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A Project Report

on

Cost Analysis of Installing Photovoltaic System for Battery Swapping charging Station using RET-Screen Expert

In partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY (B. TECH)

IN

ELECTRICAL ENGINEERING

Submitted by:

Krishnakant kurmi (0901EE191059)

MADHAV INSTITUTE OF TECHNOLOGY & SCIENCE

GWALIOR, M.P. - 474005

(*A Govt. Aided UGC Autonomous & NAAC Accredited Institute, Affiliated to RGPV Bhopal*)

MAY 2022

CANDIDATE'S DECLARATION

I/We hereby declare that the project titled **"Cost Analysis of Installing Photovoltaic System for Battery Swapping charging Station using RET-Screen Expert"** submitted for the award of **Bachelor of Technology** degree in **Electrical Engineering** is my original work and the project has not been submitted elsewhere for the award of any other degree, diploma, fellowship, or any other similar titles.

Krishnakant kurmi (0901EE191059)

Place: Gwalior

Date:24/5/2023

This is to certify that the above statement made by the candidate is correct to my knowledge and belief.

Guided By

Dr. Yashwant Sawle
Assistant Professor
Dept. of EE
MITS, Gwalior

Approved By

Dr. Sulochana Wadhwani
Prof. & Head, EED
MITS, Gwalior

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I am extremely grateful to my department staff members and friends who helped me in successful completion of this internship.

Date: 24/5/2023 **krishnakant kurmi**

Place: Gwalior **0901EE191059**

ABSTRACT

The pressure of the energy crisis and environmental pollution has given electric vehicles (EV) more prospects for growth in recent years. These vehicles are currently best solution over convention vehicle because of less carbon emission and more economic efficiency. But the lack of charging station and time-consuming charging method is the main concern. This report provides a comprehensive cost analysis of implementing photovoltaic (PV)-based battery swapping stations for electric vehicle (EV) integration. With the growing adoption of EVs in India, it is crucial to address the challenge of longer charging times compared to traditional refueling. Battery swapping stations offer a promising solution by enabling the exchange of depleted EV batteries for fully charged ones. This report focuses on assessing the financial aspects of installing PV systems in battery swapping stations to overcome this obstacle. The report explores each cost factor in detail, considering initial investment, lifecycle costs, and potential cost savings associated with PV energy utilization. It also examines the financial viability and return on investment (ROI) of PV-based battery swapping stations, taking into account potential revenue streams such as battery swapping fees and renewable energy incentives. This report provides valuable guidance for stakeholders interested in installing PV modules for battery swapping stations. By utilizing the RETScreen Expert software, it offers a comprehensive understanding of the associated expenses. The findings contribute to the knowledge base on battery swapping stations and highlight the potential for cost savings and environmental benefits. This analysis encourages further research and development in PV-based battery swapping stations to accelerate the transition towards sustainable transportation.

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LIST OF ABBREVEATIONS

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1. EVs – Electric Vehicles
2. BSS – Battery Swapping Station
3. PV – Photo voltaic
4. 2-W – 2-Wheeler
5. 3-W – 3-Wheeler
6. 4-W – 4-Wheeler
7. NPV – Net Present value
8. CEA – Central Electrical Authority
9. GHG – Green House Gas

INTRODUCTION

In the modern era, there is a growing demand for safe and environmentally friendly transportation options. Electric vehicles (EVs) have emerged as a viable solution to address the issues associated with internal combustion engines (ICE), such as harmful gas emissions and contribution to global warming. Governments worldwide, including India, are actively promoting EV adoption through incentives and targets for market penetration.

However, the lack of a robust charging infrastructure hinders widespread EV adoption. Limited availability of charging stations undermines the confidence of individuals in switching to electric vehicles. To overcome these limitations, battery swapping is an efficient solution where depleted batteries can be swiftly exchanged with fully charged ones. This significantly reduces charging time compared to plug-in charging methods. To support the battery swapping infrastructure, a grid-connected photovoltaic system can be installed at the charging stations. This allows for efficient energy utilization, with excess power fed back to the grid and additional power drawn when needed. To assess the feasibility and financial viability of implementing such a charging infrastructure, this research paper calculates the projected cost of installing photovoltaic modules using the RETScreen Expert software.

