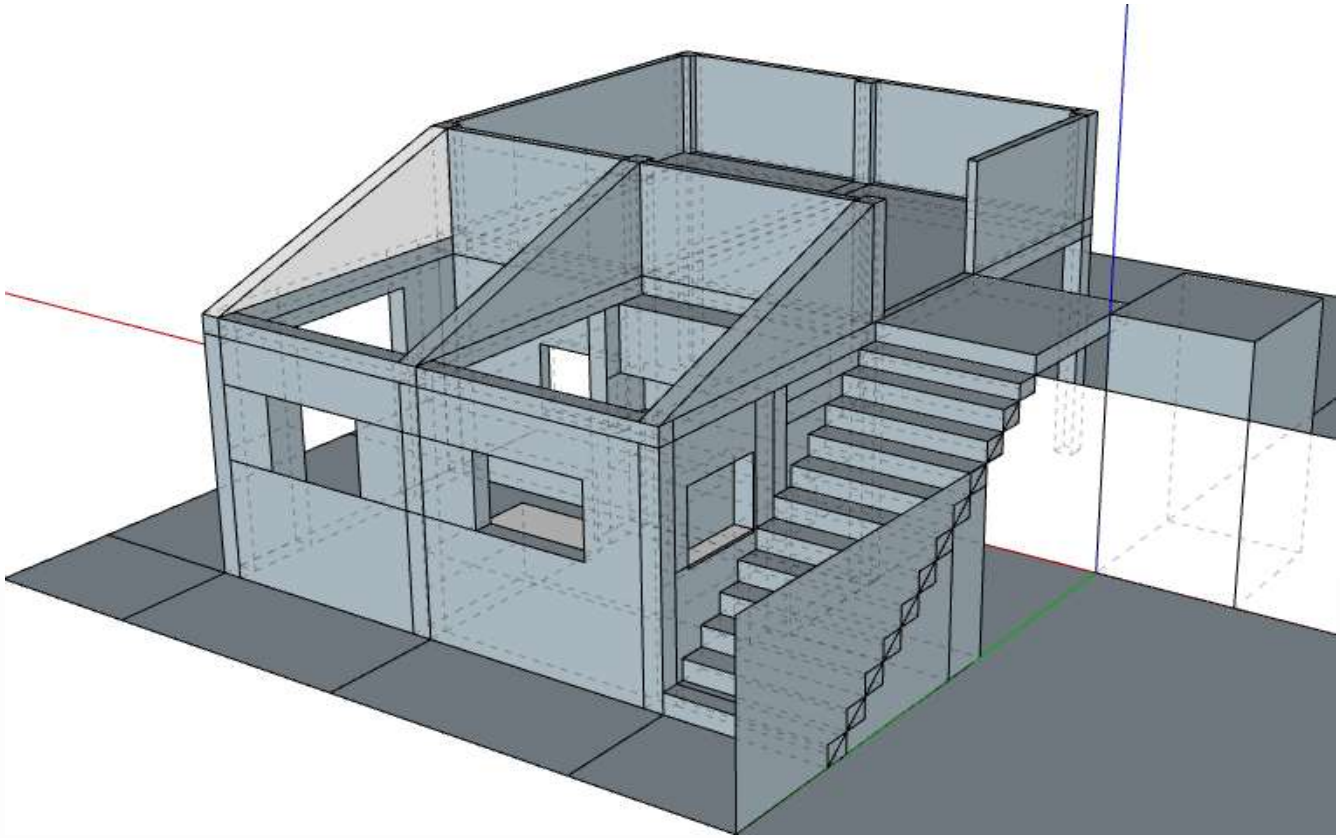

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ARTIFICIAL INTELLIGENCE IN RENEWABLE ENERGY SYSTEMS BASED ON SMART ENERGY HOUSE

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CONTENTS

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a) Introduction
b) Different parameters of a Smart Home System
c) State of the art in the content of the theme
d) Research & Theoretical design
e) Smart control system of an Energy Efficient House
   i. Equipment used for the process of installation
   ii. GPIO pins and their functionality of Raspberry Pi
   iii. Typical application of a DHT-11 sensor
   iv. Application of Water level sensor (MCP3008) in the project
   v. Analog to-Digital (A/D) converters and its working principle
   vi. Ultrasonic sensor (HC-SR04) and its application
f) Interfacing between client and server by TCP/IP networks
g) MQTT protocol and its application
h) PostgreSQL and data acquisition system
i) AI (Artificial Intelligence) and its different methods in Renewable Energy Systems
j) Financial Analysis & Critical viewpoints
k) Merits and Demerits
l) Conclusion

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INTRODUCTION

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- What is IoT: T*he network of physical objects—devices, vehicles, buildings and other items—embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data*".
- Internet of Things (IoT) is a concept that encompasses various objects and methods of communication to exchange information.
- This project involves the realization of an intelligent system to control the home by using the data received from sensors. The controller (Raspberry Pi) is the main component of the home automation system.
- Smart Home can increase the comfort of the inhabitant, for example, natural interfaces to control light, temperature or different electronic devices.
- The purpose of the project was to implement a zero-emission house with PV (photovoltaic) thermal panel which will be installed on the roof top of the house to supply electricity.
- The PV-T panel will provide the thermal energy which can also connected to the water pump system and the temperature of panel will be a source of thermal comfort and hot water.

