Advanced Testing Methods
Solar Charger Control

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Submitted by:

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4. Introduction

As the demand for sustainable energy solutions grows, solar technology has become a key component of modern energy management systems. The Solar Charger Control (SCC) project is developed to intelligently oversee the power generated by solar panels, manage the charging and discharging of battery systems, and optimize the operation of power-consuming devices such as heat pumps and lighting. Acting as a smart controller, the SCC analyzes real-time data to guide energy usage decisions that reduce costs, extend battery lifespan, and maintain overall system safety.

5. System Requirements

- **Battery Charging:**
  - Allowed if voltage < 55.1V and temperature is between 0°C and 45°C
- **Battery Discharging:**
  - Allowed if voltage > 47V and temperature between -25°C and 65°C.
  - Discharging is blocked if the battery voltage drops below 47V
- **Charge Restart Logic:**
  - Charging can resume only when the voltage crosses 51V if it previously dropped below 54.4V
- **Battery Heater Activation:**
  - Activates automatically when battery temperature is below 0°C
- **Injectors Controlled:**
  - HP, HPInjector, LightInjector1/2, BAT, BATHEAT
- **PV & Grid Interaction:**
  - PV max output: 2kW
  - Export to grid yields 0.07 €/kWh; import costs 0.40 €/kWh.

6. Feedback on Requirements

The initial requirements provide a clear functional roadmap but leave room for improvement, especially around edge cases, validation rules, and error handling. While core battery conditions and injector limits are specified, there is limited detail on:

- How to handle invalid inputs (e.g., string passed to a set_* method)
- System behavior in case of sensor failure or delayed updates
- Prioritization strategy when multiple injectors demand power simultaneously

However, some terms, such as "tbc" create ambiguity. Therefore, this key term should be clarified to ensure consistent understanding. While technical constraints like voltage and temperature limits are properly specified to ensure battery safety. But, still, there is a lack of detail on error handling and edge case behavior.

7. Impact of Failures per Component:

Test Case	Component	Failure Impact	Recommended Mitigation
test_fail_invalid_c harge_at_high_vol tage	Battery charge control	Risk of overcharging - battery damage/fire	Block charging if voltage >= 55.1V
test_fail_charge_at_cold_temperature	Battery temp safety	Cold charging - lithium plating & capacity loss	Prevent charging if temp < 0°C; enable heater if available
test_fail_discharge_overhot_battery	Discharge thermal control	Hot discharging - thermal runaway or battery failure	Block discharge if temp > 65°C
test_fail_charge_double_invalid	Combined voltage/temp check	Ignoring both limits - critical battery damage	Enforce both limits (voltage ≤ 55.1V AND temp ≤ 45°C)
test_fail_restart_before_threshold	Charge restart logic	Charging resumes too early - battery cycle inefficiency	Require voltage ≥ 51.0V before re-enabling charge after drop

Test Case	Component	Failure Impact	Recommended Mitigation
test_fail_charge_above_voltage	Battery Charge Controller	Overcharging risk - can damage the battery or cause overheating	Block charging if voltage > 55.1V
test_fail_discharge_below_voltage	Battery Discharge Logic	Deep discharge - reduces battery life and can cause failure	Block discharge if voltage < 47V
test_fail_restart_without_51v	Charging Hysteresis Logic	Charging starts too early after an undervoltage cycle damage	Enforce restart only if voltage >= 51.0V
test_fail_charge_temp_too_low	Battery Temperature Control	Charging below 0°C - lithium plating, permanent battery damage	Prevent charging if temp < 0°C; activate heater if needed
test_fail_charge_temp_too_high	Battery Temperature Control	Charging above 45°C - overheating, safety hazard	Prevent charging if temp > 45°C; trigger cooling/heating logic

8. Testing Process

8.1 Methodologies

- **Black-box Testing:** Focus on system behavior from a user input-output perspective
- **White-box Testing:** Analyze and test the internal logic flow, decision-making, and path coverage

8.2 Environment

- **OS:** Windows 11
- **Language:** Python 3.8+
- **Tools:** unittest, pytest, PyCharm, matplotlib
- **Version Control:** Git
- **Codebase:** scc.py
- **Test Suites**: test_scc_blackbox.py, test_scc_whitebox.py, run_tests_and_plot.py