The findings of this cost analysis will provide valuable insights into the economic aspects of PV-based battery swapping stations. This will facilitate informed decision-making, promote sustainable transportation solutions, and contribute to the understanding of the benefits of integrating photovoltaic systems in charging infrastructure.

CHAPTER I: Case Study

1.1 Statement of problem

The lack of a robust charging infrastructure poses a significant challenge to the widespread adoption of electric vehicles (EVs). Insufficient availability of charging stations and limited charging capacities make it difficult for individuals to confidently switch to EVs. This creates range anxiety and limits the convenience and practicality of owning an electric vehicle. To accelerate EV adoption, it is crucial to address this problem by establishing a comprehensive and reliable charging infrastructure that includes an adequate number of charging stations with diverse charging capacities. This would provide EV owners with convenient access to charging facilities, enhance their confidence in EV usage, and contribute to the transition towards sustainable transportation.

1.2 Purpose of Study

The purpose of this study is to assess the financial implications and feasibility of implementing photovoltaic (PV)-based battery swapping stations for electric vehicle (EV) charging infrastructure. The study aims to analyze the cost factors involved in installing PV systems, such as transportation costs, development costs, PV procurement costs, inverter replacement costs, and operation and maintenance expenses. By utilizing the RETScreen Expert software, the study will provide valuable insights into the financial viability and return on investment (ROI) of PV-based battery swapping stations. The study helps us fill gaps in what we already know, investigate connections between different factors, test ideas we have, or come up with practical solutions to real-world problems.

1.3 Description of Terms

Battery Swapping - Battery swapping is a logistical process that involves the efficient and expedient exchange of depleted batteries in electric vehicles (EVs) or other battery-powered devices with fully charged batteries. It is a methodical procedure designed to minimize the time required for recharging and maximize the availability and usability of EVs.

Photovoltaic technology – PV technology refers to a sophisticated device utilized for the purpose of harnessing sunlight and converting it into electricity. This renewable energy technology operates on the principle of the photovoltaic effect, which involves the interaction of photons, which are discrete energy packets present in sunlight, with a semiconductor material.

When photons strike the surface of the semiconductor material, they impart sufficient energy to liberate electrons, resulting in the creation of an electric field across the material. As a consequence, these freed electrons are set into motion, generating an electric current. This conversion process, known as the photovoltaic effect, enables the PV device to transform solar radiation directly into usable electrical energy.

RETScreen Software - RETScreen Expert is a widely used international software developed by Natural Resources Canada. It serves as a decision support tool for modeling and analyzing clean energy projects. With availability in multiple languages and a user base of over 420,000 in 222 countries, RETScreen Expert offers a range of features for project evaluation and planning. It aids in site selection by providing climate data using ground or NASA satellite data. Users can input various parameters such as technology type, fuel selection, and financial parameters to perform detailed cost and emission analyses. With its comprehensive functionality, RETScreen Expert assists users in assessing the feasibility and financial viability of clean energy projects.

CHAPTER II: Conceptual Framework

2.1 Physiology of Problem

The physiology of the problem lies in the harmful emissions generated by internal combustion engines (ICE) used in conventional transportation. The combustion of fossil fuels in ICE vehicles releases toxic gases such as carbon monoxide and carbon dioxide, contributing to global warming. This poses a threat to the environment and human health. The physiology aspect emphasizes the need to transition to electric vehicles (EVs), which operate using electricity and produce zero tailpipe emissions. By adopting EVs, we can mitigate the adverse physiological effects of air pollution and reduce our carbon footprint.

2.2 Sociology of Problem

The sociology of the problem revolves around the societal challenges associated with the inadequate charging infrastructure for EVs. The lack of accessible and sufficient charging stations hinders the widespread adoption of EVs. This creates barriers for individuals who wish to switch to electric vehicles, leading to range anxiety and a reluctance to invest in EV technology. The sociology aspect highlights the importance of timely implementation of EV charging infrastructure to support the transition towards electric mobility. By addressing this social challenge, we can promote EV adoption, reduce dependence on fossil fuels, and create a sustainable transportation system that benefits society as a whole.