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DIFFERENT PARAMETERS OF A SMART HOME SYSTEM

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Weather monitoring System:

- Temperature
- Humidity
- Wind velocity
- Control the home Appliance

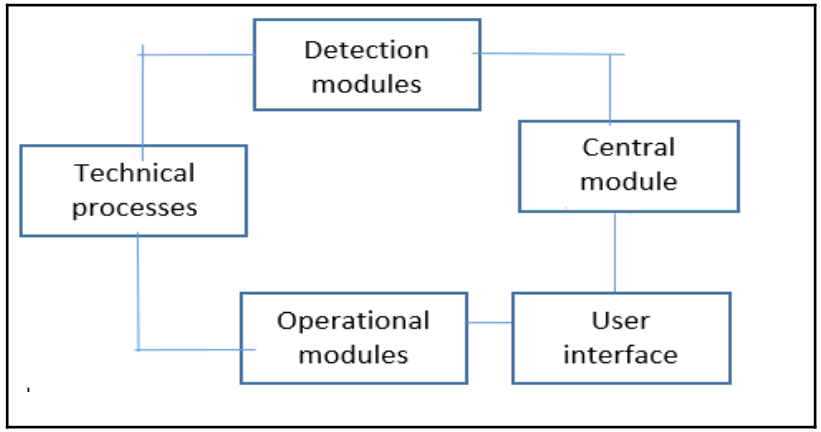

Figure : Different parameters of a Smart Home System

Product faults | **Design faults** | **Installation faults**

Smart control system can help to identify the abovementioned points and AI can play a big role in terms of project economical aspects

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STATE OF THE ART IN THE CONTENT OF THE THEME

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Energy Efficiency House

- Clay instead of brick for a better insulation.
- 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.

Collecting the data

- Step is to set up the electronic devices (e.g. DHT 11 temperature and humidity sensor).
- Data was taken from the sensor through Raspberry pi.
- DHT11 sensor and it was sending the data to the raspberry pi zero which has been used as a client.

Creating a Data Acquisition system

- The database has been created by using PostgreSQL to store the data of temperature and humidity.
- Analogue to digital converter (ADC) to process the analogue signal from water level sensor.
- Ultrasonic sensor to control the automation of pump.

Control system analysis

- The theory of our automation level controlling was to turn the motor on and then turned off when water is enough.
- Turned off the PV power to overcharge the battery when the production is low.

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RESEARCH & THEORETICAL DESIGN

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A real-time data acquisition system, using 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

Data Acquisition System) can be categorized into two types: an external box configuration or an internal plug – in board configuration.

With the internal plug in board configuration, it has the advantage of closer connectivity to the controlling CPU & allows for the system to function faster and collect data at higher rates.

The motor has to be controlled by an HC-SR04 sensor connected with relay

The power output of Solar is subject to various meteorological parameters, such as humidity, temperature etc.

Accurate solar forecasting enhances the value of renewable energy by improving the reliability and economic feasibility of these resources

It also supports integrating solar power into electric grids by reducing the integration and operation costs associated with these intermittent generation sources.

The main gap of competence was to bring all the possibilities together such as automation, cost analysis, designd making or introducing database management system & a synchronization between the client and the server.

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SMART CONTROL SYSTEM OF AN ENERGY EFFICIENT HOUSE

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Concept of an energy eff. house

- Comfort and optimum management by different sensors.
- Using PV-Thermal panel on the roof top to supply the electricity.
- The PV-T panel will provide the thermal energy which can also connected to the water pump system.
- Supply the water around the house.
- Using water to supply the water through the pipe.
- Water can be stored at storage tank to reduce extra energy cost.
- The smart monitoring system will collect temperature, humidity of panel, water level, condition of the relay.

Equipment used for the process

- Raspberry pi zero
- Raspberry pi 3b+
- DHT11 sensors
- PV module
- HC-SR04 Ultrasonic sensor
- Water level measuring sensor MCP3008 (ADC)
- Water pump (12 V dc)
- Four channel relays to connect with load (pump and the raspberry pi)
- Buzzers
- Jumper wire
- Micro USB

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SMART CONTROL SYSTEM OF AN ENERGY EFFICIENT HOUSE

GPIO pins and their functionality of Raspberry Pi

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Index	Raspberry Pi 3 B+	Raspberry Pi Zero W
Image		
SOC Type	Broadcom BCM2837B0	Broadcom BCM2835
Core Type	Cortex-A53 64-bit	ARM1176JZF-S
No. Of Cores	4	1
CPU Clock	1.4 GHz	1 GHz
RAM	1 GB DDR2	512 MB
Wi-Fi	2.4GHz and 5GHz 802.11 b/g/n/ac	802.11n

Table : Difference between Pi 3b+ and Pi zero W

Power: Pins that are labeled 5.0v supply 5 volts of power and those labeled 3V3 supply 3.3 volts of power. There are two 5V pins and two 3V3 pins.

GND: These are the ground pins. There are eight ground pins.

Input/output pins: These are the pins 7, 11, 12, 13, 15, 16, 18, 22, 29, 31, 32, 33, 36, 37, 38, 40 used for input or output that simply be used to turn devices on and off.

SPI: Serial Peripheral Interface is a used for short distance communication, are labeled MOSI, MISO, SCLK, CE0, and CE1. (e.g., 19, 21, 23, 24, 26.)

