

CHAPTER IV : RESULTS AND DISCUSSION

Based on the design justifications made in chapter 3, the wiring schematics of the system is designed as follows:

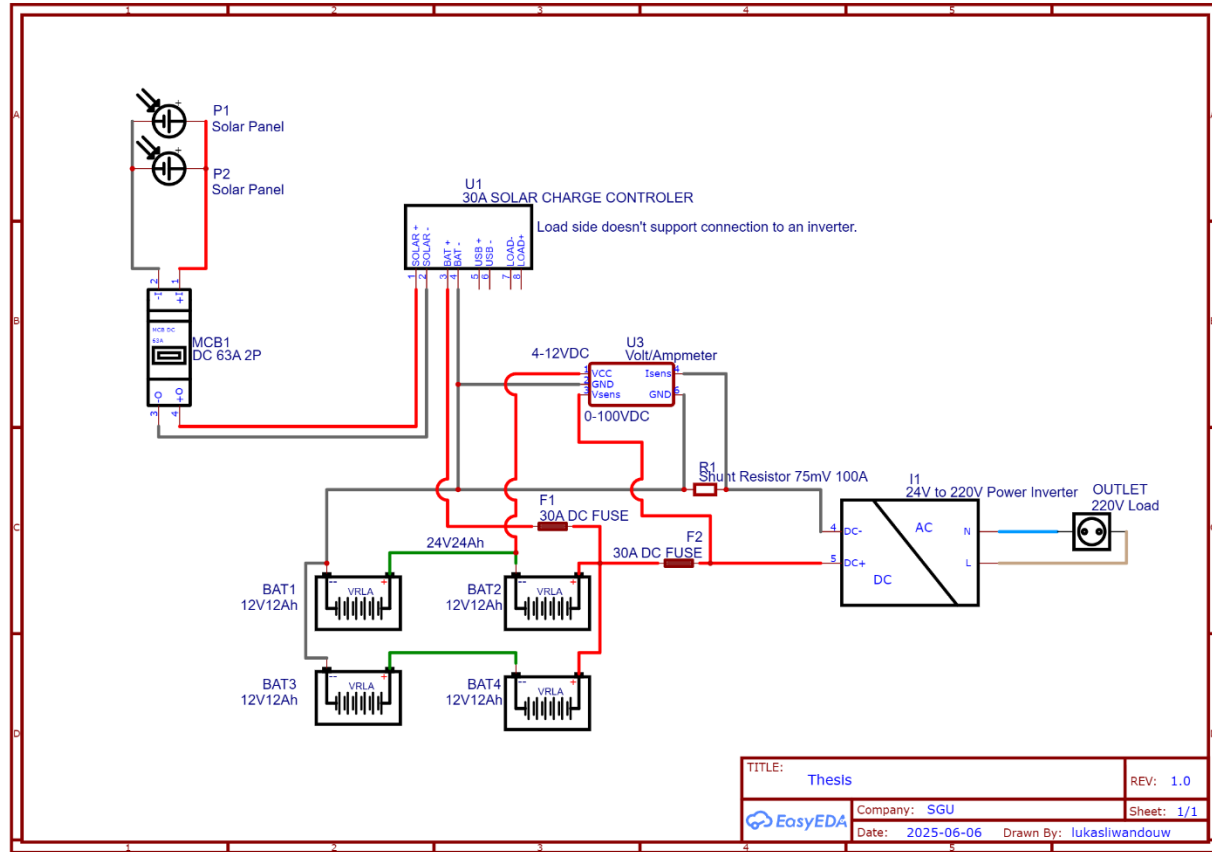


Figure 4.1: Design Schematics

The experiments yield results that are discussed in key points as described in the following sub-chapters.

4.1 Result and Discussion for Inverter Efficiency

Efficiency is calculated by using the following formula:

$$\frac{P_{out}}{P_{in}} \times 100\%$$

With the P_{in} value being the direct current power supplied to the inverter, calculated by voltage x current $V \times I$. This is measured using the DC dual voltage & current meter combo. The P_{out} value being the measured alternating current power outputted by the inverter, which is measured using the AC power meter. The inverter is loaded with various loads, including soldering iron, light bulbs, phone chargers and ultrasonic cleaner with its water bath heater.

