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**Optimal Location and Sizing of battery-coupled Solar PV System for Electric
Vehicle Charging Station in Radial Distribution System: A Case Study of Byasi**

Feeder

by

Tilak Giri

A THESIS

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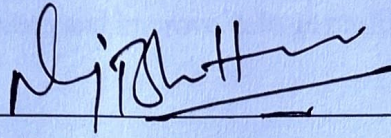
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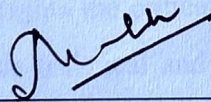
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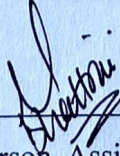
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ABSTRACT

This study examines the challenges of unplanned electric vehicle charging station (EVCS) integration in radial distribution systems (RDS), including voltage instability, power losses, and overloads. To mitigate these issues, it proposes an optimized solar PV-battery storage (PV-BESS) solution using a multi-objective particle swarm optimization (PSO) algorithm to minimize losses and improve voltage profiles while ensuring cost-effectiveness.

Tested on the IEEE 33-bus system and Nepal's Byasi feeder, the approach significantly enhances performance: minimum bus voltage improves by 2.57% (0.9404 to 0.9646 p.u.), and active power losses drop by 56.18% (477 kW to 209 kW) with 2576 kW PV and 1311 kW BESS. Peak demand reduces by 17.4% (morning) and 38.3% (evening), flattening the load curve. Financial analysis shows a nine-year payback period. The study emphasizes balancing technical and economic factors via weighting in optimization and suggests future research on power quality impacts using dynamic load analysis and hybrid algorithms.

Keywords: Battery-coupled Solar PV; Electric vehicle charging station; Power loss; PSO; Voltage deviation; Weighting factors.

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
BESS	Battery Energy Storage System
CC	Constant Current
CV	Constant Voltage
DC	Direct Current
DG	Distributed Generations
DSO	Distributed System Operator
EMS	Energy Management System
ESS	Energy Storage System
EV	Electric Vehicle
EVCS	Electric Vehicle Charging Station
FCS	Fast Charging Station
GHG	Green House Gas
IEEE	Institute of Electrical and Electronic Engineers
kW	Kilowatt
MATLAB	MATrix LABoratory
MW	Megawatt
NEA	Nepal Electricity Authority
OF	Objective Function
PLRI	Power Loss Reduction Index
PSO	Particle Swarm Optimization
PV	Photovoltaic
RER	Renewable Energy Resource
SOC	State of Charge
SOH	State of Health
VDIRI	Voltage Deviation Index Reduction Index

CHAPTER ONE : INTRODUCTION

1.1. Background

In recent years, the consumption of energy has been increasing significantly as people are getting rich and population has been increasing significantly. Power generation has greater dependency on fossil fuel-based energy sources which is causing severe environmental hazards like greenhouse gas (GHG) emission and global warming. Because of these issues, Nepal is already suffering from problems like extreme weather, food supply disruptions, melting snows and so on. In order to get rid of these problems, best way is to electrify the transportation sector with the incorporation of renewable energy resources (RERs) as transport sector shares the greatest portion. The International Energy Agency projects that by 2070, the demand for passenger and freight aviation will triple, car ownership rates will rise by 60%, and global transport will double (Ritchie, 2020). Taken together, these factors would lead to a significant increase in transportation emissions.

RERs are widely available low-to-zero GHG emissions rate and can be harness through naturally existing energy flux i.e. free of cost and non-depleting in nature like Solar irradiance, wind velocity, marine waves and many other resources. With the advancement of the technology in the field of power electronics devices, control and monitoring technologies, harnessing of energy using RERs technologies have made more profitable and viable. Nowadays, adoption rate of Electric Vehicles (EVs) has been increasing drastically because of increasing GHGs and uncertainties in the petroleum products cost. With the increase in the number of the EVs on the road, the installation of EVCSs have been increasing tremendously. However, in the context radial distribution system (RDS), EVCSs located at the farthest point from the supply end could suffer from low voltage issue which may force the charger to withdraw more current from the supply to maintain consistent power supply that leads to more power loss resulting reduced efficiency. Apart from that, low voltage slower down the charging speed of the EVs and may damage the charging equipment. To overcome these issues, nowadays renewable energy integrated EV charging station has been gaining popularity as it simultaneously addresses the issues of low voltage, power loss, environmental degradation and burden on the public utility grid. In spite of that, intermittent characteristic and primary level technology development of RERs are challenging

