmission to a centralized server or an IoT (Internet of Things) platform. An antenna optimized to improve signal quality is used, as shown in Figure 3.

**Figure 3** GSM SIM800L module [1, 5]

### *2.1.5. Additional modules*

We also used additional modules, such as: the liquid crystal display (LCD) for local visualization, real-time clock (RTC) for precise timestamping of measurements, EEPROM memory for temporary data storage [3, 5].

## 2.2. Methodology

### *2.2.1. Hardware Design*

Detailed schematic representations of the circuits integrating the sensors, the microcontroller, the power system, and the GSM (Global System for Mobile Communications) module. The optimization of the wiring is carried out with the aim of minimizing interference and losses [2].

The synoptic diagram in Figure 4 below shows the details of the assembly of the various components used.

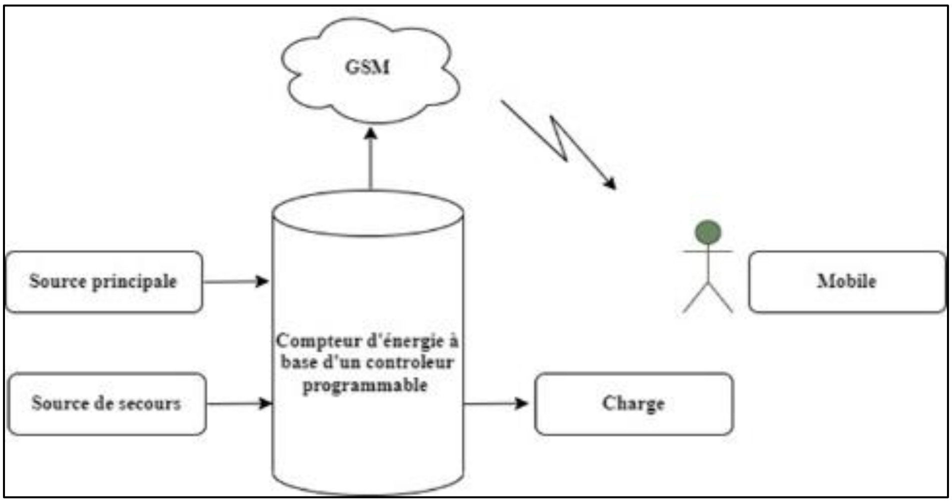


**Figure 4** Synoptic diagram of the system

### *2.2.2. Software development*

The programming of measurement functions, calculation of energy consumed (watt-hours), management of backup power, and implementation of a GSM communication protocol for periodic data transmission. The implementation of self-calibration algorithms is carried out to ensure accuracy.