Results of the efficiency calculations are as follows:

Table 4.1: Inverter Efficiency Data

Output Power (W)	Input Power (W)	Efficiency (%)
0	12	0
7.8	25.38	30.73
8.1	28.1	28.83
15.3	58.8	26.02
23.4	43	54.51
27.6	61.82	44.65
28.5	61.6	46.27
31.5	75.6	41.67
48.9	106.4	45.96
68.8	140.25	49.05
102.1	220.76	46.25
201.3	433.8	46.40
Average Inverter Efficiency:		38.36%

These efficiency numbers are quite low, especially when the industry now has inverters that can achieve more than 90% efficiency. This proves that the quality of the inverter is poor, as on average more than 50% of the energy is wasted into heat. The manufacturer did not specify any efficiency numbers for the inverter. This inverter also uses traditional transformer instead of the much efficient toroidal transformer, further hurting its efficiency.

When plotted to a graph, the results are as follows:

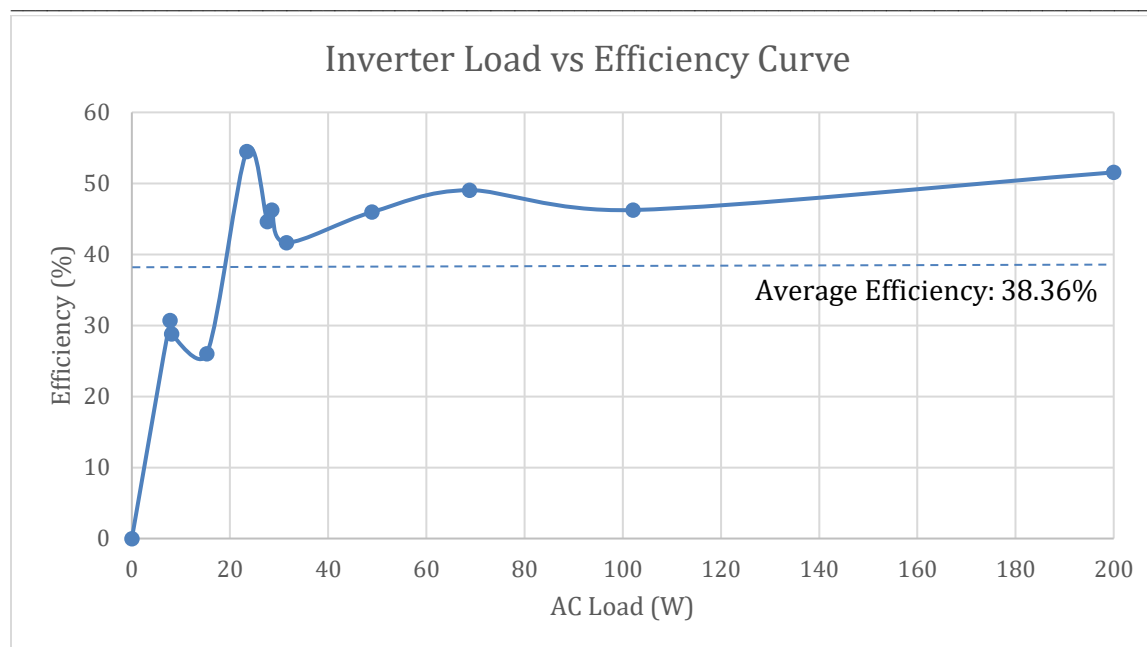


Figure 4.2: Inverter Load vs Efficiency Curve

4.2 Result and Discussion for Battery Discharge Curve without Load [®]

When the battery bank is not charging from the solar panels and is only connected to the controller without any load is drawn from the inverter, the voltage slowly drops overtime which can be observed in Figure 4.2.

