

CHAPTER III. RESEARCH METHODOLOGY

In this chapter, systematic approach is taken to tackle the research problem, starting with the location of the research, the design, materials and equipment used, as well as the procedure.

3.1 Venue and time

The research is conducted in SGU LST Lab, mainly on the third floor of the H36 lab. It is done in the period of March until June 2025.

3.2 Materials and equipment

The materials and equipment used in this experiment is stated in this subchapter.

3.2.1 Materials

In order to conduct this research and to build the project, there are several components that are used, which are as follows:

Table 3.1: Main Components

Component	Quantity	Unit	Description
Solar Panel	2	Piece(s)	LONGi 550Wp Panels
Solar Charge Controller	1	Piece(s)	PowMr 30A PWM SCC
Batteries	4	Piece(s)	Sinus 12V 12Ah SLA
Inverter	1	Piece(s)	Taffware 1000W 24V Inverter

Table 3.2: Mounting Components

Component	Quantity	Unit	Description
Hollow iron	2	Piece(s)	Mounted to the roof and connected with L feet studs
Roofing nails	10	Piece(s)	6 cm, used to mount hollow iron to roof
Mounting bracket	2	Piece(s)	Long rail to place solar panels
L feet	6	Piece(s)	To hold the mounting bracket
Mid clamp	2	Piece(s)	Clamp between the panels
End clamp	4	Piece(s)	Clamp at the end of the panel

Table 3.3: Protection Devices

Component	Quantity	Unit	Description
MCB DC	1	Piece(s)	32A Overcurrent protection for panels
Fuse	2	Piece(s)	30A DC Fuse for Battery and Inverter

Table 3.4: Cabling Components

Component	Quantity	Unit	Description
DC solar panel cable	22	Meters	Connects panels to the device
PV solar connector	4	Set(s)	MC4 connector for solar cables
Y-Branch joiner	2	Set(s)	To create parallel connection
Y2 connector	8	Piece(s)	To connect cables to battery terminals
4mm ² NYAF cable	5	Meters	General purpose cable for DC connections
19mm Blade Fuse holder	2	Piece(s)	Holder for blade fuses

1) Solar modules



Figure 3.1: LONGi 550Wp Mono PERC Halfcut

The two solar modules used in this experiment is the LONGi Passivated Emitter and Rear Contact (PERC) Halfcut Solar Module with the model number of LONGI LR5-HPH-550M. PERC solar cells have an extra layer within the back side of the cell. This allows some of the sun's rays to reflect back into the solar cell, giving them another opportunity to be turned into energy. PERC solar cells generally produce 6-12% more energy compared to traditional monocrystalline solar cells. The specification of this particular solar panel is as follows:

Power : 550Wp	Efficiency : 21.3% (Longi Solar, 2024)
Voc : 49.8V	Dimensions : 2278 x 1134 x 35mm
Vmp : 41.95V	Cell type : Monocrystalline PERC cells
Isc : 13.98A	Cell count : 144 (6 x 24)
Imp : 13.12A	Weight : 27.2kg $\pm$ 3%

2) Mounting system



Figure 3.2: Solar mounting system on rooftop

In order to mount the solar panel, at first an aluminum bar is mounted on the roof. Then struts are mounted on top of the aluminum bar, and then the mounting bracket is then fitted on top of the strut, and then the solar panels are mounted on top of it, secured with the clamp lock at the ends and on the middle. The strut was needed since the bracket cannot be mounted directly on the roof due to the roof structure. Aluminum is used due to its resistance against corrosion.