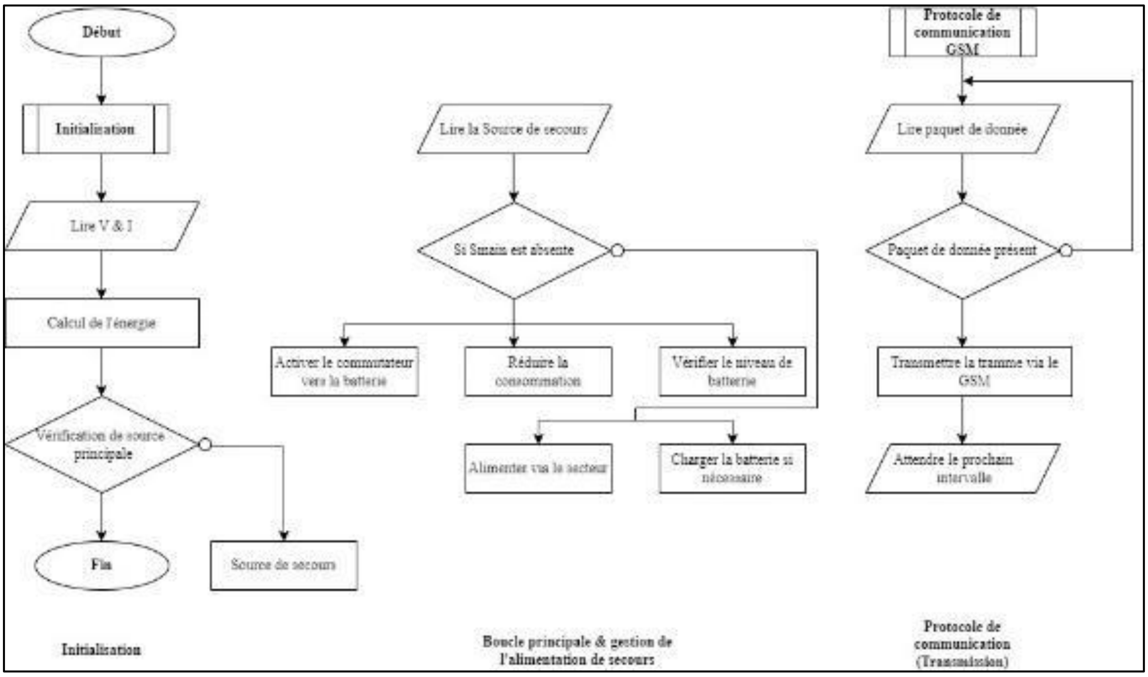


**Figure 5** Software flowchart

*2.2.3. Prototype under Proteus ISIS*

The use of specialized software, such as Proteus ISIS, has allowed for the simulation of the meter's behavior under various electrical scenarios, power outages, and transmission conditions [4].

Figure 6 illustrates the homepage of the software designed for computer-aided design and simulation (Proteus ISIS) in the field of electronics.

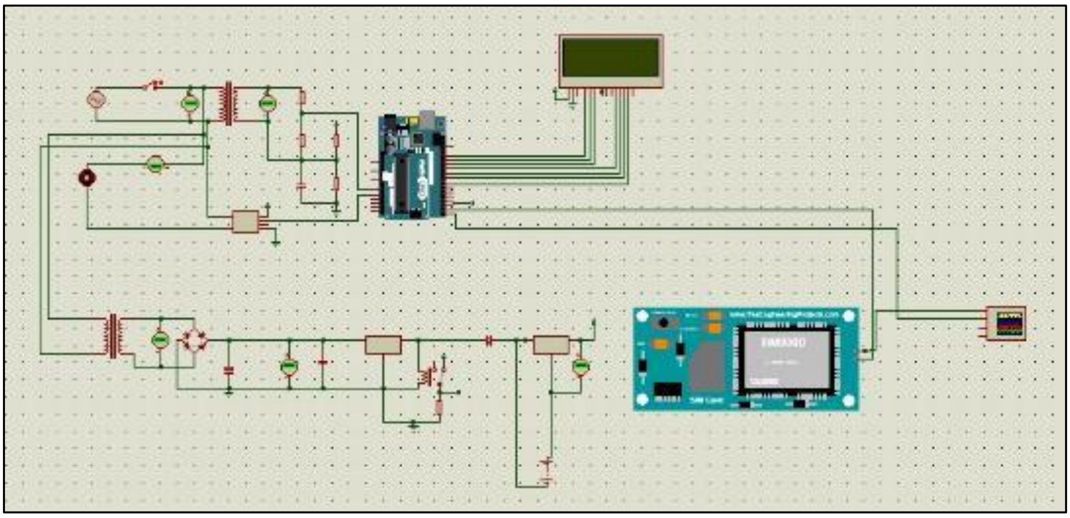

**Figure 6** Homepage of the Proteus ISIS software

*2.2.4. Testing and validation*

It is necessary to simulate power interruptions, rapid load variations, as well as GSM signal losses, in order to evaluate the system's resilience and associated recovery strategies [2, 4].

## 3. Results and Simulation

The planned simulation aims to evaluate the operationality of the energy meter, notably thru the comparison of measured values with those obtained by empirical methods, the monitoring of the backup system's operation, and the assessment of real-time communication.

### 3.1. Resistive load

In the context of the resistive load, a lamp with a resistance of 550 ohms was selected.

The measured values are displayed on the liquid crystal screen, as illustrated in figure 7.


**Figure 7** Measured values displayed on the liquid crystal screen

Table 1 below presents the results from a simulation applied to a resistive load, including the measured and displayed values, as well as the difference, error, and conclusion related to voltage, current, and power.

**Table 1** Results for a resistive load

| Measurement | Measured value | Displayed value | Difference | Error | Conclusion |
|---|---|---|---|---|---|
| Voltage | 220V | 220V | 0V | 0% | Acceptable |
| Current | 0.46A | 0.46A | 0A | 0% | Acceptable |
| Power | 95.26W | 96.36W | 1.3W | 1.3% | Acceptable |

### 3.2. Inductive load

In the context of the study of inductive load, a fan was used to observe the behavior of the meter.

The quantified values within the context of an inductive load are represented in Figure 8.