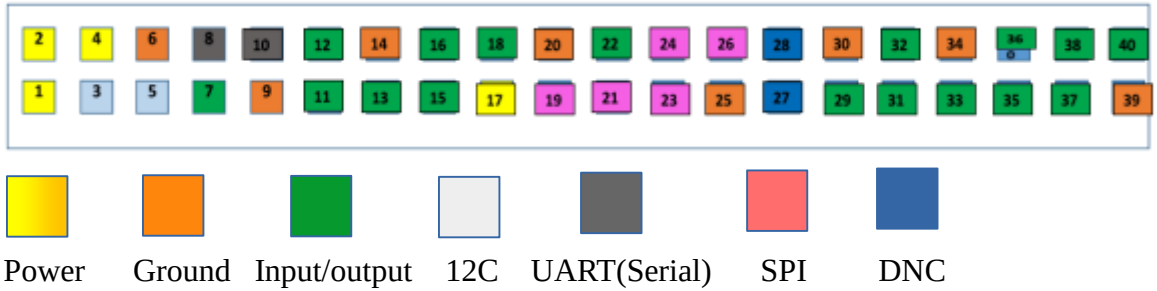

Figure : GPIO pins and their functionality

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Typical application of a DHT-11 sensor

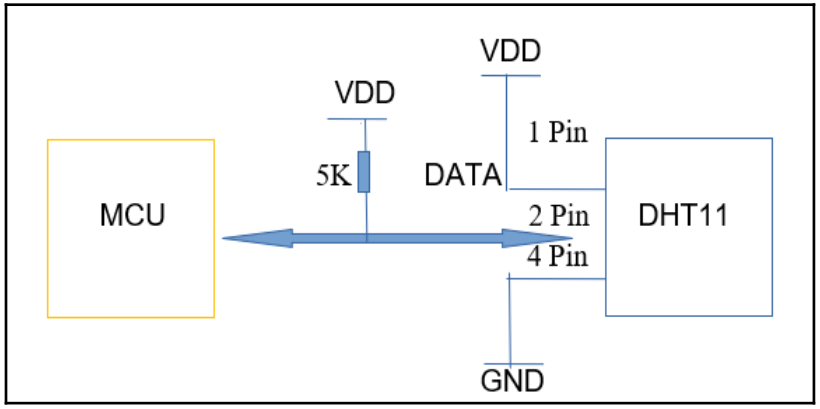

Figure: Typical Application

Power and Pin: DHT11's power supply is 3-5.5V DC. When power is supplied to the sensor, do not send any instruction to the sensor in within one second in order to pass the unstable status. One capacitor valued 100nF can be added between VDD and GND for power filtering.

Note: 3Pin – Null; MCU = Micro-computer Unite or single chip Computer When the connecting cable is shorter than 20 meters, a 5K pull-up resistor is recommended. when the connecting cable is longer than 20 meters, choose an appropriate pull-up resistor as needed.

This sensor is ideal for remote mounting since they can operate up to 65 feet (20 meters) apart using a long wire

DHT11 Temperature & Humidity Sensor features a temperature & humidity sensor complex with a calibrated digital signal output

It includes a resistive-Type humidity measurement component, NTC temperature measurement component with 8-bit microcontroller

DHT11's power supply is 3-5.5V DC

```
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
```

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Application of Water level sensor (MCP3008) in the project

Operating voltage	**2.0V-5.0V**
Output type	Analog output
Detectable depth	48mm
Dimensions	19.0mm*63.0mm
Fixing hole size	2.0mm

Pin No	Symbol	Descriptions
1	AOUT	Analog output
2	GND	Power ground
3	VCC	Power supply (3.3V-5.0V) +v

Table: Description of Interfaces pin Number

- Operating principle: Current amplification by a transistor.
- Conduct the current between the base and the positive power supply.
- Current is generated between the base and the emitter.
- An electric current is produced in a certain amplification factor between the collector and the emitter and applied to the resistant in the emitter to produce a voltage.
- Then, this voltage will be collected by an AD converter.
- It identifies the amount of water through exposed parallel line track.
- The work voltage is 3-5 V.

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SMART CONTROL SYSTEM OF AN ENERGY EFFICIENT HOUSE

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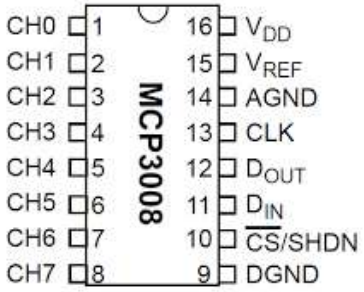
MCP3008 PDIP, SOIC	Symbol	Description
1	CH0	Analog Input
2	CH1	Analog Input
3	CH2	Analog Input
4	CH3	Analog Input
5	CH4	Analog Input
6	CH5	Analog Input
7	CH6	Analog Input
8	CH7	Analog Input
9	DGND	Digital Ground
10	CS/SHDN	Chip Select/Shutdown Input
11	D_{IN}	Serial Data In
12	D_{OUT}	Serial Data Out
13	CLK	Serial Clock
14	AGND	Analog Ground
15	V_{REF}	Reference Voltage Input
16	V_{DD}	+2.7V to 5.5V Power Supply

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

Figure: output of the system

Analog to-Digital (A/D) converters and its working principle



- Employ a conventional SAR, Successive approximation-register architecture.
- A sample is acquired on an internal sample/hold capacitor for 1.5 clock cycles starting on the first rising edge of the serial clock once CS has been pulled low.
- Following this sample time, it uses the collected charge on the internal sample and hold capacitor to produce a serial 10-bit digital output code.
- Communication with the device is accomplished using a 4-wire SPI-compatible interface