9. Test Cases/Data:

Test Case ID	Test Type	Description	Pre-conditions	Test Data	Expected Result	Actual Result	Comment
TC_Black_01	Black Box	Standard charging within range	1. The system controller (scc) is initialized and in a functional state. 2. The PV input and battery status sensors are operational.	PV Power - 1500 W Battery Voltage 52.0 V Battery Temperature 25°C	The system correctly identified safe charging conditions and recommended charging by returning a positive BAT value, confirming expected behavior.	Returned a positive value greater than 0	Pass

			3. No faults or error states are present.				
TC_Black_02	Black Box	Standard discharging case	System controller initialized, sensors for PV, light level, heat pump, battery voltage, and temperature working properly, no faults present.	PV = 0, Light Level = 1000, Heatpump Level = 300, Battery Voltage = 52.0 V, Battery Temperature = 20°C	Battery output (BAT) should be greater than or equal to 0, indicating the system allows discharging or stable battery operation	Battery output (BAT) was greater than or equal to 0.	Pass
TC_Black_03	Black Box	Charging at low temperature boundary	System controller initialized, sensors for PV, battery voltage, and temperature functioning correctly, no error states.	PV = 1800, Battery Voltage = 52.0 V, Battery Temperature = 0°C.	Battery output (BAT) should be greater than or equal to 0, allowing charging at the low temperature boundary	Battery output (BAT) was greater than or equal to 0.	Pass
TC_Black_04	Black Box	Charging at high temperatu	System controller initialized, PV, battery voltage, and	PV = 1800, Battery Voltage = 52.0 V, Battery	Battery output (BAT) should be greater than	Battery output (BAT) was greater	Pass

		re boundary	temperature sensors working properly, no faults present.	Temperature = 45°C.	or equal to 0, allowing charging at the high temperature boundary	than or equal to 0.	
TC_Black_05	Black Box	Discharging at low temperature boundary	System controller initialized, sensors for PV, light level, heat pump, battery voltage, and temperature working correctly, no errors.	PV = 0, Light Level = 1200, Heatpump Level = 500, Battery Voltage = 50.0 V, Battery Temperature = -25°C.	Battery output (BAT) should be greater than or equal to 0, allowing discharging at the low temperature boundary	Battery output (BAT) was greater than or equal to 0.	Pass
TC_Black_06	Black Box	Discharging at high temperature boundary	System controller initialized, sensors for PV, light level, heat pump, battery voltage, and temperature functioning correctly, no faults detected.	PV = 0, Light Level = 1200, Heatpump Level = 500, Battery Voltage = 50.0 V, Battery Temperature = 65°C.	Battery output (BAT) should be greater than or equal to 0, allowing discharging at the high temperature boundary	Battery output (BAT) was greater than or equal to 0.	Pass

TC_Black_07	Blac k Box	Required keys present in suggestion	System controller initialized, PV, battery voltage, and temperature sensors operational, no faults present.	PV = 1000, Battery Voltage = 52.0 V, Battery Temperature = 25°C.	Suggestion result contains keys 'BAT' and 'BATHEAT'.	Suggest ion results included keys 'BAT' and 'BATHEAT'.	Pass
TC_Black_08	Black Box	Charging when net power is positive	System controller initialized, sensors for PV, light level, heat pump, battery voltage, and temperature functioning correctly, no errors.	PV = 2000, Light Level = 300, Heatpump Level = 300, Battery Voltage = 50.0 V, Battery Temperature = 20°C.	Battery output (BAT) should be greater than 0, indicating charging when net power is positive.	Battery output (BAT) was greater than 0.	Pass
TC_Black_09	Black Box	Heater should be ON below 5°C	System controller initialized, battery temperature sensor working properly, no faults.	Battery Temperature = 2°C.	Battery heater (BATHEAT) should be ON (True) when temperature is below 5°C.	Battery heater (BATHEAT) was ON (True).	Pass

TC_Black_10	Black Box	Heater should be OFF above 5°C	System controller initialized, battery temperature sensor working correctly, no faults.	Battery Temperature = 10°C.	Battery heater (BATHEAT) should be OFF (False) when the temperature is above 5°C.	Battery heater (BATHEAT) was OFF (False).	Pass
TC_Black_11	Black Box	Charging should be blocked at high voltage	System controller initialized, PV and battery sensors functioning correctly, no errors.	PV = 1800, Battery Voltage = 55.2 V, Battery Temperature = 20°C.	Battery output (BAT) should be 0, blocking charging due to high voltage.	Battery output (BAT) was 0.	Pass
TC_Black_12	Black Box	Discharging should be blocked at low voltage	System controller initialized, sensors for PV, light level, heat pump, battery voltage, and temperature working correctly, no faults.	PV = 0, Light Level = 1500, Heatpump Level = 300, Battery Voltage = 46.0 V, Battery Temperature = 25°C.	Battery output (BAT) should be 0, blocking discharging due to low battery voltage.	Battery output (BAT) was 0.	Pass