3) Cabling system

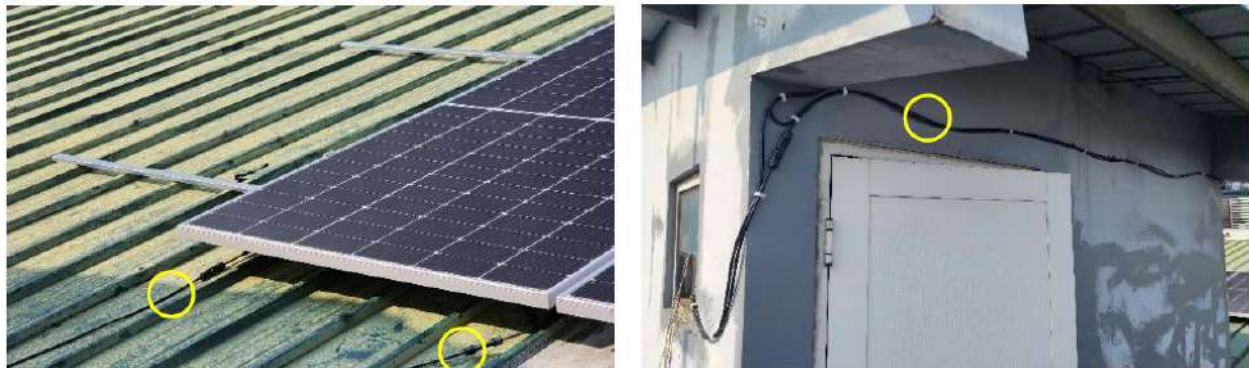


Figure 3.3: Rooftop Cabling System

The solar panels come preinstalled with 2 x 6 mm stranded wire cable (NYAF) with MC4 connectors at the ends. Both cables are then connected to a Y-combiner to connect both solar panels in a parallel configuration. These cables are rated for a maximum current of 53A PT KMI Wire and Cable Tbk (2015) which is more than enough for the theoretical maximum 26A of the I_{mp} in a parallel configuration. The Y-combiners are then connected to another 2 x 6 mm stranded wire for the length of 22 m.

4) Power inverter



Figure 3.4: Taffware Inverter



Figure 3.5: Front and back side of inverter

Spesifikasi

Wave Form	Pure Sine Wave / Gelombang Sinus Murni
Voltage Input	24 V
Voltage Output	220 V
Kontinu Power	Daya Nominat: 500 W Rekomendasi Maksimal Daya Nominat: 350 W
Surge Power	Daya Puncak: 1000 W Rekomendasi Maksimal Daya Puncak: 700 W
Frekuensi	Frekuensi Output: 50 Hz
Material	Case: Plastik dan Aluminium Alloy
Dimensi	21 x 9,9 x 5,4 cm

Figure 3.6: Inverter Specifications (Taffware, 2022)

The inverter used is Taffware 1000W 24V Pure Sine Wave Power Inverter. It converts 24VDC to 220VAC. According to its detailed specs, it can handle 19.5-28.5V on its input (Taffware, 2022). It has a recommended maximum surge power of 700W and a continuous power rating of 350W.

5) Battery



Figure 3.6: Battery Picture (diagonal)



Figure 3.7: Battery Picture (side)

SINUS ELECTRIC

MS 12-12 12V12AH
MS SERIES-VRLA Battery

Specification

Nominal Voltage	12V
Nominal Capacity(20HR)	12AH
Dimension	Length 151 ±1mm (5.95 inches) Width 98 ±1mm (3.86 inches) Container Height 95 ±1mm (3.74 inches) Total Height (with Terminal) 99.5 ±1mm (3.98 inches)
Approx Weight	Approx 3.4kg (7.5lbs)
Terminal	T1 / T2
Container Material	ABS
Rated Capacity	12.0 AH/0.60A (20hr, 1.80V/cell, 25°C/77°F) 11.2 AH/1.12A (10hr, 1.80V/cell, 25°C/77°F) 10.2 AH/2.04A (5hr, 1.75V/cell, 25°C/77°F) 9.2AH/3.06A (3hr, 1.75V/cell, 25°C/77°F) 7.54AH/7.54A (1hr, 1.60V/cell, 25°C/77°F)
Max. Discharge Current	180A (5s)
Internal Resistance	Approx 17mΩ
Operating Temp. Range	Discharge : -15 ~ 50°C (5 ~ 122°F) Charge : 0 ~ 40°C (32 ~ 104°F) Storage : -15 ~ 40°C (5 ~ 104°F)
Nominal Operating Temp. Range	25 ± 3°C (77 ± 5°F)
Cycle Use	Initial Charging Current less than 3.6 A/Voltage 14.4V~14.9V at 25°C(77°F)Temp. Coefficient -30mV/°C
Standby Use	No limit on Initial Charging Current Voltage 13.5V~13.8V at 25°C(77°F)Temp. Coefficient -20mV/°C
Capacity affected by Temperature	40°C (104 °F) 103% 25°C (77 °F) 100% 0°C (32 °F) 86%
Self Discharge	Techline batteries may be stored for up to 6months at 25°C (77°F)and battery should be recharge before use. For higher temperatures the time interval will be shorter.

