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ARTIFICAL INTELLIGENCE IN RENEWABLE ENERGY SYSTEMS BASED ON SMART ENERGY HOUSE

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Abstract: This paper develops a feasibility study to identify the problem regarding energy efficiency house and implementation of the home automation system in that. Therefore, the possibilities were profoundly analyzed to determine the key points which were necessary to that project. Energy efficiency can play a significant role in reducing electrical cost, and the attachment of Smart Energy House made the idea more unique and challenging to implement it. Furthermore, the possibilities were analyzed and successfully demonstrated with a view to reducing the temperature impact and minimizing the effect in the power source by controlling the connected load into the system.

Key words: IoT, Raspberry pi, DHT11, Ultrasonic, relay, Water level, MQTT, PostgreSQL.

1. INTRODUCTION

The management of energy resources is an issue for smart homes. It is possible to put on standby the devices that are not in use when the users are absent, or automatically adapt the use of electrical resources according to the needs of the residents to reduce the wastes of energy resources [1]. This project involves the realization of an intelligent system to control the home using the sensors' data. The controller (Raspberry Pi) is the main component of the home automation system; it has the essential role of implementing mechanisms necessary to act in response to the needs of the user. Internet of Things (IoT) is a concept that encompasses various objects and methods of communication to exchange information. Today IoT is more a descriptive term for a vision that everything must be connected to the internet [2]. According to the load calculation, the total requirements were 3556 Wh/day and served by 1 KW system. After the theory and the practical analysis, the plan was able to access the loads, which matched the automation. The financial analysis has been done, and it can be visible that the system's cash flow model is beneficial to implement. This project can be extended, and it can be implementing more new technologies relevant to renewable energy and energy efficiency. The data which has been collected through the DHT11 sensor has also been analyzed. The data of temperature and humidity was stored on the PostgreSQL database to reduce the temperature effect on the photovoltaic panel. The electrical load connected to the system was controlled by programming language using raspberry pi and connected sensors such as water level and ultrasonic sensor.

2. RELATED WORK

Various intelligent home systems have been developed, and they can communicate via the Internet [3] or short message services (SMS) [4]. These systems consist of a home network unit and a gateway [5]. In the past decades, various issues concerning intelligent systems have attracted the attention, but the installation cost is still high, so the design optimization is required. Besides, Artificial Intelligence can be a great opportunity in RE (Renewable Energy) field by predicting future values using data that is getting from different sensors or open data from other resources [6]. A data acquisition node/system uses various sensors, dedicated hardware, and respective software to measure and store physical signals like the voltage, temperature, pressure, etc. The present report describes the design of a real-time data acquisition system, using a low cost, credit card-sized computer known as a Raspberry Pi to collect various environmental data related to wind, solar, water level, temperature and humidity, which can be used for further analysis and predictive model development [7].

The central gap of competence was bringing all the possibilities together, such as automation and cost analysis. Database management systems such as (PostgreSQL) and which make synchronization between the client and the server. Those data were collected and served as a CSV file, which was further analyzed for predict upcoming production of solar energy and global solar horizontal irradiation.

2.1. Methodology of the system

The project's purpose was to implement a zero-emission house and put clay instead of brick for better insulation. The clay block walls ensure a balanced indoor climate and protect against sudden temperature changes, which allow the owners to control all the parameters affecting their comfort and optimum management of the maintenance cost. The net passive house is a structural element of the house, but the PV (photovoltaic) thermal panel will be installed on the rooftop of the house, which will supply electricity. The PV-T board will provide thermal energy, which can also be connected to the water pump system. The primary purpose is to deliver the water around by a DC water pump and the rated capacity of about 70 watts. The inside diameter to supply the water into the house with an inner 12 mm and outer 16 mm diameter. The length of the pipe should be around 240 m to provide the water. One hot water pump will be used as a submersible pump with a rated capacity of 40 watts. This pump is a solar pump directly run by the DC of PV (Photovoltaic) or battery. The hot water will store at the storage tank, and we will use this water to supply.