TC_Black_13	Black Box	Charging should be blocked at too low temp	System controller initialized, sensors for PV, battery voltage, and temperature working correctly, no faults.	PV = 1500, Battery Voltage = 52.0 V, Battery Temperature = -10°C.	Battery output (BAT) should be 0, blocking charging due to the temperature being too low.	Battery output (BAT) was 0.	Pass
TC_Black_14	Black Box	Discharging should be blocked at too high a temperature	System controller initialized, all sensors working correctly, no errors	PV=0, Light Level=1200, Heat pump Level=400, Battery Voltage=50.0 V, Battery Temperature =70°C	Battery output (BAT) = 0, discharging blocked due to high temperature	Battery output (BAT) = 0	Pass
TC_Black_15	Black Box	Restart blocked if voltage < 51V	System controller initialized, voltage sensor working properly	Battery Voltage first set to 54.0 V, then 50.0 V, PV=2000, Battery Temperature =25°C	Battery output (BAT) = 0, restart charging blocked due to voltage below threshold	Battery output (BAT) = 0	Pass
TC_Black_16	Black Box	PV over max is still handled	System controller initialized, PV	PV=2500 (above max), Battery Voltage=50.	Battery output (BAT)	Battery output (BAT)	Pass

			sensor functioning	0 V, Battery Temperature =25°C	capped at or below 3000	≤ 3000	
TC_B lack_ 17	Bla c k Box	Injectors are still draining power	System controller initialized, all sensors working	PV=0, Light Level=0, Heat pump Level=0, Battery Voltage=52. 0 V, Battery Temperature =20°C	HPInjecto r output is True	HPInj e ctor output was True	Pass
TC_B lack_ 18	Bla c k Box	No charging if both temp and voltage are invalid	System controller initialized, sensors working	PV=2000, Battery Voltage=56. 0 V (high), Battery Temperature =-10°C (low)	Battery output (BAT) = 0, no charging due to invalid voltage and temperature	Batter y output (BAT) = 0	Pass
TC_B lack_ 19	Bla c k Box	Chargin g should NOT happe n above 55.1V	System controller initialized, sensors working	PV=2000, Battery Voltage=56. 0 V, Battery Temperature =25°C	Battery output (BAT) = 0 (chargin g blocked)	Batter y output (BAT) > 0 (chargi ng incorre ctly allowe d)	Fail

TC_Black_20	Black Box	Charging below 0°C should fail	System controller initialized, sensors working	Battery Temperature =-5°C, PV=1500 , Battery Voltage=52.0 V	Battery output (BAT) = 0 (charging blocked below 0°C)	Battery output (BAT) > 0 (charging incorrectly allowed)	Fail
TC_Black_21	Black Box	Discharging over 65°C should fail	System controller initialized, sensors working	Battery Temperature =70°C, Battery Voltage=50 V, PV=0, Light Level=1000, Heatpump Level=200	Battery output (BAT) = 0 (discharging blocked over 65°C)	Battery output (BAT) > 0 (discharging incorrectly allowed)	Fail
TC_Black_22	Black Box	Charging at 56V and 50°C (both invalid)	System controller initialized, sensors working	PV=1500, Battery Voltage=56.0 V, Battery Temperature =50°C	Battery output (BAT) = 0 (charging blocked)	Battery output (BAT) > 0 (charging incorrectly allowed)	Fail