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SMART CONTROL SYSTEM OF AN ENERGY EFFICIENT HOUSE

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Ultrasonic sensor (HC-SR04) and its application

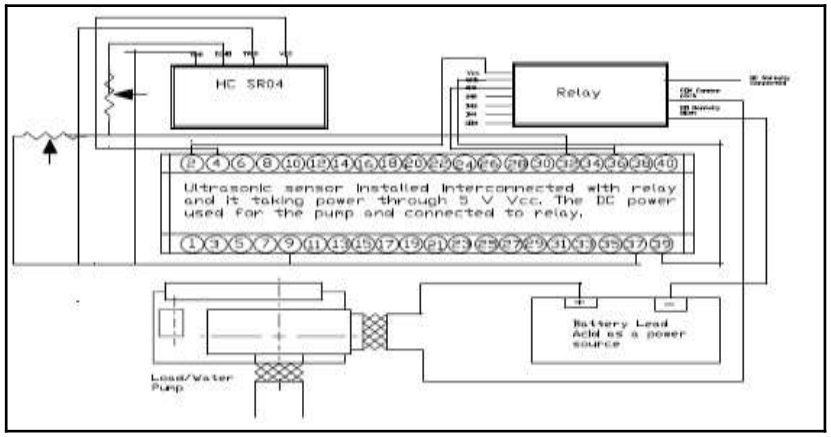
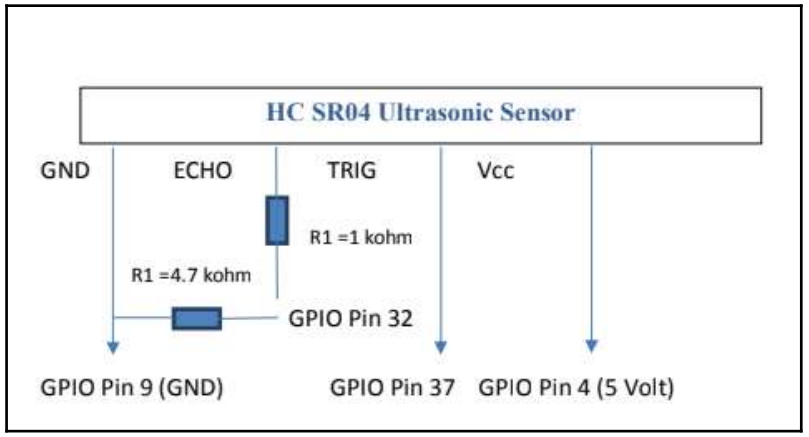


Figure: Automation of water pump and relay.



- The transmitter emits a 8 bursts of an directional 40KHz ultrasonic wave when triggered and starts a timer.
- Ultrasonic pulses travel outward until they encounter an object, The object causes the the wave to be reflected back towards the unit.
- The velocity of the ultrasonic burst is 340m/sec. in air.

Output of the demonstration:

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

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Ultrasonic sensor (HC-SR04) and its application

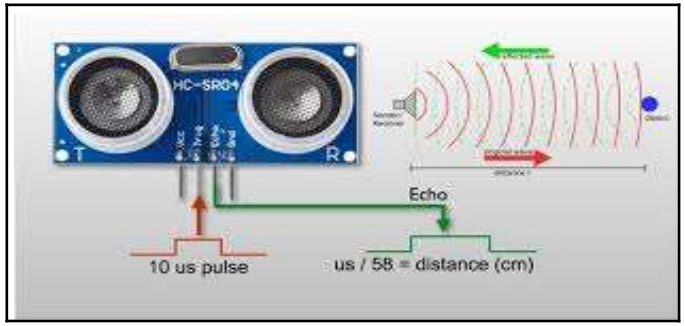

Figure: Module Pin Assignments

Wire connecting direct as following:

- ✓ 5V Supply
- ✓ Trigger Pulse Input
- ✓ Echo Pulse Output
- ✓ 0V Ground

- ✓ Module Operation. Using IO trigger for at least 10us high level signal.
- ✓ The Module automatically sends eight 40 kHz and detect whether there is a pulse signal back.
- ✓ The velocity of the ultrasonic burst is 340m/sec. in air.
- ✓ IF the signal back, through high level , time of high output IO duration is the time from sending ultrasonic to returning. The Echo is a distance object that is pulse width and the range in proportion.
- ✓ Test distance = (high level time×velocity of sound (340m/s) / 2

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INTERFACING BETWEEN CLIENT AND SERVER BY TCP/IP NETWORKS

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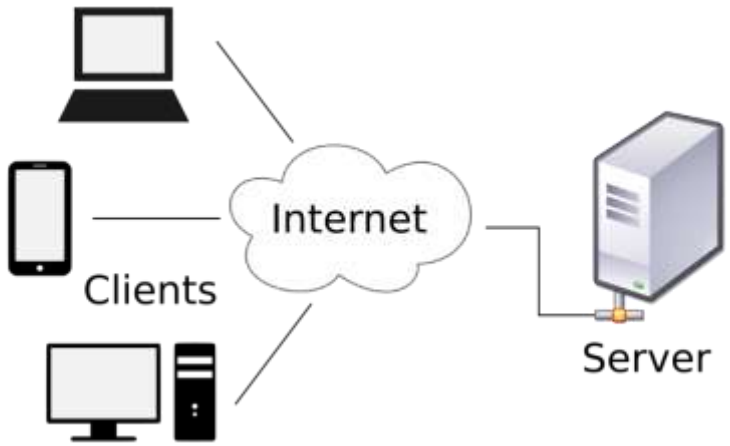

Figure: Client and server model

- ✓ The core principle is to use different algorithm to read the data from the Server and Client with the help of Raspberry Pi 3B+ and Raspberry pi zero and store the data in Database management system such as PostgreSQL.
- ✓ The background behind is to store the data as .CSV file to predict the most relevant data from the data logging system and use predictive analysis with some Machine Learning tools.