The automation process was necessary for this project to maintain the load balance. Another parameter also to see the future opportunity by predicting solar irradiation, temperature, and humidity and to see how the AI (Artificial Intelligence) model can be helpful by time series forecasting. Time series forecasting is a powerful AI tool for predicting future business case and production opportunity analysis. It can be used alongside with the automation process of the prediction analysis by ARIMA and Persistence model. Due to the substantial increase in solar power generation, the predictions of incoming solar energy are too important and necessary to predict the amount of energy produced. The first step is to set up the electronic devices (e.g., DHT 11 temperature and humidity sensor). Firstly, the data was taken from the sensor through a Raspberry pi. The DHT-11 is an essential, ultra-low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and produces a digital signal on the data pin.

It is simple to use but requires careful timing to obtain data. It has humidity range of 20-80% with ±5% accuracy and temperature range of 0-50ºC with accuracy of ±2ºC. The first parameter (11) indicates which sensor was used (11 for the DHT11) and the second, to which GPIO it is connected (not the pin number, but the GPIO number) [8]. Output values obtained from the DHT11 sensor as follows which also saved as CSV file:

```
Jun  7 17:54:22 raspberrypi python3[4518]: [pyDHT11] 2019-06-07 17:54:22.487460, 36.0 %, 28.0 deg
Jun  7 17:54:28 raspberrypi python3[4518]: [pyDHT11] 2019-06-07 17:54:28.082743, 36.0 %, 28.0 deg
Jun  7 17:54:36 raspberrypi python3[4518]: [pyDHT11] 2019-06-07 17:54:36.213609, 36.0 %, 28.0 deg
Jun  7 17:54:39 raspberrypi python3[4518]: [pyDHT11] 2019-06-07 17:54:39.278703, 36.0 %, 28.0 deg
```