TC_Black_23	Black Box	Restart charging without reaching 51.0V	System controller initialized, voltage sensor working	Battery Voltage first 54.3 V, then 50.5 V, PV=1800, Battery Temperature =25°C	Battery output (BAT) = 0	Battery output (BAT) > 0	Fail
TC_White_01	White Box	Charging must be blocked above 55.1V	The system is initialized and operational. Evaluates battery output based on inputs like battery voltage, temperature, and PV power.	Battery Voltage: 55.2 V, Battery Temperature: 25 °C, Photovoltaic Power: 1500 W	The controller is expected to stop charging the battery due to over-voltage protection being triggered at or above 55.2V.	'BAT' is 0.	Pass
TC_White_02	White Box	Discharging blocked if voltage < 47V	Solar Charge Controller (scc) is initialized and functional	Battery Voltage: 46.5 V, Battery Temperature: 25 °C, PV Power: 0 W, Light Level: 800 ,Heat Pump Load: 500	'BAT '== 0 (battery output disabled due to low voltage)	'BAT' == 0	Pass

TC_White_03	White Box	Charging is not allowed until the battery reaches 51V after being <54.4V	Solar Charge Controller (SCC) is initialized. The battery was previously at high voltage (54.0V), indicating it may have triggered an over-voltage state.	Previous Battery Voltage: 54.0 V Current Battery Voltage: 50.9 V, Battery Temperature: 25 °C ,PV Power: 2000 W	'BAT' == 0 (charging should remain blocked due to hysteresis logic)	'BAT' == 0	Pass
TC_White_04	White Box	Charging resumes after reaching 51V again	Solar Charge Controller (SCC) is initialized. Battery was previously over-voltage (54.0V), then dropped to a safe level.	Previous Battery Voltage: 54.0 V, Current Battery Voltage: 51.0 V,Battery Temperature: 25 °C, PV Power: 2000 W	'BAT' > 0 (charging allowed after voltage drops to safe range)	'BAT' > 0	Pass
TC_White_05	White Box	Charging allowed at 0°C	Solar Charge Controller (scc) is initialized. System is operating at the lower safe	Battery Temperature: 0 °C Battery Voltage: 50 V	'BAT' >= 0 (charging is allowed at low but safe temperature)	'BAT' >= 0	Pass

			temperature boundary.	PV Power: 2000 W			
TC_White_06	White Box	Charging is allowed at 45°C	Solar Charge Controller (SCC) is initialized. System is operating at the upper safe temperature boundary.	Battery Temperature: 45 °C Battery Voltage: 50 V PV Power: 2000 W	'BAT' >= 0 (charging is allowed at high but safe temperature)	'BAT' >= 0	Pass
TC_White_07	White Box	Discharge blocked below -25°C	Solar Charge Controller (scc) is initialized. Battery temperature is below the safe discharge threshold.	Battery Temperature: -26 °C Battery Voltage: 50 V PV Power: 0 W	'BAT' == 0 (discharge blocked due to low temperature)	'BAT' == 0	Pass
TC_White_08	White Box	Discharge blocked above 65°C	Solar Charge Controller (scc) is initialized. Battery temperature exceeds the	Battery Temperature: 66 °C Battery Voltage: 50 V	'BAT' == 0 (discharge blocked due to high temperature)	'BAT' == 0	Pass

			safe discharge limit.	PV Power: 0 W			
TC_White_09	White Box	Net power is negative; discharging allowed	Solar Charge Controller (scc) is initialized. System must handle net power deficit correctly.	PV Power: 500 W Light Load: 1500 W Heat Pump Load: 500 W Battery Voltage: 50 V Battery Temperature: 20 °C	'BAT' >= 0 (battery should discharge to help meet the load)	'BAT' >= 0	Pass
TC_White_10	White Box	Net power is positive; charging allowed	Solar Charge Controller (scc) is initialized. System must manage surplus power correctly.	PV Power: 2000 W Light Load: 200 W Heatpump Load: 200 W Battery Voltage: 50 V Battery Temperature: 20 °C	'BAT' >= 0 (battery should charge with excess power)	'BAT' >= 0	Pass

TC_White_11	White Box	Heater ON below 5°C	Solar Charge Controller (scc) is initialized. Battery heating system is available.	Battery Temperature: 2 °C	'BATHEAT' == True (battery heater turns on below 5°C)	'BATHEAT' == True	Pass
TC_White_12	White Box	Heater OFF above 5°C	Solar Charge Controller (scc) is initialized. Battery heating system is available.	Battery Temperature: 10 °C	'BATHEAT' == False (heater off above 5°C)	'BATHEAT' == False	Pass
TC_White_13	White Box	Charging blocked at >45°C	Solar Charge Controller (scc) is initialized. Battery temperature limit for charging is enforced.	Battery Temperature: 50 °C PV Power: 1800 W Battery Voltage: 50 V	'BAT' == 0 (charging blocked due to high temperature)	'BAT' == 0	Pass
TC_White_14	White Box	Discharging blocked at < -25°C	Solar Charge Controller (scc) is initialized. Battery discharge	Battery Temperature: -30 °C PV Power: 0 W	'BAT' == 0 (discharge blocked due to low temperature)	'BAT' == 0	Pass