Applications

- All purpose
- Uninterruptable Power Supply (UPS)
- Electric Power System (EPS)
- Emergency backup power supply
- Emergency light
- Railway signal
- Aircraft signal
- Alarm and security system
- Electronic apparatus and equipment
- Communication power supply
- DC power supply
- Auto controlsystem

ISO 9001 ISO 14001 OHSAS 18001

CE RoHS

Figure 3.8: Battery Specification

The battery used in this device is SINUS MS12-12. It is a 12V12Ah Valve Regulated Lead Acid battery. The device uses four of this batteries, in a two series and two parallel configuration, resulting in a 24V24Ah total rated voltage and capacity.

5) Solar Charge Controller



Figure 3.9: PowMr SCC Controller

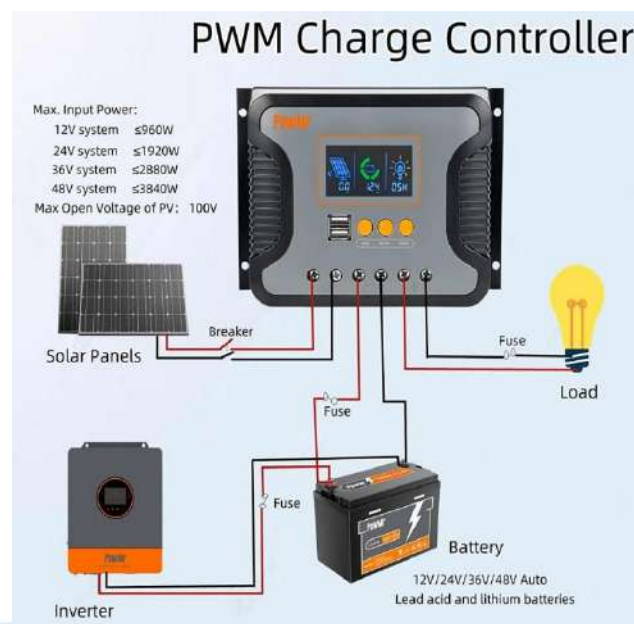


Figure 3.10: Controller Wiring Diagram

This PowMr 30A PWM Charge controller had been decided to be used in this project. This is due to its specifications that supports 30A, and supports for many battery types, including SLA/VRLA batteries, which are the battery type that is to be used in the system. It also supports up to 1920Wp PV panels for 24 system. Other than that, it also includes easy to read display, and offers numerous protections, which includes (PowMr, no date):

- Reverse polarity protection
- Over charging protection
- Over discharging protection
- Overheating protection
- Load short circuit protection

It is a solid choice for the project design and provides the peace of mind of being safe, considering the product might also be deployed in under-developed areas.

3.2.2 Equipment

To combine all the parts together, the following equipment and hand tools are needed:

Table 3.5: Measuring equipment list

Measuring Equipment	Quantity	Description
Multimeter	1	It is used to measure voltage, current, and resistance.
Power Meter Plug	1	It is used to measure AC voltage, current, power, and power factor from outlet.
DC Volt/Amp Meter Combo	1	Used to measure DC voltage and current.

Table 3.6: Hand tools list

Measuring Equipment	Quantity	Description
Cutting Pliers	1	It is used to cut connectors and cables, as well to strip cable ends.
Pinching/Combination Pliers	1	It is used to pinch and cut connector ends, cables, and secure some lock nuts.
Screwdriver PH2	1	It is used to fasten connector screws.
Soldering iron, solder and soldering flux	1	It is used to solder some cables to some connectors.



Figure 3.11: Multimeter



Figure 3.12: Watt Meter



Figure 3.13: Hand tools



Figure 3.14: Soldering Iron, Solder & Flux



Figure 3.15: Volt/Amp meter combo with 100A 75mV shunt resistor

3.3. Design of experiment

The experiment consists of connecting all the parts together, placed in a polypropylene box. Multimeters and other measuring devices would be used to measure important parameters such as voltage, amperes, power, etc. The main goal of the experiment is to know how much power the device can generate and store, as well as the impact the device could make for the community. In order to design the device in a systematical manner, certain procedures need to be followed correctly. This ensures the smooth and safe operations as the project proceeds further. Below flowchart is modelled to provide a general overview how the experiment was designed.