- In a client/server network arrangement, network services are in a dedicated computer whose only function is to respond to the requests of clients.
- The server contains the file that is continuously available to respond to client requests.
- Telnet, part of the TCP/IP protocol suite, is a virtual terminal protocol that allows us to make connections to remote devices. we used telnet as a testing purposes to see the server was responding the request of the client or not.

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INTERFACING BETWEEN CLIENT AND SERVER BY TCP/IP NETWORKS

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- ✓ IP address from SRH wireless used for both client/server and with DHCP protocol.
- ✓ The Dynamic Host Configuration Protocol (DHCP) is a network protocol which functions at the application layer of the Internet Protocol (IP) suite.
- ✓ A server which uses DHCP will be able to dynamically assign IP Addresses and other network configuration parameters to devices on the network; thus, allowing communication to a second network.
- ✓ The devices residing outside of local network cannot directly communicate via the private IP address.
- ✓ In this process a server/client python script based on TCP/IP sockets for pi 3b+ server and pi zero client was created.
- ✓ Finally DHT 11 data was sent pi zero over TCP/IP on port of the raspberry pi 3b+

Note: In our project Raspberry PI 3B is not using a Server, it is a server.

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MQTT PROTOCOL AND ITS APPLICATION

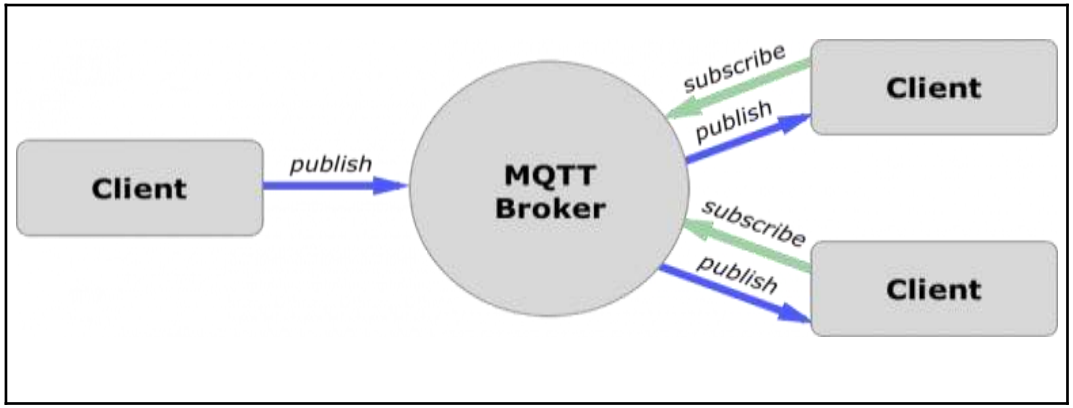

Figure: MQTT broker and client explanation

In addition, these clients are publishing and subscribing to topics. So, the broker here is the one that handles the publishing/subscribing actions to the target topics (graph).

- ✓ Message Queuing Telemetry Transport MQTT is based on clients and a server
- ✓ The server is the main who is responsible for handling the client's requests of receiving or sending data between each other. MQTT server is called a broker and the clients are simply the connected devices.
- ✓ When a device (a client) wants to send data to the broker, we call this operation a "publish".
- ✓ When a device (a client) wants to receive data from the broker, we call this operation a "subscribe".

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MQTT PROTOCOL AND ITS APPLICATION

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- ✓ Let's say for our device server raspberry 3b plus which is mqtt broker, the client raspberry pi zero that has a water level sensor. Certainly, it wants to send his readings to the broker. On the other side, our mqtt client relay wants to receive this water level value. Therefore, 2 things will happen:

i. The device defines the topic it wants to publish on, ex: "connected to mqtt broker". Then, it publishes the message "relay on".

ii. The mqtt client raspberry pi zero application subscribes to the topic "connected to mqtt broker". Then, it receives the message that the device has published, which is the relay on. For the project if the water level was more than adc_value 300 then the relay was turned off otherwise it was turned on until the tank was full.

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POSTGRESQL AND DATA ACQUISITION SYSTEM