CHAPTER III: Methodology

The methodology employed in this report involves the utilization of RET-Screen Expert software, a powerful tool developed by the Government of Canada for evaluating the technical and financial feasibility of renewable energy projects. RET-Screen Expert integrates various modules and algorithms to assess the potential of PV installations, calculate energy production, and estimate project costs.

3.1 Site Selection:

The first step in the methodology is to identify and select a suitable location for the battery swapping charging station. Factors such as solar resource availability, land availability, proximity to electrical grid infrastructure, and local regulations are taken into consideration during the site selection process. RET-Screen Expert provides databases and tools to assist in this stage, ensuring the selection of an optimal site for the PV system.

3.2 Climate Data Analysis:

Accurate climate data is crucial for assessing the performance and energy production of the PV system. RET-Screen Expert allows for the integration of ground-based analysis data or data obtained from reliable sources like NASA satellites. Parameters such as air temperature, humidity, solar radiation, atmospheric pressure, wind speed, earth temperature, and heating/cooling degree-days are considered to determine the site-specific solar resource potential.

3.3 Technical Viability:

The technical viability of the PV system is evaluated based on several technical parameters. RET-Screen Expert considers factors such as solar collector efficiency factor, solar technology, and solar tracking mode. In this study, the fixed solar tracking mode is selected due to its cost-effectiveness and simplified components. The slope angle of the solar panel, optimized to maximize solar radiation absorption throughout the year, is determined based on the sun's path. The azimuth angle, representing the orientation of the solar panels, is set at 0°.

3.4 Financial Analysis:

The financial analysis is conducted to evaluate the economic sustainability of the PV-based battery swapping charging station. RET-Screen Expert incorporates various financial parameters such as inflation rate, debt ratio, debt equity, and debt interest rate. The analysis includes the cost of transportation, infrastructure, labor, and other project-specific expenses. Key financial indicators such as internal rate of return, net present value, benefit-cost ratio, simple payback period, and annual life cycle savings are calculated using the software's financial worksheets.

3.5 Cost Analysis:

The cost analysis section of the methodology focuses on assessing the different cost components involved in installing the PV system. It considers costs related to transportation, development, PV purchasing, inverter replacement, and operation and maintenance. Detailed cost calculations are performed, taking into account market prices of PV modules, labor costs, and miscellaneous expenses. The analysis also incorporates potential subsidies and the impact of debt terms on the overall cost structure.

3.6 Sensitivity Analysis:

A sensitivity analysis is conducted to evaluate the project's response to changes in key parameters. RET-Screen Expert enables variations in parameters such as electricity export rate, initial investment, and debt interest rate to assess their impact on financial indicators and energy production costs. This analysis provides insights into the project's resilience and flexibility under different scenarios.

3.7 Risk Analysis:

The risk analysis stage assesses uncertainties associated with the PV-based charging station project. RET-Screen Expert employs a Monte Carlo simulation technique, running 5000 iterations, to recalculate the energy production cost. The impact graph and distribution graph generated by the software illustrate the relationship between parameter variations and changes in energy production costs. The analysis considers a risk threshold of 20% and identifies the lower 10% and higher 10% values, ensuring a robust evaluation of project risks.

CHAPTER IV: Outcome and Discussion

4.1 Outcome

The Outcome of this report reveal the financial parameters and cost analysis associated with the proposed project. The RETScreen Expert software facilitates the inclusion of important financial factors such as inflation rate, debt ratio, debt equity, and debt interest rate, which contribute to the practicality of the project proposal. The values for these parameters can be obtained either from the software's calculations or manually inputted based on specific project data. The economic analysis considers various costs, including transportation, infrastructure, and labor, ensuring a comprehensive assessment. Based on the provided values, the study calculates essential financial indicators such as the internal rate of return, net present value, benefit-cost ratio, and the annual life cycle of the plant. Additionally, the simple payback period, indicating the time required for the system to generate a return on the initial investment, is determined.