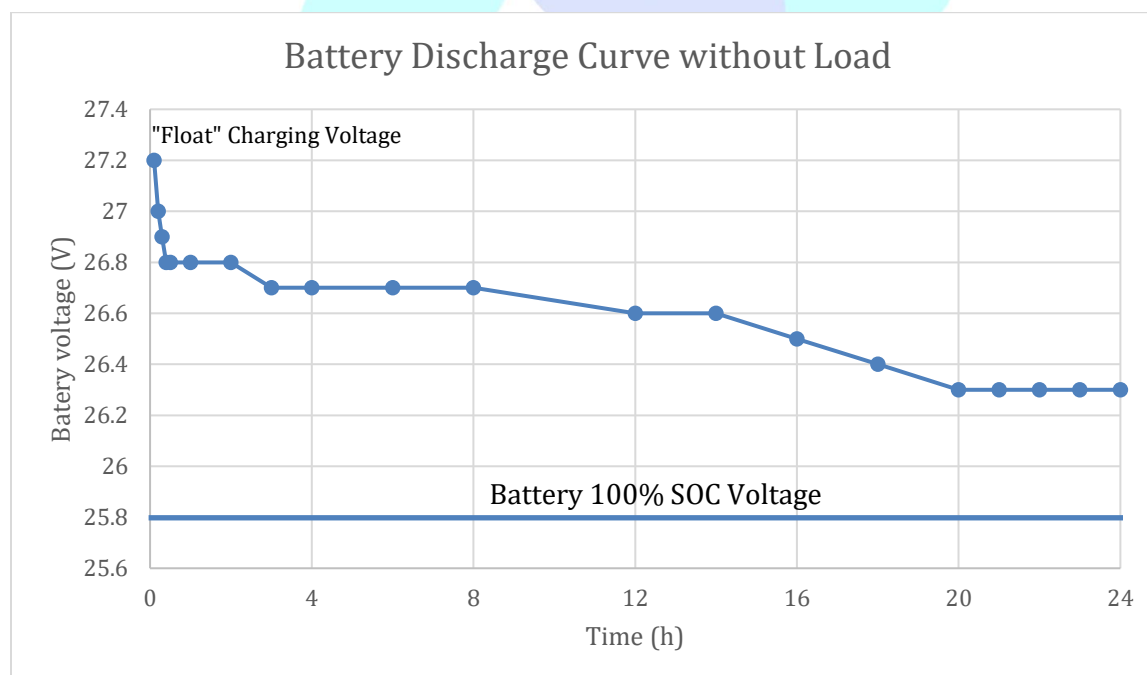


Figure 4.3: Battery Discharge Curve without Load

This indicates that the incremental drop in voltage is normal and expected. The solar charge controller was left on for the entire duration of the testing, which means that the controller is also consuming very little current from the battery over time. A battery 100% SOC voltage at 25.77V is represented by the horizontal line. This indicates that theoretically the battery is still over its 100% SOC voltage and it can still be considered fully charged even after it has been discharging slightly.

Table 4.2: 24V SLA Battery Voltage Chart (Nature's Generator, 2023)

24V Sealed Lead-Acid Battery Voltage Chart	
Voltage (V)	Capacity
25.77	100%
25.56	90%
25.31	80%
25.02	70%
24.81	60%
24.45	50%
24.21	40%
23.91	30%
23.61	20%
23.40	10%
23.25	0%