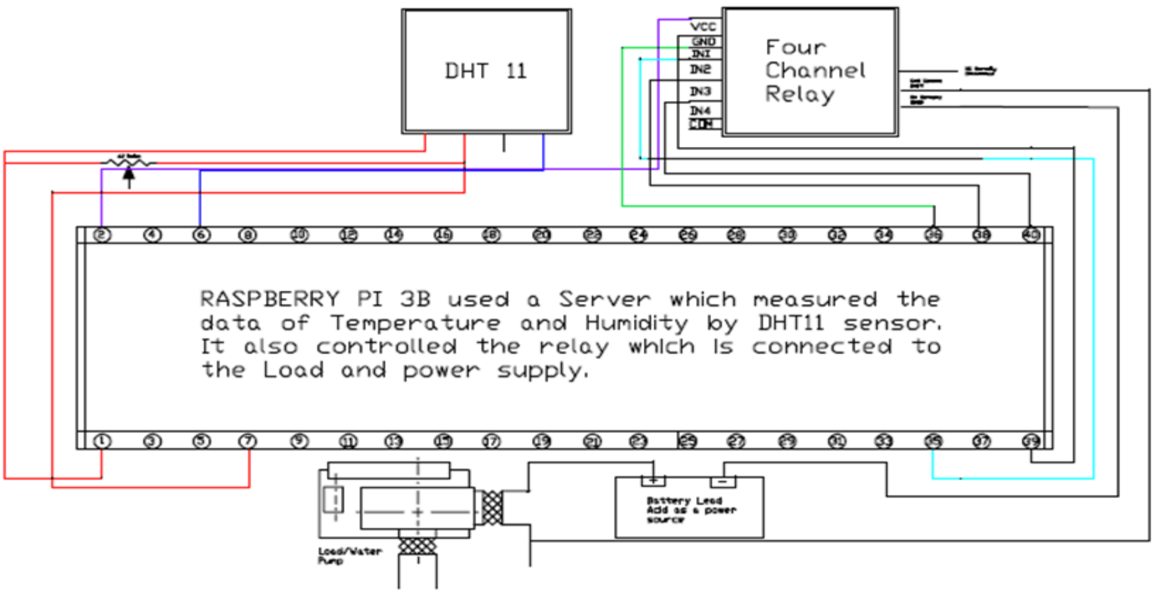


Fig. 1. Circuit Diagram of the DHT 11 sensor with relay

In the demonstration one client and server was made under the same network. That means the raspberry pi 3b plus which was used as a server and collecting the data for DHT11 sensor and it was sending the data to the raspberry pi zero which has been used as a client. The database has been created by using PostgreSQL to store the data of temperature and humidity.

2.2. Technical design of the system based on automation

To measure the water level as only the digital signal can be processed by raspberry pi, we needed to add an analogue to digital converter (ADC) to process the analogue signal from water level sensor. The work voltage of this sensor is DC 3V-5V and use 3.3V. The whole system is demonstrating with DHT11 sensors and the water pump which will control the level the water. The water level will detect by the water level sensors and with the help of ADC converter. The pump will not operate when the water will reach to the highest level. It will give a signal to the database and one can monitor the data from the system. If there is not enough sun and battery is low the connection of the load (water pump) should be disconnected because the PV array will be unable to recharge the battery and to give enough power to the pump. Another possibility was to use also Ultrasonic sensor to control the automation of pump.

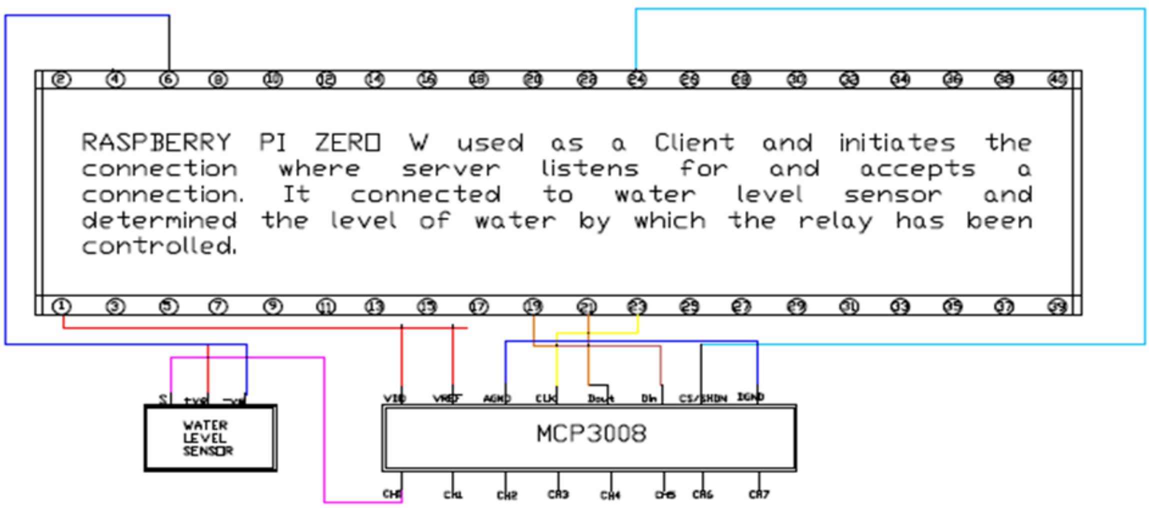


Fig. 2. Client connection with the Water level and the A/D converter

Output values obtained from the Water level sensors as follows:

```
pi@raspberrypi:~ $ ./waterlevel.py
will start detec water level
tank is not full
adc_value= 0
tank is not full
adc_value= 0
adc_value= 303
tank is full
```