In terms of costing, the estimated cost of the project encompasses different components. Feasibility study expenses for the chosen location account for 0.95% of the total cost, while development costs, including materials and labor, represent 1.9% of the initial cost. The setup and wiring carried out by a technical team amount to 1.9% of the total initial cost. The panels themselves, requiring 6 units priced at Rs 80,000 per panel, constitute the majority of the cost at 94.3% of the total. Miscellaneous expenses make up the remaining 0.95%. Regarding revenue and savings, the project's annual costs, which include operation and management expenses, are minimal due to the fixed orientation of the system. Government subsidies, along with a debt term of 10 years and an annual payment, help cover the initial cost. Inverter replacement, conducted periodically, incurs an approximate annual cost. Moreover, with the export of electricity to the grid, the project is estimated to generate revenue/savings of Rs 65,948.

The findings indicate a simple payback period of 8.3 years and an equity payback period of 8.5 years based solely on the export of electricity. The net present value of the project is calculated at Rs 2,57,500, indicating its economic viability. The project also yields an annual life cycle saving of Rs 26,215, and the benefit-cost ratio is determined to be 4.3, demonstrating favorable financial returns.

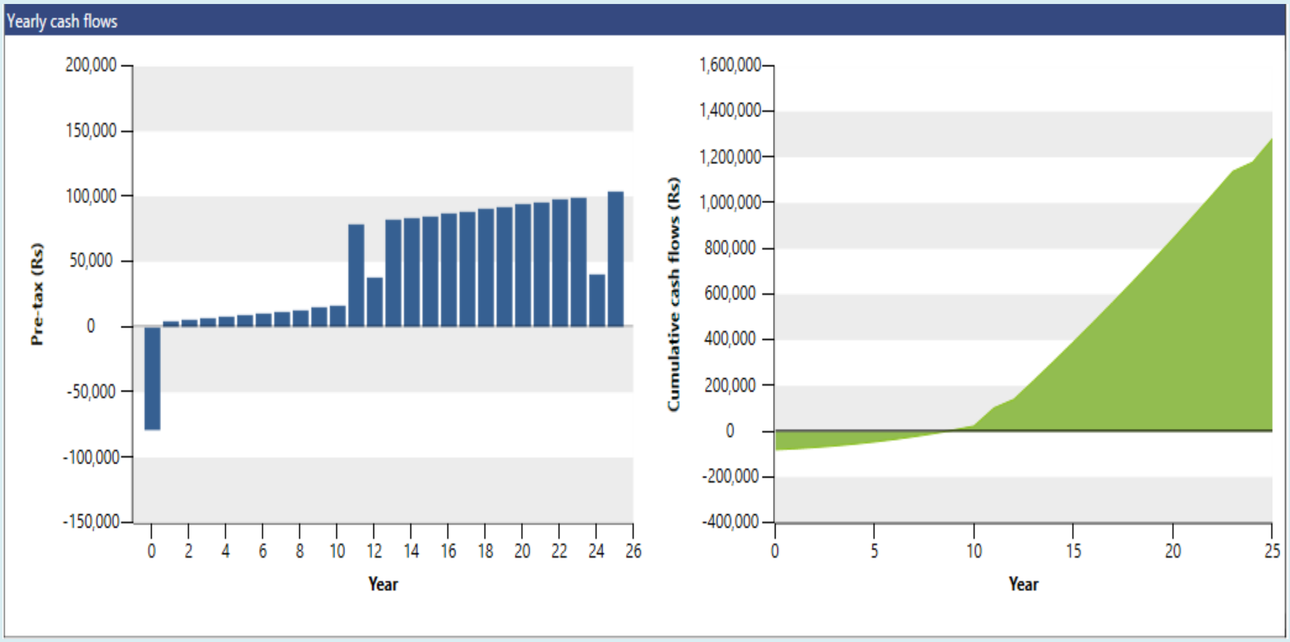


Fig. 1. Yearly Cash Flow

Table 1. Financial input variable

Financial Parameters	Value	Unit
Inflation rate	3	%
Discount rate	9	%
Reinvestment rate	6	%
Project life	25	Year
Debt ratio	85	%
Debt interest rate	6	%
Debt term	10	Year
Debt payment	60,839	Rs
Electricity export rate	7	Rs/kWh
Electricity export escalation rate	2	%
Total Initial cost	5,26,800	Rs
Operation and Maintenance Cost	2,174	Rs
Total Annual cost	63,012	Rs