4.3. Result and Discussion for Battery Discharge Curve with Load

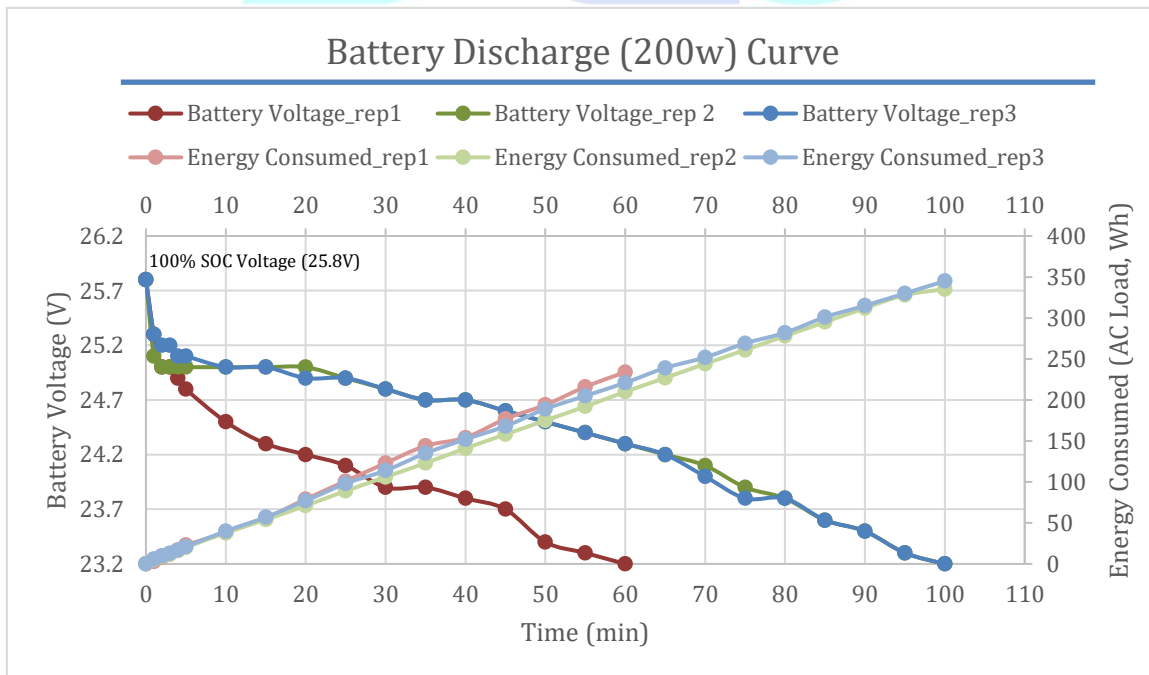


Figure 4.4: Discharge Curves and Energy Consumption for a 200W Rice Cooker

For this curve, the testing was conducted with three repetitions, each marked with rep1, rep2 and rep3 respectively. During the load testing, the rice cooker is observed to draw 201.3W constantly. It is filled with water and replaced regularly so the water stays cool and the rice cooker will not trip to warm mode. The testing is conducted when the battery is at 25.8V and stopped at 23.2V.

For the first repetition, the battery lasts only 60 minutes and the energy consumed is recorded to be only 234Wh. I believe this is due to the fact that the battery might not be fully charged before the testing begins, even though the battery was charging at 27.2V prior to the testing. With this in mind, I made sure to see that the controller is not drawing much current, meaning that it is not charging the battery bank and only applying maintenance voltage (float voltage) to the batteries. The solar panels are then disconnected, and the batteries are allowed to settle for about 10 minutes. If no significant drop in voltage is observed, the rice cooker is then connected to the inverter until the battery voltage drops to 25.8V (theoretical 100% SOC voltage) which acts as a baseline. This usually takes less than one minute. The voltage is recorded from the controller display.

For the first five minutes, the voltage is recorded every one minute, and from that point onwards, every five minutes until the battery voltage reaches 23.2V. The usage of this starting baseline makes the data taking more consistent for the following repetitions thereafter.

At the second and third repetition, the testing stops at the 100-minute mark, consuming 335Wh and 345Wh measured from the AC wall watt meter, respectively. During these last two repetitions, it is recorded at the beginning that the inverter consumes 433.8W from the battery, and as the battery voltage drops the current increases to a maximum recorded value of 18.6A at 23.2V, which translates to about 3W deviation at the very end of both tests. Multiplying the power drawn from the batteries by the entire duration of the test, results in 723Wh.

For the raw data table, see Appendix A.