The most important part was to define MQTT. Client and to relate with values of ADC (house/relay/off) and “on,” which described for detecting the water level. A function has created to establishing the connection between relay and the water level sensor, which sees the water level and print as (tank is full). If the “adc” value was zero, then it printed no water was available, and the client published that tank is complete, and the relay must be turned off. The (broker_url) and port number with a username and password has been created. As we used MQTT, which decouples the publisher from the subscriber, client connections are always handled by a broker. That is why MQTT imported as a client with a given username, hostname & URL port. Any device that speaks MQTT over a TCP/IP stack can be called an MQTT client. The counterpart of the MQTT client is the MQTT broker. The broker is at the heart of any publish/subscribe protocol. The broker is responsible for receiving all messages, filtering the notifications, determining who is subscribed to each letter, and sending the message to these subscribed clients. Another responsibility of the broker is the authentication and authorization of clients [9]. A relay (channel_handler) function has created for turning on and off and (mqtt_on: connect) relay channel turning on and off. MQTT is a simple messaging protocol designed for constrained devices with low bandwidth. MQTT allows sending commands to control outputs, read and publish data from sensor nodes and much more. Therefore, it makes it easy to establish communication between multiple devices. An MQTT client is any device (from the server) that runs an MQTT library and connects to an MQTT broker over a network.

The automation part, including a water level sensor, was also implemented with a machine to machine messaging protocol (MQTT). Mosquitto is a popular MQTT server (or broker) with excellent community support and is easy to install and configure. It is possible to define the hostname of the MQTT server and the topic name into the protocol. The MQTT protocol requires specifying a password mosquito_passwd, and from the command prompt, one can define it. For the project, the password in the mqtt_client function has been described, including the broker_url and password. To test this functionality, a public, browser based MQTT client was used. For that purpose, we must use the host (the domain the Mosquitto server), port number, client id, path (can be left as default), username, and password. After pressing Connect, the Paho browser-based client will connect to your Mosquitto server. The ADC value is defined, and if greater than 300, than the output is the tank is full, and it turns off the relay. If it is not, then it will print the tank is not complete.