Table 2. Financial output variable

Financial Viability	Value	Unit
Internal rate of return		
Net Present Value	257,302	Rs
Annual life cycle saving	26,215	Rs/year
Benefit-cost (B-C) ratio	4.3	
Debt service charge	1.1	
Energy production Cost	5.63	Rs/kWh

4.2 Emission reduction

In order to evaluate the environmental impact of implementing the solar module, an emission analysis worksheet is employed to quantify the reduction in greenhouse gas (GHG) emissions. For the Indian region, the GHG emission factor (excluding transmission and distribution losses) is established as 0.856 kgCO2/kWh, with a base case emission factor of 8.063 tCO2/kWh. By inputting relevant parameters into the software, the gross annual GHG emission reduction specific to the project location can be accurately determined. It is important to emphasize that this analysis focuses solely on the operational period of the project and does not encompass its entire life cycle. In this particular case, the project yields a substantial reduction of 8.1 tCO2.

India has set a commendable target of installing 500 GW (gigawatts) of renewable energy capacity by 2030, as outlined by the Committee constituted by the Central Electricity Authority (CEA). The implementation of this project contributes significantly to the nation's efforts in achieving this ambitious goal. Moreover, RETScreen offers the potential for generating revenue through carbon trading by capitalizing on the GHG reduction achieved. This enables investors to generate additional income by selling the emission reductions attained. The scalability of the plant further enhances the reduction of carbon footprints, opening avenues to attract potential customers interested in procuring carbon credits.

4.3 Sensitivity analysis

Sensitivity analysis is a valuable technique used to assess the potential impact of varying values for an independent variable on a dependent variable. It allows us to understand how changes in input variables can affect the uncertainty of derived financial data, thereby quantifying the level of project uncertainty during analysis.

In the case of our project, the initial cost estimation stands at Rs. 5,26,800. However, conducting sensitivity analysis reveals that a 30% increase in the initial cost would result in a higher value of

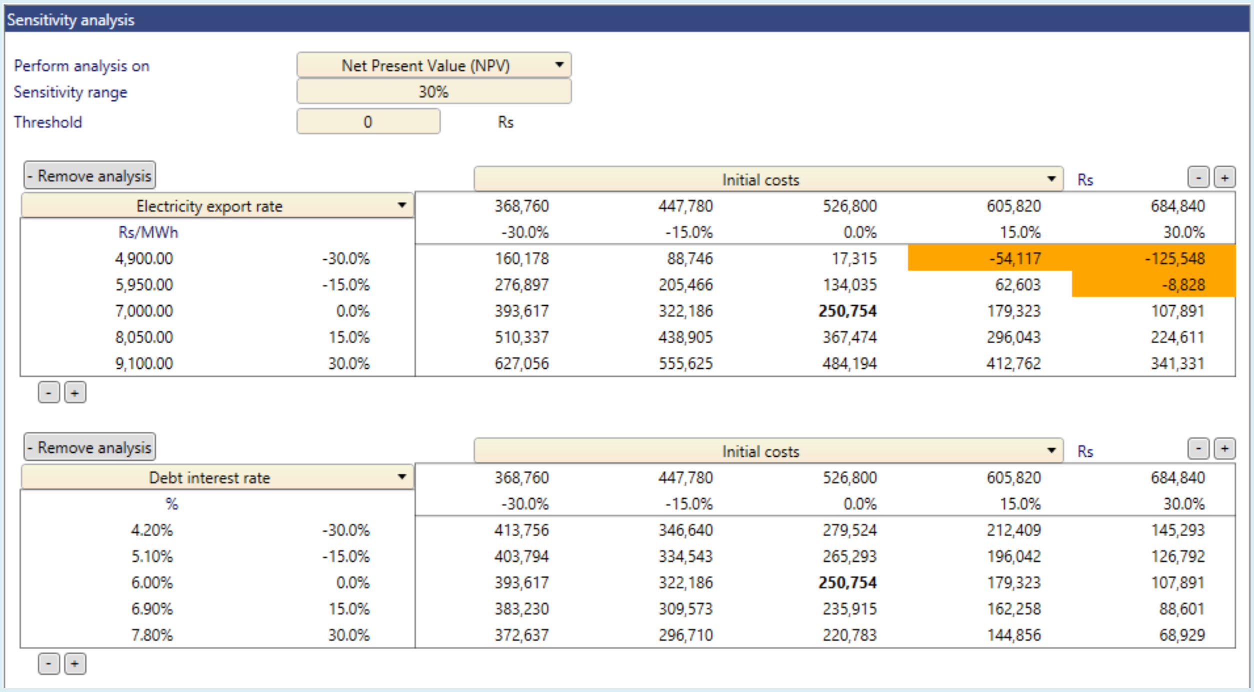
Rs. 6,84,840, while a 30% decrease would reduce it to Rs. 3,68,760. This demonstrates the range of possible cost scenarios and highlights the importance of careful cost estimation. Similarly, the rate of electricity export to the grid, which currently stands at Rs. 5,26,800, is also subject to sensitivity analysis. A 30% variation in this rate can lead to either an increase to Rs. 6,84,840 or a decrease to Rs. 3,68,760. This analysis underscores the significance of accurately projecting electricity export revenues for the financial success of the initiative.