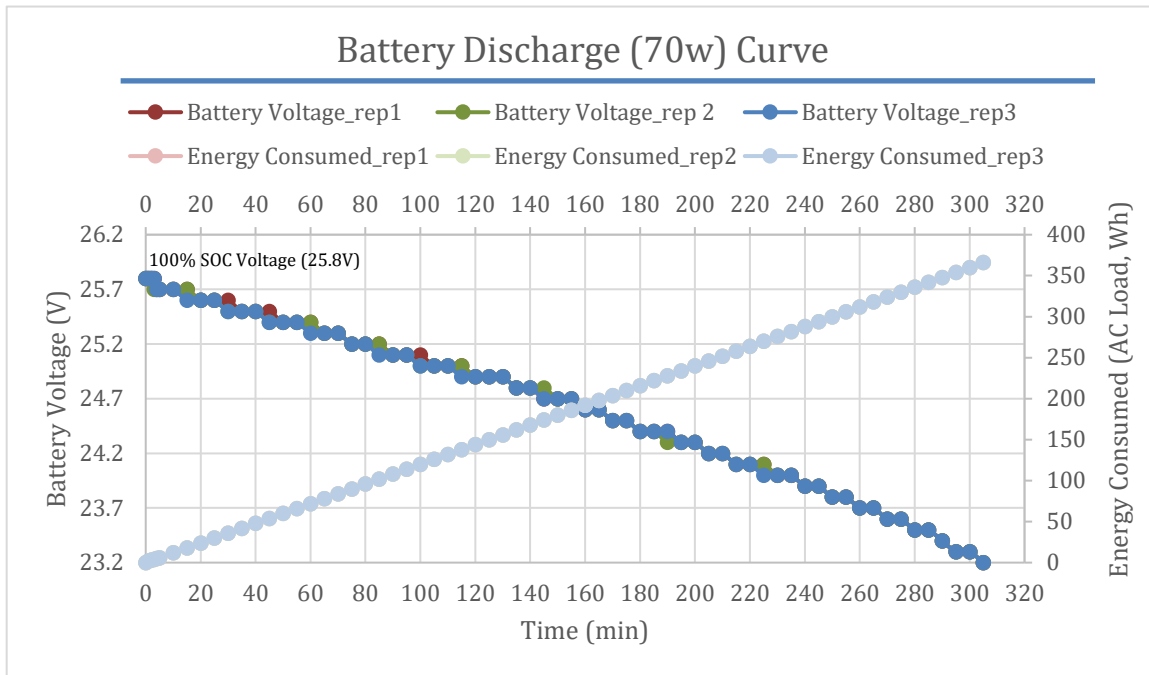


Figure 4.5: Discharge Curves for a 70W Water Bath Heater

For the 70W curve, the testing method is the same with the 200W load, except this time the load is replaced with a water heater of a small ultrasonic bath. Only the heater is turned on and the thermostat is set to highest. The current draw is confirmed to be consistent, and the water is changed every hour with cold water as it approaches 45°C. The power draw measured by the watt meter is constant at 68.8W.

For the energy consumed line, it is seen from the graph that all three repetitions are in line with each other. This is because there are no discrepancies between all repetitions. The load consumes 6Wh consistently every five minutes. As for the voltage drop data, there are only slight deviances between each repetition. This is in line with general expectation.

For the raw data table, see Appendix B.

4.4 Result and Discussion for Battery Bank Effective Capacity

The battery bank consists of four 12V12Ah VRLA battery, with groups of two batteries are connected in a series configuration, and the groups are connected together in a parallel configuration, resulting in 24V24Ah battery array, with a theoretical capacity of 576Wh. This capacity is listed on the specification datasheet with the batteries tested with a constant load with a predetermined current over 20h period. The capacity will vary whether the battery is discharged slowly over longer period of time or discharged with higher current over shorter period. See Figure 3.8 for more detailed specifications.

Based on the data collected in subchapter 4.3, at 200W load the inverter draws 433.8W from the battery for 100 minutes, and at 70W load the inverter draws 140.25W for 305 minutes. By multiplying the power drawn with the duration, it is calculated that the inverter consumed 723Wh and 712.94 Wh from the batteries respectively. These figures are higher than the theoretical battery capacity, which meets the expectation of this project.