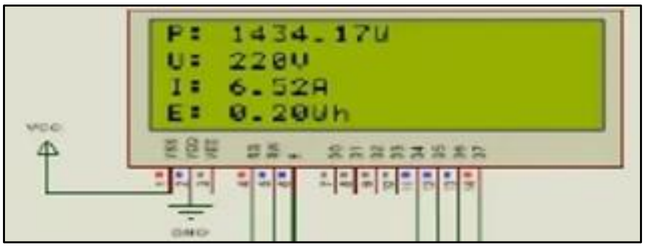


**Figure 8** Quantified values in the context of an inductive load

Table 2 below presents the results from a simulation applied to an inductive load.

**Table 2** Results for an inductive load

| Measurement | Measured value | Displayed value | Difference | Error | Conclusion |
|---|---|---|---|---|---|
| Voltage | 219V | 220V | 1V | 0.45% | Acceptable |

| | | | | | |
|---|---|---|---|---|---|
| Current | 6.50A | 6.52A | 0.02A | 0.30% | Acceptable |
| Power | 1423.5W | 1423.5W | 10.6W | 0.74% | Acceptable |

### 3.3. Backup system

The backup system was subjected to tests to evaluate its behavior in the event of a power outage or restoration.

The notification indicating the absence of voltage on the electrical grid is illustrated below, figure 9.

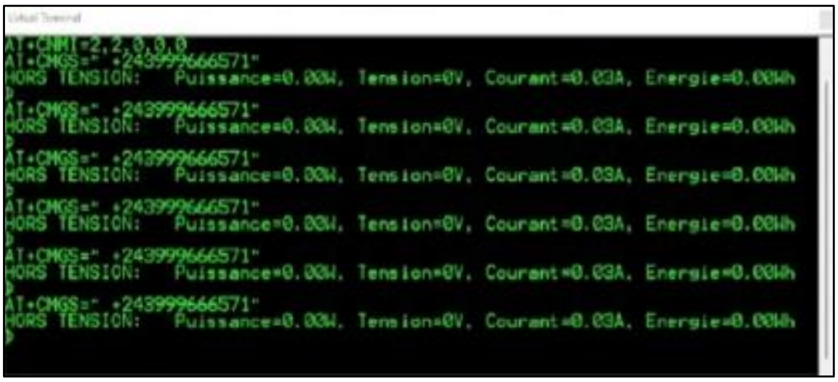


**Figure 9** Notification indicating the absence of voltage on the electrical grid.

The signaling of the presence of voltage at the mains power supply is shown in Figure 10.

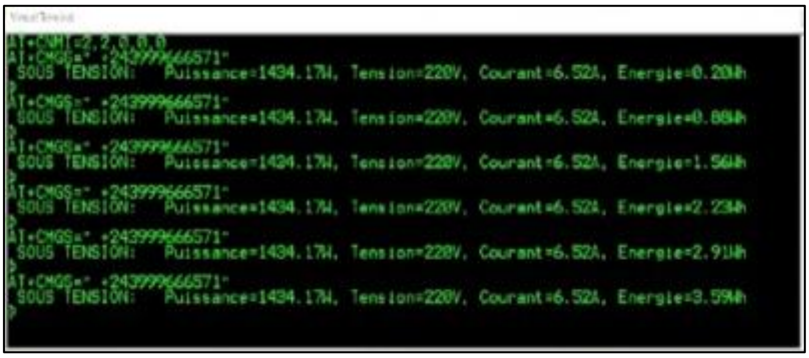


**Figure 10** Signaling the presence of voltage at the mains power supply

## 4. Discussion

The controlled integration of emergency power modules has significantly increased overall reliability. The charge and discharge cycles revealed behavioral stability, which suggests adequate durability of the batteries used. Although GSM communication exhibits a certain stability, it remains dependent on network quality; it is therefore advisable to consider alternative communication protocols for areas characterized by limited coverage. The programmable card used has sufficient resource capacity to allow for future extensions, including the management of multiple tariffs and integration into a home automation network. Lastly, the simulation made it possible to anticipate and correct various potential failures, thereby ensuring the robustness of the prototype before its production.

## 5. Conclusion

The project resulted in the development of a programmable electric energy meter, integrating a reliable backup power system as well as an operational GSM interface. The simulation results corroborated the accuracy of the measurements, the resilience to power interruptions, as well as the ease of remote data access. This device represents a significant advancement in intelligent energy management solutions, designed to meet current requirements.

The perspectives under consideration include energy optimization thru embedded algorithms as well as the diversification of communication methods, with the aim of increasing flexibility.

## Compliance with ethical standards

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*Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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