Furthermore, the sensitivity analysis reveals that the Net Present Value (NPV) is more sensitive to fluctuations in the electricity export rate than to changes in the initial investment or the debt interest rate. This finding emphasizes the need for precise forecasting and monitoring of the electricity export market to ensure the financial viability of the project. By conducting sensitivity analysis, we gain insights into the potential impact of different variables on the project's financial performance. This knowledge enables us to make informed decisions and develop strategies to mitigate risks and optimize the project's outcomes.

4.4 Risk Analysis

Prior to implementing solar energy projects, a rigorous risk analysis is conducted to assess and anticipate uncertainties, similar to sensitivity analysis. However, risk analysis differs from sensitivity analysis in that it considers the interactions and variations of all parameters within a specific range. In this study, the RETScreen software employs a Monte Carlo simulation technique, performing 5000 simulations to recalibrate the energy production cost. The outcomes are presented through an impact graph and a distribution graph. The impact graph reveals that changes in different parameters directly influence the cost of energy production. While both the amount of electricity sent to the grid and the rate of electricity export significantly impact the project, they have opposing effects on the initial cost. An increase in power export to the grid reduces energy production costs, whereas a rise in electricity import rates elevates production expenses. To establish a risk threshold at 20%, the distribution graph excludes the lower 10% and higher 10% values that extend beyond the 90% confidence level.

Given the energy production cost of Rs. 4,07,338 per kilowatt hour, which closely aligns with the actual cost of energy at Rs. 2,49,806 per kilowatt hour, the project demonstrates feasibility and bankability. The comprehensive risk analysis provides valuable insights into the project's financial viability and substantiates its potential for successful implementation.



Sensitivity analysis

Perform analysis on: Net Present Value (NPV)
Sensitivity range: 30%
Threshold: 0 Rs