			temperature limit is enforced.	Light Load: 1000 W Heat Pump Load: 300 W Battery Voltage: 50 V			
TC_White_15	White Box	Net power exactly zero; no charging/discharging	Solar Charge Controller (scc) is initialized. System handles balanced power scenario.	PV Power: 1500 W Light Load: 1000 W Heat Pump Load: 500 W Battery Voltage: 0 V Battery Temperature: 25 °C	'BAT' == 0 (no battery charge or discharge needed as power is balanced)	'BAT' == 0	Pass
TC_White_16	White Box	Charge power capped at 3000W	Solar Charge Controller (SCC) initialized. The system has a defined maximum battery charge	PV Power: 5000 W (high input) Light Load: 0 W Heatpump Load: 0 W	'BAT' <= 3000 (charge limited to max allowed rate)	'BAT' <= 3000	Pass

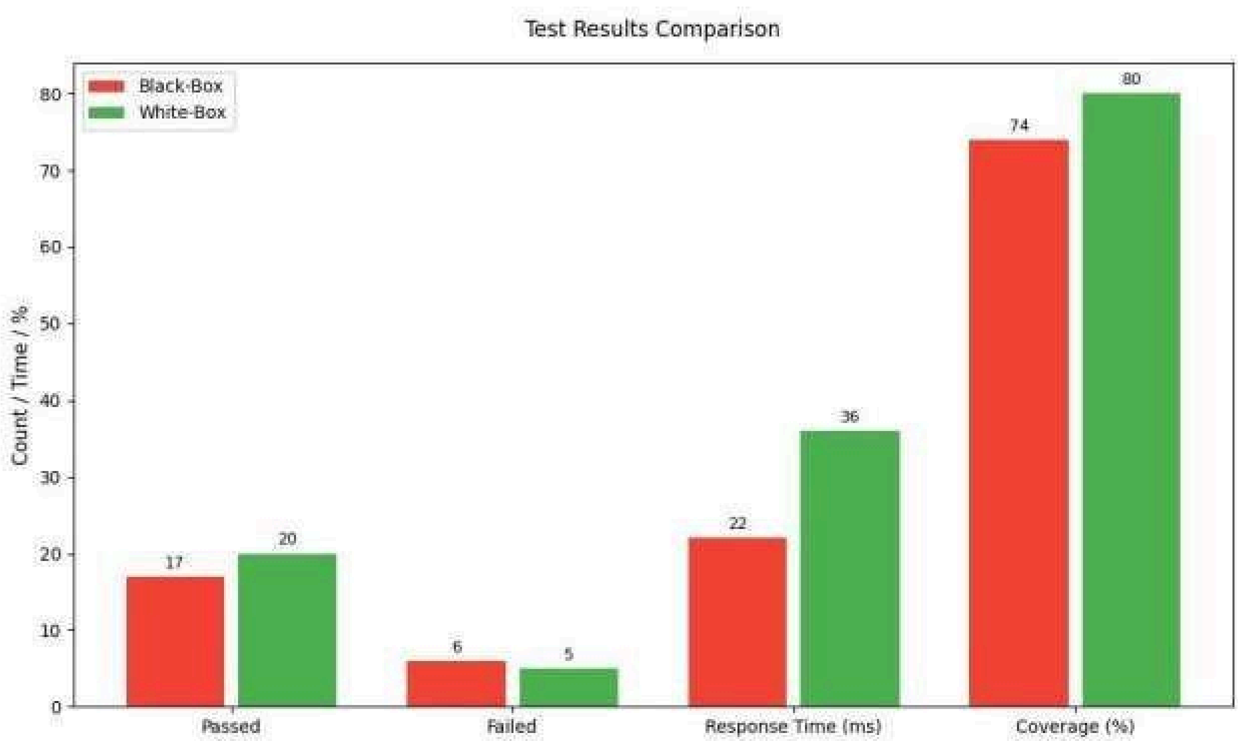
			limit (3000 units).	Battery Voltage: 50 V Battery Temperature: 25 °C			
TC_White_17	White Box	Light clamped at 1800W	Solar Charge Controller (SCC) initialized. Light power output has a maximum clamp limit.	Light Level Input: 5000	'Light' <= 1800 (light power output clamped to max allowed)	'Light' <= 1800	Pass
TC_White_18	White Box	Heat pump is clamped at 400W	Solar Charge Controller (SCC) initialized. Heat pump power output has a maximum clamp limit.	Heatpump Level Input: 800	'HP' <= 400 (heatpump power clamped to max allowed)	'HP' <= 400	Pass
TC_White_19	White Box	Normal charge scenario	Solar Charge Controller (SCC) initialized. Battery voltage and temperature	PV Power: 1500 W Battery Voltage: 52.0 V	'BAT' > 0 (charging allowed)	'BAT' > 0	Pass