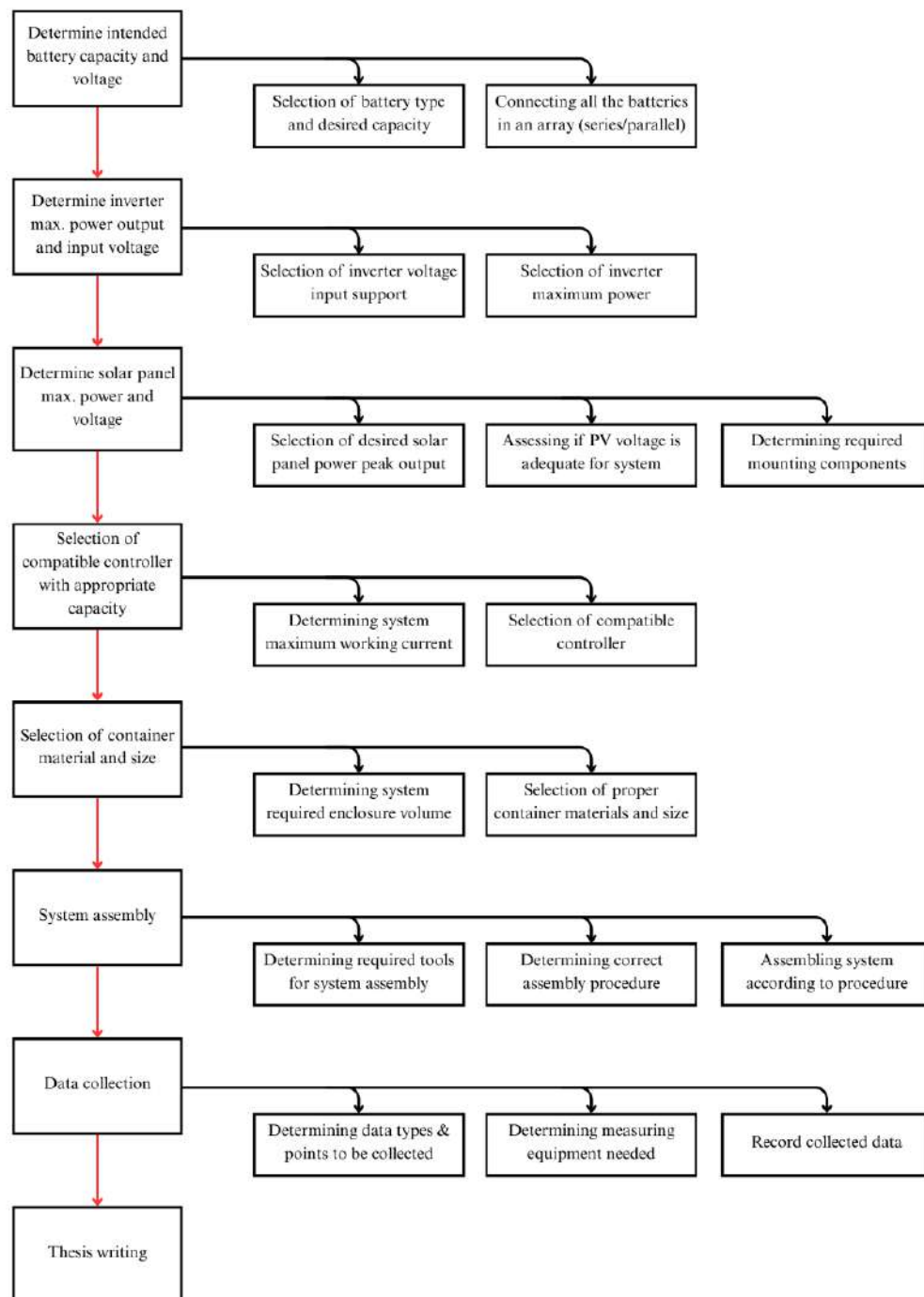


Figure 3.16: Design of experiment flowchart

3.4. Experimental Procedure

In accordance to build the design of the product, there are procedures of experiments that needs to be done which are described below. The design justifications involves at first determining the user's specification about the energy demand, followed up by selecting battery based on its type, capacity and voltage. Then the inverters with appropriate voltage and capacity is selected. Next, the controller is selected that matches the system voltage and amperage. Its compatibility with the whole system as well as the battery type is considered. The solar panels are chosen based on its voltage, as it needs to be higher than the battery voltage in order to charge it.