2.3. Control the electrical load

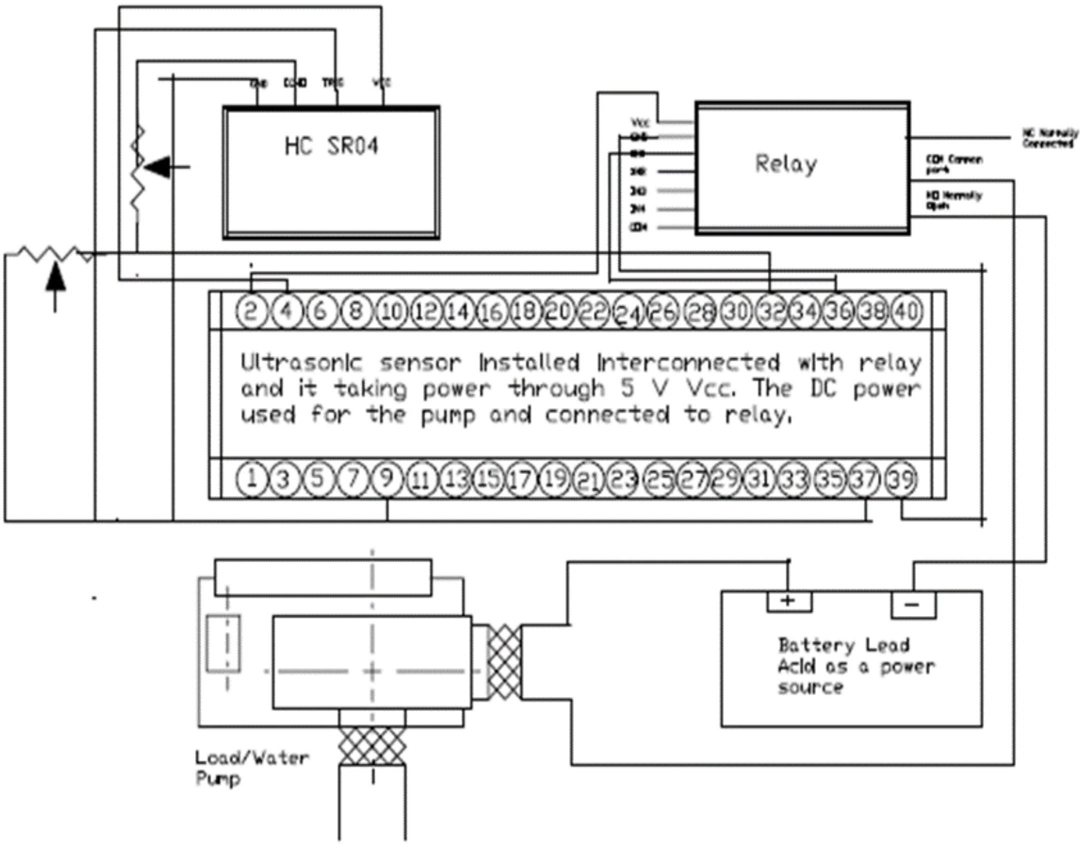


Fig. 3. Automation of water pump and relay

From the circuit we can see the connection of the system. Required library has imported in the program and different pins of the distance measurement sensor was specified which has been connected through the GPIO pins of the raspberry pi 3b plus (echo pin, of the distance measurement sensors where the relay is connected. The height of the tank in cm has specified for the demonstration. The maximum distance has entered, and it can sense the water level. When the motor started and enter number of seconds that the motor can run. The calculated value above is the time it takes for the ultrasonic pulse to travel the distance to the object and back again. It is needing the distance of the object and finally rounding the measured the distance by covering the float values the integer to display the percentage of water. For the calculation under water_percetage variable and actual percentage is the subtracted value from 100 because it needs to measure remaining water available the level of the water is in cm and percentage will be calculated to display. If water level of its above minimum water level disabling the motor.

Output of the demonstration:

```
Available Water = 47.36842105263158%
Enough Water! Motor is not running
waiting for sensor to settle
Calculating distance
```

2.4. Prediction analysis

The data of global solar horizontal irradiance has been taken and analyzed for the specific area of the location. The temperature and humidity data which has been stored in PostgreSQL database but for better understanding the concept of future prediction analysis the time series analysis which is a strong tool for artificial intelligence has been analyzed.

From the output below we can see the database has been created:

```
CREATE TABLE
logdb=# \dt
public | tempsens01 | table | logu
logdb=# select * from tempsens01;

  1 | 2019-05-27 18:24:22.015359 |   44 |  24
  2 | 2019-05-27 18:24:25.090111 |   44 |  24
  3 | 2019-05-27 18:24:40.833150 |   44 |  24
  4 | 2019-05-27 18:24:43.904889 |   44 |  24
```