			are within the normal charging range.	Battery Temperature: 25 °C			
TC_White_20	White Box	Normal discharge scenario	Solar Charge Controller (scc) initialized. Battery voltage and temperature are within the normal discharge range.	PV Power: 0 W Light Load: 1000 W Heat Pump Load: 300 W Battery Voltage: 52.0 V Battery Temperature: 25 °C	'BAT' >= 0 (discharge allowed to meet load)	'BAT' >= 0	Pass
TC_White_21	White Box	Charging should be blocked above 55.1V	Solar Charge Controller (SCC) initialized. Battery voltage above safe charging limit.	PV Power: 2000 W Battery Voltage: 56.0 V Battery Temperature: 25 °C	'BAT' == 0 (charging blocked above voltage limit)	'BAT' > 0 (charging allowed unexpectedly)	Fail
TC_White_22	White Box	Discharge should be blocked at	Solar Charge Controller	PV Power: 0 W	'BAT' == 0 (discharge blocked	'BAT' > 0 (dischar ge	Fail

		voltage < 47V	(scc) initialized. Battery voltage below safe discharge limit.	Light Load: 1000 W Heat Pump Load: 300 W Battery Voltage: 46.0 V Battery Temperature: 25 °C	below voltage limit)	allowed unexpectedly)	
TC_White_23	White Box	Charging restart not allowed until reaching 51.0V	Solar Charge Controller (SCC) initialized. Battery voltage dropped from an over- voltage state, but below the restart threshold (51V).	Previous Battery Voltage: 54.0 V Current Battery Voltage: 50.8 V PV Power: 2000 W Battery Temperature: 25 °C	'BAT' == 0 (charging blocked until voltage reaches 51V threshold)	'BAT' > 0 (charging allowed prematurely)	Fail
TC_White_24	White Box	Charging should not happen below 0°C	Solar Charge Controller (SCC) initialized. Battery temperature is near the low	Battery Temperature: -5 °C Battery Voltage: 52.0 V	'BAT' == 0 (charging blocked due to low temperature protection)	'BAT' > 0 (charging allowed despite low	Fail

			operational limit.	PV Power: 1500 W		temper a ture)	
TC_White_25	White Box	Charging should not happen above 45°C	Solar Charge Controller (SCC) initialized. Battery temperature above safe charging limit.	Battery Temperature: 46 °C Battery Voltage: 52.0 V PV Power: 1500 W	'BAT' == 0 (charging blocked due to high temperature)	'BAT' > 0 (charging allowed despite high temper a ture)	Fail

10. Metric Suggested:



The SCC system achieved around **74% test coverage** for black-box testing and **80% test coverage** for white-box testing, validating most logic paths and edge cases. In black-box testing, there are **17 passed** test cases along with **6 failed test cases**, and in white-box testing, there are **20 passed** test cases along with **5 failed** cases intentionally included to simulate real-world issues and ensure robustness. Black-box testing took **22 ms** and white-box testing took **36 ms responding time**, confirming suitability for real-time environments.