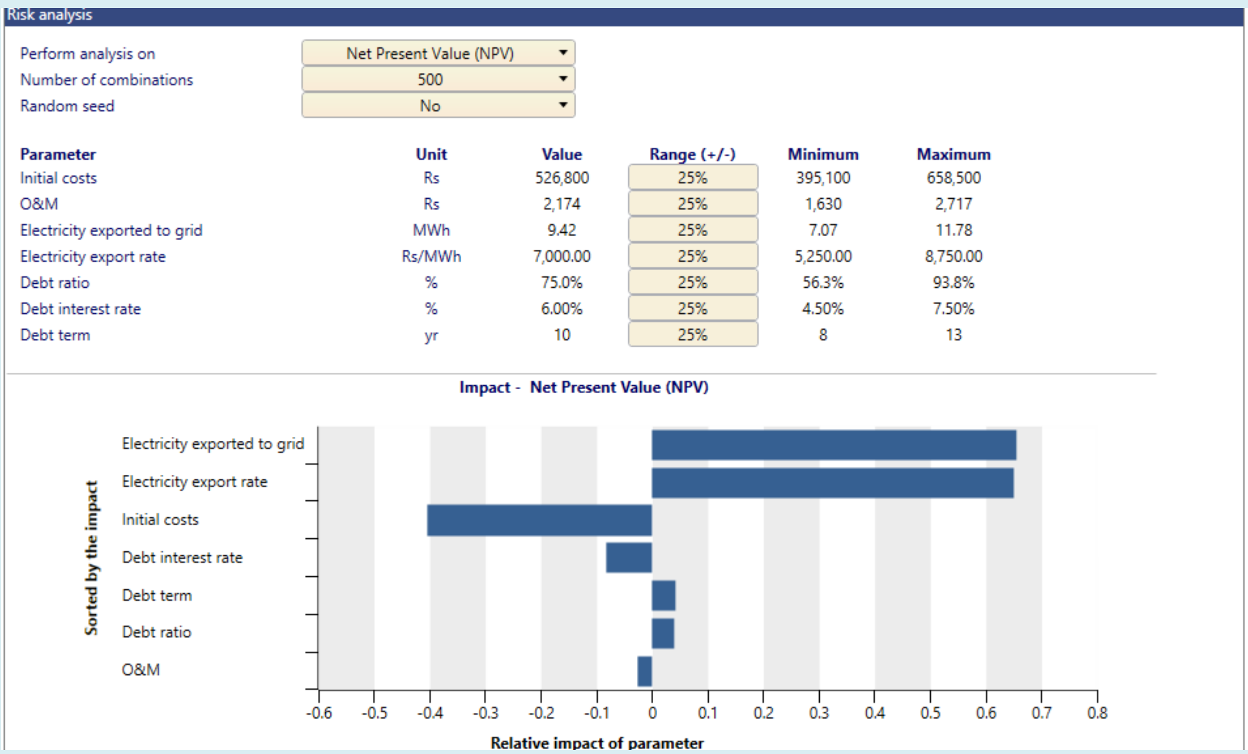
- Remove analysis

Electricity export rate		Initial costs (Rs)				
		368,760	447,780	526,800	605,820	684,840
Rs/MWh		-30.0%	-15.0%	0.0%	15.0%	30.0%
4,900.00	-30.0%	160,178	88,746	17,315	-54,117	-125,548
5,950.00	-15.0%	276,897	205,466	134,035	62,603	-8,828
7,000.00	0.0%	393,617	322,186	**250,754**	179,323	107,891
8,050.00	15.0%	510,337	438,905	367,474	296,043	224,611
9,100.00	30.0%	627,056	555,625	484,194	412,762	341,331

- Remove analysis

Debt interest rate		Initial costs (Rs)				
		368,760	447,780	526,800	605,820	684,840
%		-30.0%	-15.0%	0.0%	15.0%	30.0%
4.20%	-30.0%	413,756	346,640	279,524	212,409	145,293
5.10%	-15.0%	403,794	334,543	265,293	196,042	126,792
6.00%	0.0%	393,617	322,186	**250,754**	179,323	107,891
6.90%	15.0%	383,230	309,573	235,915	162,258	88,601
7.80%	30.0%	372,637	296,710	220,783	144,856	68,929

Fig. 2. Sensitive analysis of Photovoltaic Module used for Battery Swapping



Risk analysis

Perform analysis on: Net Present Value (NPV)
Number of combinations: 500
Random seed: No

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Initial costs	Rs	526,800	25%	395,100	658,500
O&M	Rs	2,174	25%	1,630	2,717
Electricity exported to grid	MWh	9.42	25%	7.07	11.78
Electricity export rate	Rs/MWh	7,000.00	25%	5,250.00	8,750.00
Debt ratio	%	75.0%	25%	56.3%	93.8%
Debt interest rate	%	6.00%	25%	4.50%	7.50%
Debt term	yr	10	25%	8	13

Fig. 3. Impact Graph of Risk analysis of Photovoltaic Module used for Battery Swapping