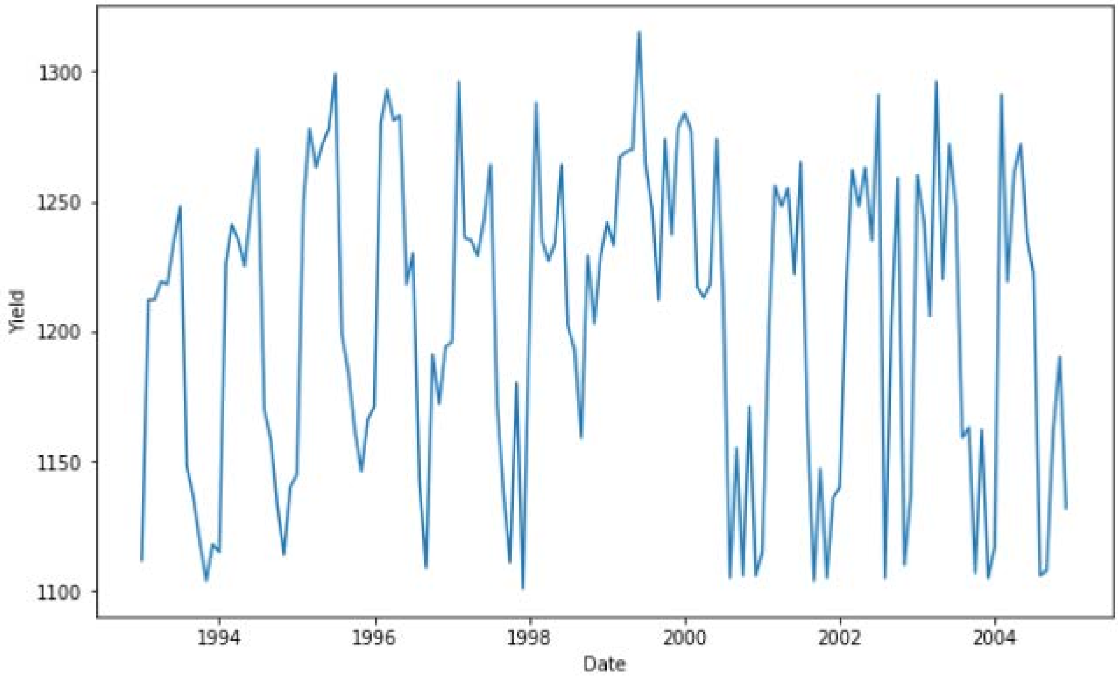
It has different parameters and in this process the theory behind this process and how to implement it for different data set for example temperature, GHI (Global Horizontal Irradiance), Solar Production, Specific Yield. Those data set has been taken according to the location and it has correlated with different models of prediction analysis. An analysis has done by using a dataset which is content of daily solar global horizontal irradiance. The data from homer software has taken and putted in it to 365 of days to see the range in KWh/KWp. Then the ARIMA model has been implemented. ARIMA was used to analyze the data where it is an auto regressive moving average process. It depends on the value of p, d and q where: p is the autoregressive, the number of lag observations included in the model, also called the lag order, d is the order of differentiation, the number of times that the raw observations are differenced, also called the degree of differencing. And q is the moving average, the size of the moving average window, also called the order of moving average. For the future value analysis based on the previous data the prediction is Y = (Auto-Regressive Parameters) + (Moving Average Parameters) [10]

results_ARIMA.plot_predict(1,264)

x=results_ARIMA.forecast(steps=120)

Here 264 cames for 120 months and with the 144 of observation

We can see the from the figures the approximate prediction is possible by using different tools of forecasting.