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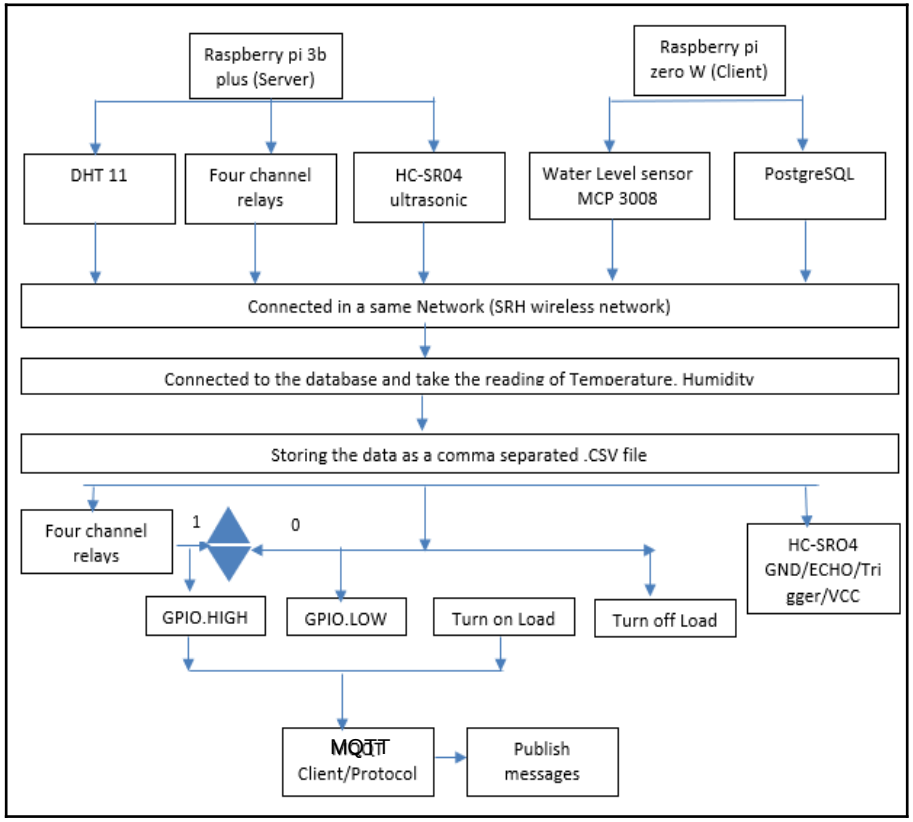

Figure: Block Diagram for the entire process

- ✓ The main objective is to build up and monitoring and data logging system which will give us the all Temperature, Humidity, Water Level, Water pump controlling (with relay), Solar Irradiation data into the system.
- ✓ If the water level is higher than the limit the pump will switch automatically which can reduce cost and energy consumption.

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POSTGRESQL AND DATA ACQUISITION SYSTEM

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- Connecting the database on raspberry pi 3b plus (server)
- Creating the table if doesn't exist.
- Reading the temperature and humidity from the sensor and writing the data into the file and the database.
- Re starting the script and rebuild the "db" connection if needed.
- The PostgreSQL has installed into the pi 3b plus which will be automatically populated by the script on pi zero

Note: CSV file was only for the troubleshooting or as an additional logger. The measured data are being stored into DB. CSV was basically only for troubleshooting.

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POSTGRESQL AND DATA ACQUISITION SYSTEM

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```
user@IT-PC:/etc/postgresql/11/main$ telnet 127.0.0.1 5432
Trying 127.0.0.1...
Connected to 127.0.0.1.
user@IT-PC:/etc/postgresql/11/main$ telnet 10.5.2.246  5432
Trying 10.5.2.246...
Connected to 10.5.2.246.
user@IT-PC:/etc/postgresql/11/main$ sudo -u postgre psql
user@IT-PC:/etc/postgresql/11/main$ sudo -u postgres psql
[sudo] password for user:
user@IT-PC:/etc/postgresql/11/main$ sudo -u postgres psql
postgres=# create database logdb;
CREATE DATABASE
postgres=# create user logu with password 'logu';
CREATE ROLE
postgres=# grant all privileges on database logdb to logu;
GRANT
postgres=# \c logdb;
You are now connected to database "logdb" as user " logu ".
logdb=# create table tempsens01 (id serial primary key not null, timestamp char(255) not null, value float(32) not null);
CREATE TABLE
logdb=# \dt
public | tempsens01 | table | logu
```

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