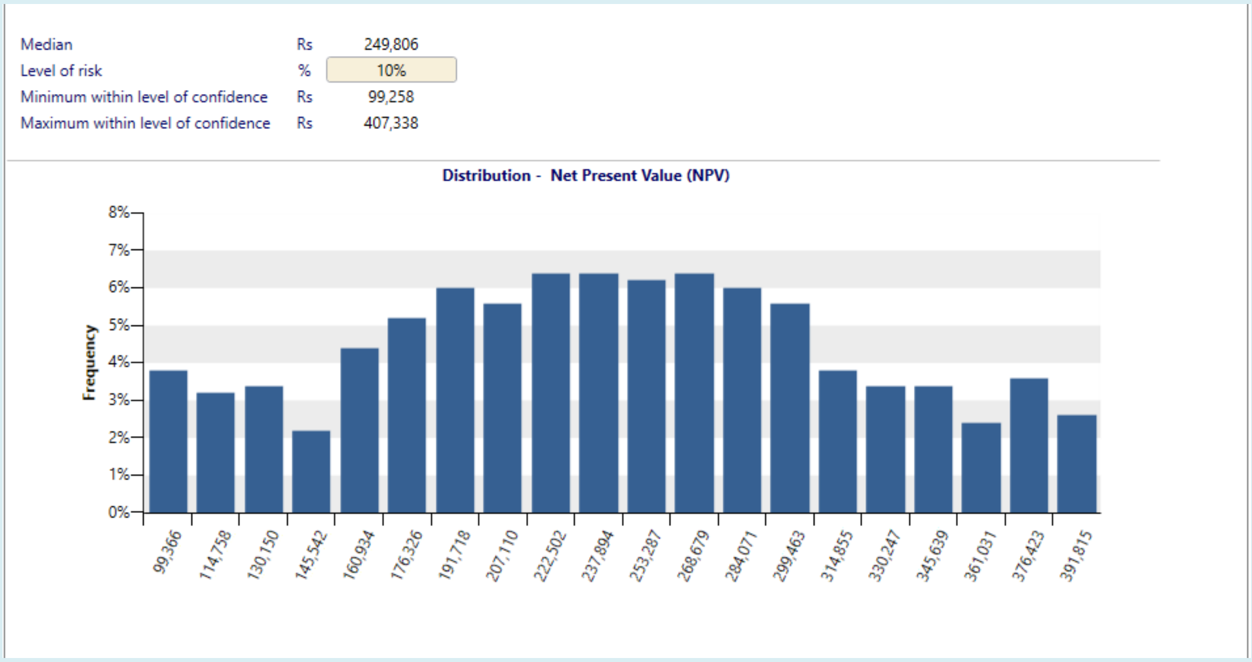


Fig. 4. Distribution Graph of Risk analysis for Photovoltaic Module used for Battery Swapping

CHAPTER V: CONCLUSION

This study has examined the viability of installing a PV-based battery swapping station, with a focus on cost analysis. The benchmark costs for grid-tied PV systems have been determined, considering both the regular and special category states/UTs. The climate data for the selected location has been collected through the RETScreen software, which will aid in assessing the technical sustainability of the project. Economic sustainability has also been evaluated, taking into account factors such as inflation rate, debt ratio, and financial parameters provided by RETScreen.

The costing, saving, and revenue aspects of the project have been thoroughly discussed, encompassing the initial costs, annual costs, subsidies, and potential electricity export revenue. Sensitivity analysis has been conducted to understand the impact of varying input parameters on financial data, while risk analysis has been employed to assess the level of uncertainty in the project. The findings indicate that the project is financially feasible and bankable, with a favorable Net Present Value (NPV) and a benefit-cost ratio of 4.3.

The cost associated with charging the batteries in a standard battery swapping station is significantly higher compared to utilizing a PV-based battery swapping station. The use of photovoltaic technology allows for harnessing solar energy to charge the batteries, eliminating or reducing the need for grid electricity consumption. This cost advantage enhances the economic feasibility and attractiveness of PV-based battery swapping stations as a sustainable and cost-effective alternative. Secondly, the reliability of the PV-based battery swapping station is notably higher compared to a standard battery swapping station. While a standard station relies solely on the grid for power supply, the PV-based station incorporates both the grid and solar energy generated by PV modules. This dual power source adds an extra layer of reliability, reducing dependence on the grid and enhancing the station's resilience against power outages or disruptions. Consequently, the integration of PV technology enhances the overall reliability and stability of the battery swapping station.

Overall, this study provides valuable insights for those considering the installation of PV modules for battery swapping stations. The research highlights the importance of technical and economic sustainability, emphasizing factors such as solar technology, solar tracking mode, and cost considerations. By comprehensively examining the costs, savings, and revenue potential, this study contributes to a broader understanding of the financial implications associated with PV-based battery swapping stations.

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