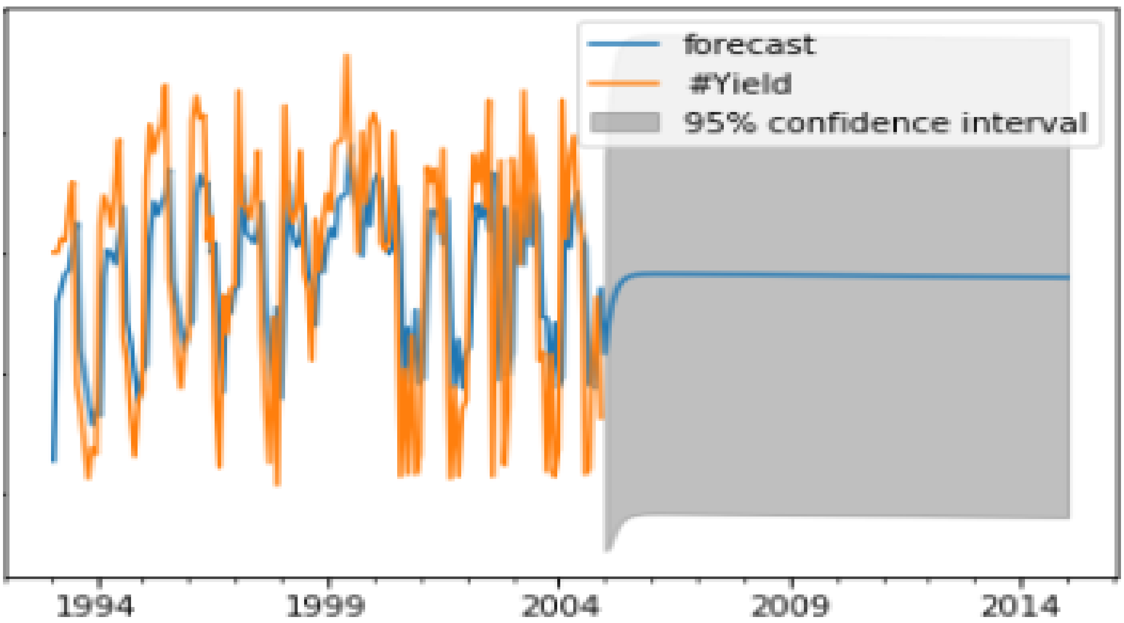


Fig. 4. Prediction model using previous historical data

3. BLOCK DIAGRAM OF THE ENTIRE SYSTEM

From the block diagram we can easily see the whole process of the system which was done in terms of automation. For smart energy house 3-D modeling was also done by using simulation tools and software.