3.4.1. Selection of Battery

At the heart of this system is the battery array. In order to determine the desired capacity, the intended purpose of the device must first be determined. As previously stated in subchapter 2.9, a typical Indonesian per capita consumption of electricity during an average duration of a blackout will be 136.2Wh every hour or 180Wh for the entire average blackout duration. Another possible application for this device is that it is targeted to be able to power a small rice cooker until it has finished cooking the rice. This is because cooking rice is considered an essential need of electricity use. Lamps should also be supported for longer periods of time, because if the device can power a small rice cooker, it can definitely power many household light bulbs. A typical small rice cooker usually draws 200w from the grid, and led lamps typically use 6w of power for the standard home use. A normal rice cooking time usually lasts on average of 25 minutes, depending on the rice cooker size and the amount of rice to be cooked. This equates to about 83Wh for one batch of rice. So the battery capacity has to be higher than this amount. In Indonesia, lamps typically used during the sun down hours of 6pm and turned off before sleep, around 12am. One lamp of 6W turned on for 6 hours equates to 36Wh. For two lamps, this equates to 72Wh. Assuming this essential use of electricity, the demand equates to 155Wh. After that it is assumed that the device will charge during daytime, and the power can be used directly from the PV, while the batteries are being charged.

With this consideration in mind, the higher number of 180Wh is taken, as this figure will also cover the above-mentioned possible use case for the device. In addition to that, the battery costs relatively inexpensive.

On the market, 12V12Ah VRLA batteries are sold, and usually gives the best monetary value compared to other battery types and sizes. However, this specification is measured for 20h period, and the capacity will decrease as the current demand increases. In other words, the battery will have more capacity if it's discharged with lower current over longer periods of time, compared to when it's discharged with higher current over shorter periods of time. After this consideration, for this project the battery capacity is determined to use four of these batteries with each set of two batteries connected in series, then connected together in parallel, resulting in a theoretical capacity of 24V24Ah, which equates to 576Wh of rated theoretical capacity.

This amount of capacity is more than enough for our targeted use case, making the device more flexible on tackling longer periods of power interruption, providing ease of mind for its users.

3.4.2. Selection of PV Panels

In Indonesia, the average household during a typical duration will on average consume 180Wh, or 136.2Wh for every hour. However, it is also considered that during the daytime, electrical demand may increase to support other devices, such as electric fan, which uses on average 80W, and phone charger that uses on average 20W. TV also uses on average 50W and rice cooker might be used with power draw of 200W. For this particular project, an already installed PV array is used, which has 1100Wp rated peak power (Karel Christoferro, 2024). For this product deployment in rural areas, a 550Wp PV is recommended for each household.

As for the panel configuration, it is determined for the panels to be connected in parallel setup. This is because the panels have open circuit voltage of 49.8V, and running the panels in series would create too high of a voltage that can damage the controller and battery. Connecting panels in series also will be more sensitive to shading (Staff, 2024).

3.4.3 Selection of Solar Charge Controller

The controller selected for this project is the PowMr 30A PWM SCC. It is chosen because it can handle 30A, supports the battery type, includes a smart display, and other protections. It is a PWM controller, and while it is not as efficient as MPPT controllers, it is adequate for this deployment and budget friendly. It also has numerous protection features that ensures the safety of the project.

3.4.4. Selection of Inverter

The inverter chosen for this system is the Taffware 1000W 24V Pure Sine Wave Inverter. This is due to it being able to handle 24V and output a theoretical peak of 1000W and cost-effective for our purpose. Despite saying it can handle 1000W peak, its manual only recommends a peak for up to 700W and a continuous load of no more than 350W. This should be enough for our intended load, which is common house appliances such as rice cooker, lamps and electric fan.

Despite its small size, the inverter offers many safety features, such as Over Current Protection (OCP) Over Voltage Protection (OVP) Over Power Protection (OPP) as well as under voltage cutoff and battery reverse polarity protections.

With all these considerations and design choices in mind, the system is then assembled and placed inside a polypropylene container. This material is chosen because the system needs to be water resistant. The container used also offers wheels on its base, enhancing its portability. The wiring is then conceptualized based on user manuals from the components as well as online resources.

3.4.5. System Assembly and Data collection

All of the materials are then placed inside a polypropylene box. It is chosen as this will provide a waterproof and easy to modify for this use case. It is also sturdy and heat resistant.