```
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
```

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Figure: input and output for the entire process

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AI (ARTIFICIAL INTELLIGENCE) AND ITS DIFFERENT METHODS IN RENEWABLE ENERGY SYSTEMS

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- Artificial Intelligence can be a great opportunity in RE (Renewable Energy) field and some latest research is based on the open power system data
- Build a tool as a machine learning algorithm to develop future prediction.
- Calculated and the solar parameters radiation (W/m2) and the total ground horizontal radiation (W/m2).
- Different techniques: Auto regressive model, Persistence/Naïve forecasting, Moving average model etc.
- The data of global solar horizontal irradiance has been taken and has been analysed for the specific area of the location.
- for better understanding the concept of future prediction analysis the time series analysis which is a strong tool for artificial intelligence has been analysed.

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AI (ARTIFICIAL INTELLIGENCE) AND ITS DIFFERENT METHODS IN RENEWABLE ENERGY SYSTEMS

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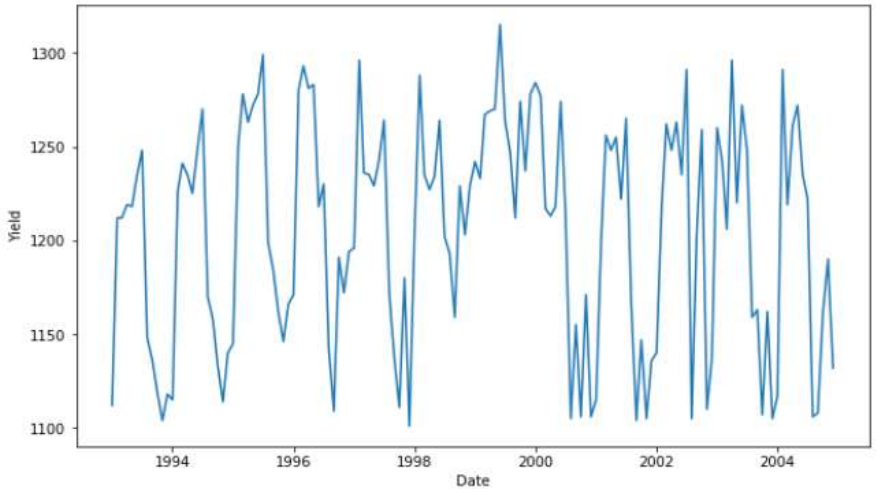
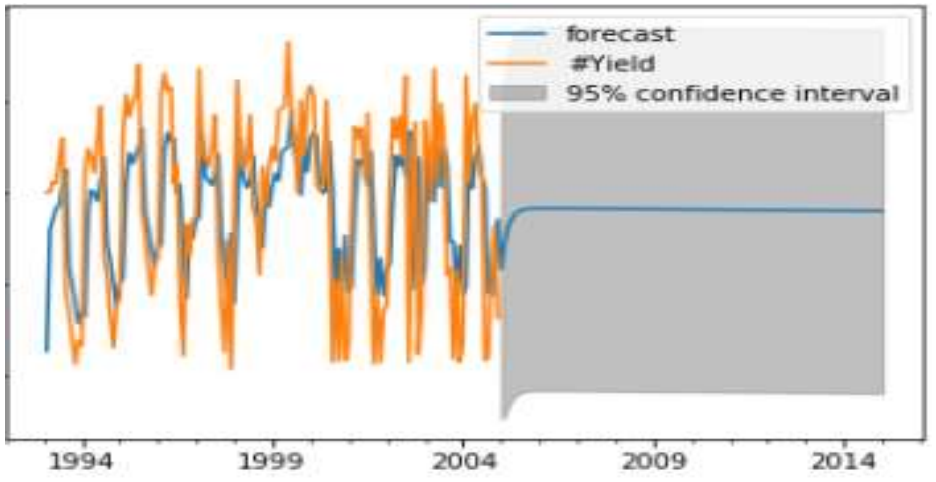
Explanation of a model ARIMA

- It is an auto regressive, moving average process. It depends on the value of p, d and q where:
- p = autoregressive, the number of lag observations included in the model, also called the lag order.
- d = order of differentiation, the number of times that the raw observations are differenced, also called the degree of differencing.
- q = moving average, the size of the moving average window, also called the order of moving average.
- y = (Auto-Regressive Parameters) + (Moving Average Parameters)





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FINANCIAL ANALYSIS & CRITICAL VIEWPOINTS

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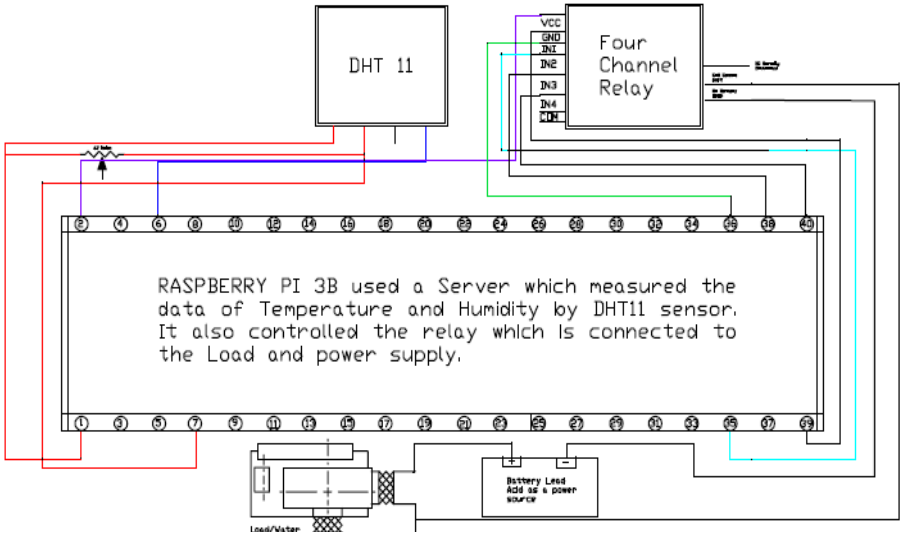

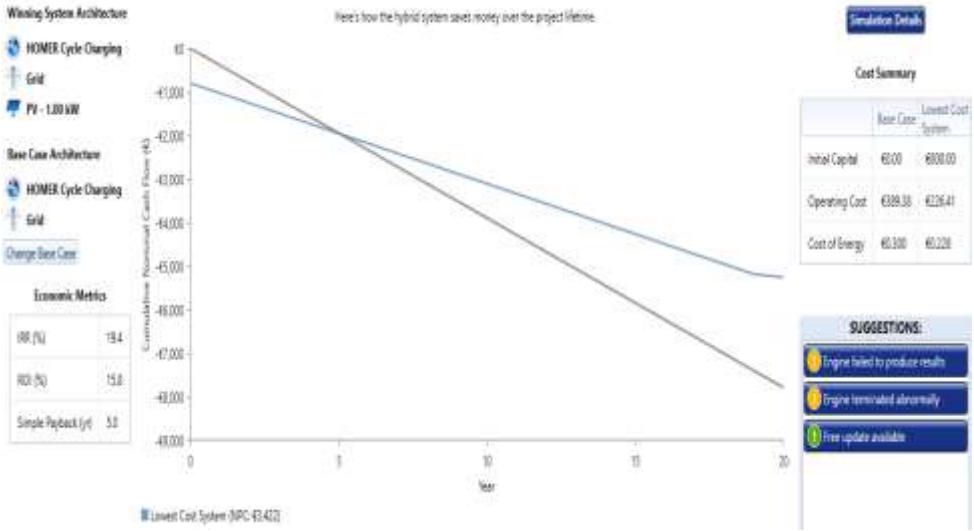

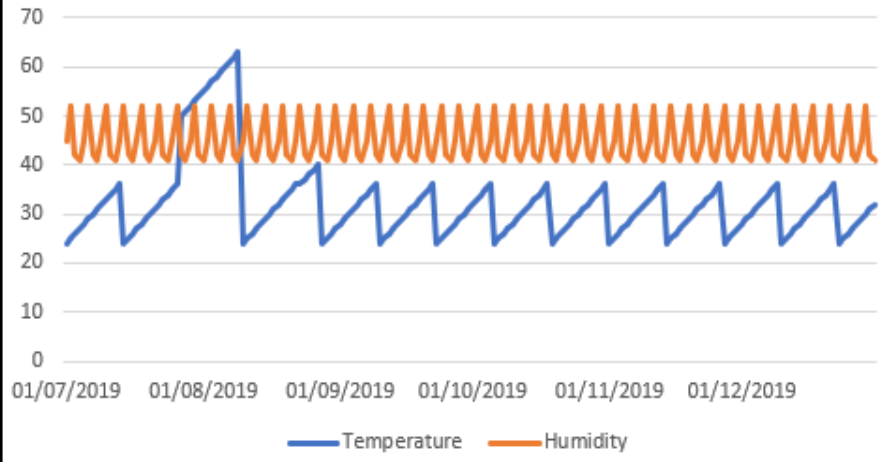

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MERITS AND DEMERITS

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Systems	Advantages	Disadvantages
DHT-11 sensor	-Features a calibrated digital signal output with the temperature and humidity sensors -This sensor includes a resistive element and a sense of wet NTC temperature measuring devices	-It can operate up to 65 feet (20 meters) apart using a long wire
Raspberry pi	-Low cost (~35$) -Huge processing power in a compact board -Many interfaces (HDMI, multiple USB, Ethernet, onboard Wi-Fi and Bluetooth, many GPIOs, USB powered, etc.) -Supports Linux, Python (making it easy to build applications) -Developing such an embedded board is going to cost a lot of money and effort	-A GPIO pin should never be connected to a voltage source greater than 3.3V -The microprocessor on the Raspberry Pi generates heat which must be managed else it may impact the reliability of the board.