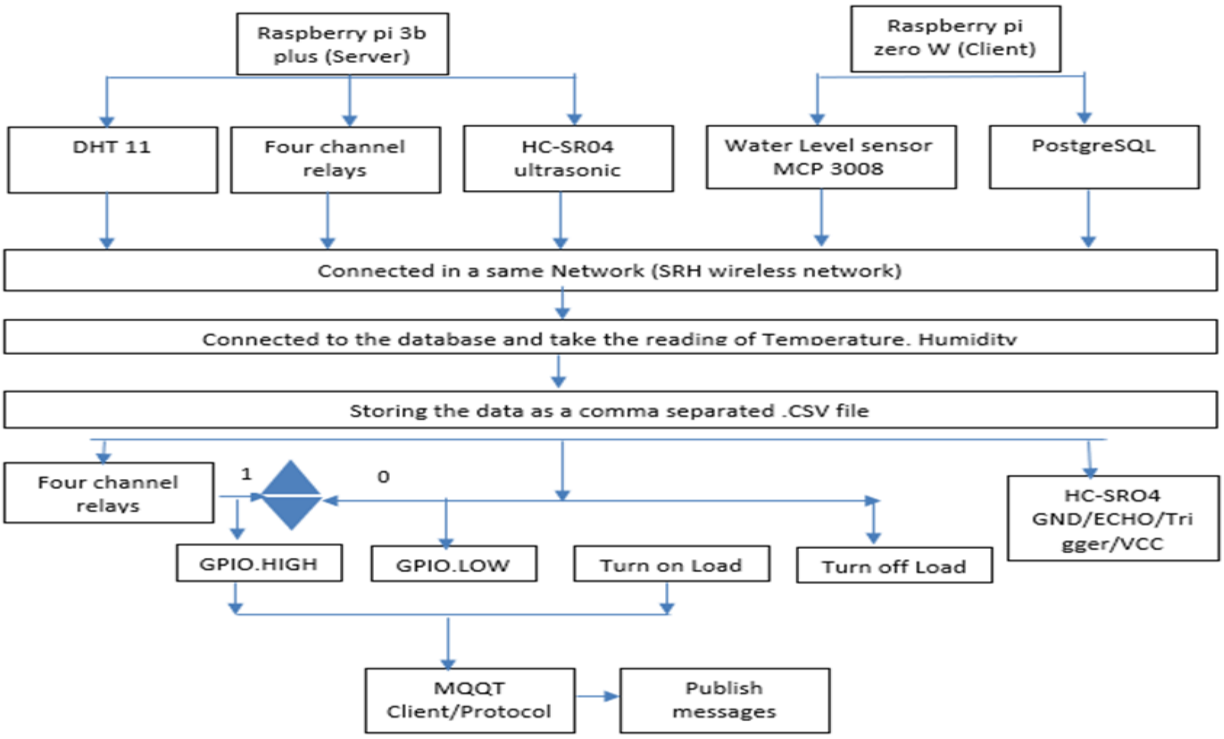


Fig. 5. Automation of water pump and relay

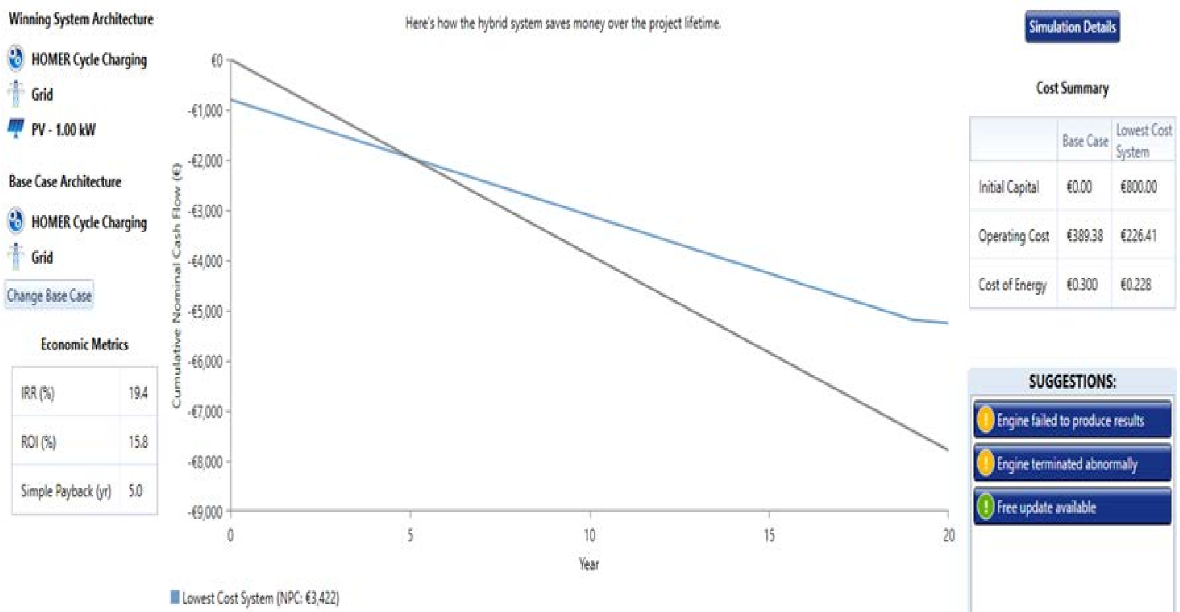


Fig. 6. Cash flow model by using Homer Pro software

Table. 1. Economical analysis after extracting the information from software

Investment costs €/kWp / CapitalCost Multiplier-homer	Focus 1kW 800 / 1.0 (With optimum CAPEX)	High 1kW 1200 / 1.5 (With a High CAPEX)
Project IRR (before tax)	19.4%	12.1%
Simple Payback Time (yr)	5.05	7.57
PV LCOE (EUR ct/kWh)	0.036	0.052

4. CONCLUSION

A simple cash flow model has done, and it was visible that including all components costs and putting the capital cost of panels the system was feasible to implement. Not but the least this master thesis can play a significant role in terms of sustainable house with automation system. The Levelized cost of electricity was calculated by the total initial cost of the system with accordance to the production. The electricity cost including renewable energy resources was calculated and compared with the different cost multiplier to see the benefit of the project. All cost of the sensors and the photovoltaic panel was also included to the entire system. The prediction analysis was a subtopic of this project where the future value of the production was calculated which can be also a cost optimization criterion in renewable energy field. The extension of this project is possible with a medium or a higher system.

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