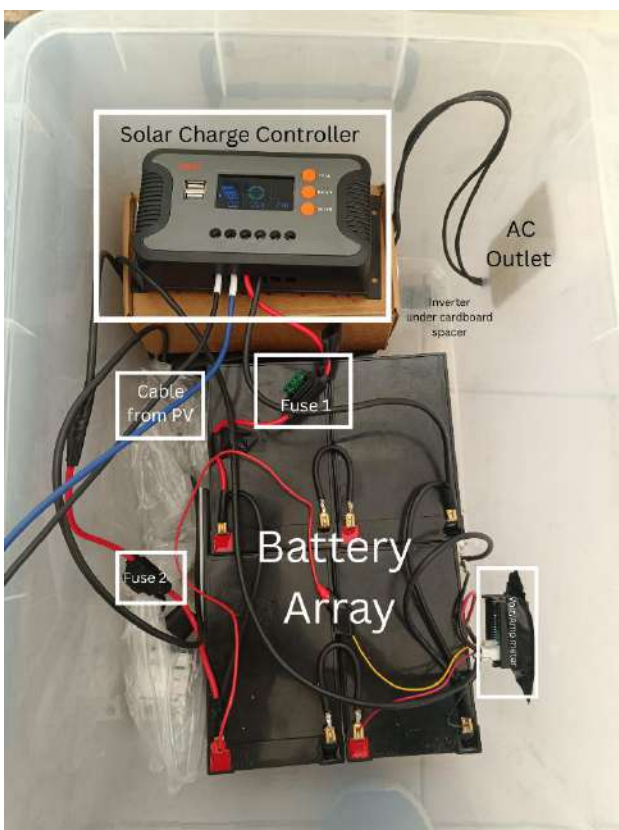


Figure 3.18: Assembled System



Figure 3.19: Solar Charge Controller



Figure 3.20: Cable from PV



Figure 3.21: Cable Connected to MCB

As to collect the data, there are specific equipment and measuring tools needed. This includes the use of multimeter, which measures the voltage. This enables the measurement of the PV input voltage, as well as the battery array voltage, providing knowledge of operational voltage of the system. For the load, wall plug watt meter is used and connected to the output side of the inverter. A dual volt/amp meter combo is installed according to the design schematic, which is used to monitor the voltage and current draw of the inverter directly from the batteries.

For the 200W data, a rice cooker is chosen to be the load. It consists of a resistive heating element, thus making it a resistive load. The rice cooker has a thermal sensor on the bottom which senses the temperature of the cooking pot of the rice cooker. Usually it triggers at 100°C (Toothman, 2023) switching the rice cooker from cook mode to warm mode. When this happens, the bottom heating element is disconnected from the power, and the side heater with lower power is connected to provide a constant warm heat around the cooking pot. On this particular model, it draws 23.4W when the rice cooker is in warm mode.



Figure 3.22: Power Measurement 200W



Figure 3.23: 200W Rice cooker

As for the 70W measurement data, the same method is used with the 200W load, except this time, the rice cooker is replaced with an ultrasonic bath device that has a heater built in. The ultrasonic part of the device is kept turned off during the entire test, and only the heater is used, with the its thermostat set to maximum temperature of 80°C. It is observed that at the very beginning it draws 100W starting power, but then immediately turns down to a continuous power draw of 68.8W

during the entire testing phase. The bath is filled with water, the lid is kept open and a glass thermometer is placed inside the water. The water is changed every hour when it reaches 45°C. This is due to the fact that the heater is very weak and cannot heat the water quickly. With this method, the load acts as a constant resistive load.

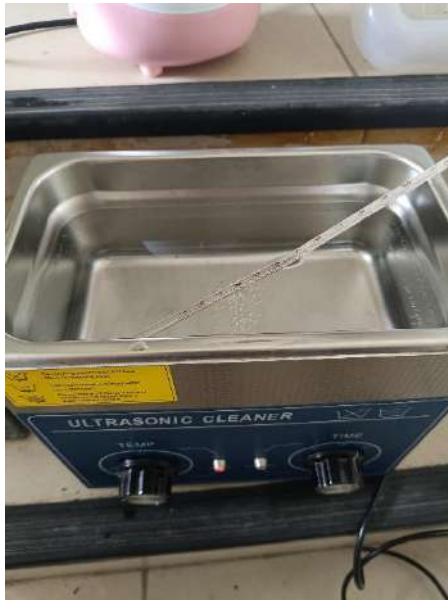


Figure 3.24: Thermometer inside Bath



Figure 3.25: Thermostat of Water Heater



Figure 3.26: Front look of the device