Water Level sensor	-Easy to operate -Very simple construction	-As only the digital signal can be processed by raspberry pi, we need to add analogue to digital converter (ADC) to process the analogue signal from water level sensor.
Ultrasonic sensor	-It has sensing capability to sense all the material types. -This sensor is not affected due to atmospheric dust, rain, snow etc. -It has higher sensing distance (in centimetres and inches) compare to inductive/capacitive proximity sensor types.	-It is very sensitive to variation in the temperature. -It has more difficulties in reading reflections from soft, curved, thin and small objects.
PostgreSQL	-Postgres is an object-relational database, while for example MySQL is a purely relational database -It is an open source and allows to store different programming language orient data.	-Postgres is not owned by one organization. -Many open source apps support MySQL, but may not support PostgreSQL

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INVESTMENT
SCENARIO 1: OFF-GRID, PV 1KW$_P$

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Facilitating business partnership:

- Connection to experienced and reliable solar company contacts
- Supporting business discussion and partnership for new technology and future business opportunities by AI.

- **Baseline: COE = 0.30 €/kWh (grid only)**
- **Focus case: COE = 0.228 €/kWh, High 0.253 €/kWh**
- **Renewable Energy System (RES) part:**
- Potential total investment: **3,422€ (800€/kW$_p$)**
- PV LCOE: **0.036 €/ kWh**
- Financial assumption: 2.00% inflation rate, 8.0% discount rate

Investment costs* €/kW$_p$ / CapitalCostMultiplier-homer	**Focus 1kW 800 / 1.0**	**High 1kW 1200 / 1.5**
Project IRR (before tax)	19.4%	12.1%
Simple Payback Time – spt (yrs)	5.05	7.57
Discounted Payback Time (yrs)	6.16	10.31
PV LCOE (ct/kWh)**	0.036	0.052

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CONCLUSION & FUTURE WORK

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- A simple cash flow model has done, and it was visible that including all components costs and also putting the capital cost of panels the system was feasible to implement.

- It is possible to extends this project by demonstrating how to use serial communication on a Raspberry Pi to connect to an MPPT solar charge controller and transmit the photo-voltaic data via a python web server.

- By using Maximum Power Point Tracking (MPPT) solar charge controller which converts the higher voltage DC output from solar panels down to the lower voltage needed to charge batteries. For that purpose, it is necessary to use voltage step-down regulator to make sure that is can supply 5 V to raspberry pi. Raspberry pi can handle both serial communication and web serving.

- There is different type of protocol such as TTL communication protocol or RS-485which is ideal for the Pi. As a conclusion it can be clearly say that this project has a great opportunity to include more parameters and which can be useful in different technical or economical aspects.

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