11. Milestone Plan:

Duration	Phase	Status
Week 1	Requirements Analysis, Test plan & Test environment setup	Completed
Week 2	Unit Testing, White Box Testing, Black Box Testing, and creating a bug report	Completed
Week 3	Bug Fixes, Reporting Analysis, and Final Documentation	Completed

12. Challenges (HR, IT, Project Management):

12.1 HR:

- Finding and retaining testers and developers with domain knowledge
- Providing training on specialized key domains and efficient workflows
- Hardware constraints: fostering cross-team collaboration

12.2 IT:

- Managing test automation infrastructure, especially powerful machines like laptops, computers, and CI/CD pipelines
- Ensuring the stability of a good internet connection
- Also, ensure that all necessary equipment is on the machine and working well

12.3 Project Management:

- Defining a test plan that covers all battery voltage, temperature, and power scenarios, including edge and failure cases
- Ensuring sufficiently skilled testers and test automation engineers are available throughout the project lifecycle
- Prioritizing test cases based on risk, especially safety-critical functionality, while managing limited testing time

- Also, managing the whole project till the deployment and ensuring all the defects are solved before the deployment

13. Test Environment Setup Plan/Skills:

13.1 Environment Setup:

- **Python version:** Ensure Python 3.8+ is installed (for compatibility with unittest and time)
- **Dependencies:** None external beyond standard library (unittest, time)
- **Project structure**:
    - scc.py - contains the SCC class
    - test_scc_blackbox.py - black-box test cases
    - test_scc_whitebox.py - white-box test cases
    - Run_tests_and_plot.py - generate a pie chart of all test cases

13.2 Test Framework:

- Use Python's built-in unittest framework
- Run tests using the terminal

13.3 Setup for Each Test:

- Each test creates a fresh SCC instance (setUp method)
- Input parameters set via set_PV, set_BatVoltage, set_BatTemp, set_LightLevel, and set_HeatpumpLevel methods
- Call suggest() method to get control decisions for assertions

14. Skills Required:

- Python Programming knowledge
- Unit Testing with unittest
- Testing Knowledge, e.g, White Box Testing and Black Box Testing
- Matplotlib knowledge (generate pie charts)
- Code quality tools - pytest
- Git Bash command

15. Initial Observations (on requirement review etc.):

- Due to a lack of proper knowledge on the requirements side, we couldn't add various test cases. However, it is possible to add more negative and positive test cases
- More discussion was needed to gain deeper knowledge of the given requirements
- Lack of clear acceptance criteria
- Also, it is hard to run tests without a GUI

16. Issue Tracking (as agreed with dev):

ID	Issue Title	Description	Severity	Priority	Owner	Status
001	Charging is not blocked above 55.1V	Charging continues even when the battery voltage is above 55.1V, violating safety voltage gate rules.	High	High	Dev Team	Open
002	Discharging not blocked below 47V	Discharging occurs even if the battery voltage is below 47V, violating the voltage safety threshold.	High	High	Dev Team	Open
003	Charging restart allowed below 51V	Charging restarts before battery voltage reaches 51V after dropping below 54.4V, violating hysteresis logic.	Medium	Medium	Dev Team	Open
004	Charging allowed below 0°C	Charging is allowed even when the battery temperature is below 0°C, which is unsafe for battery health.	High	High	Dev Team	Open
005	Charging is allowed above 45°C	Charging is allowed above 45°C battery temperature, violating thermal constraints for battery charging.	High	High	Dev Team	Open
006	Charging is not blocked above 55.1V	Charging occurs even when battery voltage exceeds 55.1V, violating voltage safety limits.	High	High	Dev Team	Open
007	Charging allowed below 0°C	Charging is allowed even if the battery temperature is below 0°C, risking battery damage in cold conditions.	High	High	Dev Team	Open

008	Discharging allowed above 65°C	Discharging is allowed even when the battery temperature exceeds 65°C, violating thermal safety limits.	High	High	Dev Team	Open
009	Restart charging allowed before 51.0V	Charging restarts before battery voltage reaches 51.0V after dropping, ignoring the hysteresis requirement.	Medium	Medium	Dev Team	Open

17. Conclusion

In conclusion, the Solar Charger Control (SCC) project has demonstrated significant progress in ensuring the safety and reliability of solar energy management through rigorous testing methodologies. Moving forward, it is imperative to prioritize defect resolution for all safety-critical functionalities to prevent potential system failures. Continuous collaboration between testers and developers will be essential for efficiently addressing outstanding issues and maintaining test coverage. Re-testing previously failed scenarios after bug fixes will validate corrective actions, while active monitoring and documentation will help identify any emerging defects. Once these steps are complete, a final validation phase will ensure the system meets all functional and safety requirements, paving the way for a secure and successful deployment.

GitHub link of our project:

https://github.com/Rakibul-cyber/solar-charger-control-testing-methods/tree/main/__pycache__