factors for capturing sufficient energy with the minimal cost of investment. Many researchers are involved on attaining better solution by developing hybrid energy system through integration of many RERs and energy storage system (ESS). Currently, grid connected renewable energy (RE) especially PV based energy system has been widely adopting as it can provide a number of advantages, including reactive power supply, load sharing, peak power shaving, harmonic correction, and powering important loads while grid power is unavailable. ESS integrated power system mitigates the intermittence energy production of RERs, thus enhanced the availability of the energy and helps to control the power flow within the power system components. More than that, integrated PV in the RDS anticipated and lessen the high electricity cost during peak demand periods.

Nepal Electricity Authority (NEA) has already inaugurated 51 fast charging station (FCS) simultaneously throughout the country at the prime locations with the aim of electrifying the transportation sector. Apart from that, 11 stations are under installation process along with different private sectors are also engaged in the same task at different locations across the country. With the integration of charging station in the grid, it will definitely suffer from problems like power loss, voltage instability, over-loading of the transformer and so on. In NEA's vision for future charging station, it emphasized on propelling the nation towards sustainable and electrify future with the installation of robust charging station network supported by Solar PV and Battery Energy Storage System (BESS) (NEA, 2023). NEA is the sole entity of distribution system expansion, operation and maintenance in Nepal hence, NEA must be aware on the integration of renewable sources of energy in the grid considering the loading condition of any feeder rather than supplying the power demand of the charging station from these resources only.

1.2.Problem Statement

In the context of Nepal, RDS is widely preferred due to its low initial cost and simple in planning and operation. However, in lengthy feeder, voltage towards the farthest point from the supply end suffers from low voltage owing to a voltage drop throughout the feeder's span. In the contrast, installation of the EVCS is increasing annually in the same distribution system with minimal or no improvement resulting more voltage drop and power losses in the system.

RERs integrated with BESS powered distribution system can utilize the locally available energy resources, improve reliability of the system, reduced voltage drops and maintain the voltage at each point of the load connection, however it may pose difficulties for system coordination and management. Thus, to alleviate the negative impact of the integration on the system, proper allocation and sizing of the PV and BESS unit is crucial. Therefore, this study intended to focus on enhancing performance of the EV charging station with the strategic sizing and placing of Solar PV unit along with BESS in radial distribution system.

1.3.Objectives

1.3.1. Main Objective

The main objective of this research is:

- To optimize the location and sizing of Solar PV and BESS for EVCS in RDS.

1.3.2. Specific Objectives

The specific objectives to meet the main objective are as follows:

- To perform the load flow analysis at base case and observe the voltage profile and power loss of IEEE 33 Test bus system and Byasi feeder emanated Bhaktapur Substation using backward/forward sweep algorithm in MATLAB
- To conduct load flow and observe the voltage profile and power loss with the placement EVCSs at different prime locations
- To obtain the appropriate size and location of Solar PV with BESS unit, optimize the fitness function based on weighted summation of power loss reduction index (PLRI) and voltage deviation index reduction index (VDIRI) using PSO algorithm
- To analyze voltage profile enhancement and power loss reduction with the connection of Solar PV and BESS unit in EVCS integrated radial system.
- To adopt energy management strategy and carry out the financial analysis of the proposed system.
- To perform the impact assessment of the weighting factors on the final solution.

1.4.Assumptions and Limitations

The average life expectancy of Solar module and BESS, per unit cost of energy losses, per kW cost of grid connected Solar PV, per kWh cost of BESS is assumed in this research work.

The limitations of the study include:

- The BESS's state of health, which is not taken into account in the study, might have an influence on how the system operates.
- It is expected that the BESS's charging/discharging properties follow a linear pattern.
- The financial study does not take into account the effects of integrating a solar PV system and BESS on the power quality and harmonics of the system, nor does it account for the cost of the converters needed for these systems.
- It's possible that not all distribution system types are adequately represented by the simulation program or platform.

1.5.Thesis Organization

The remaining structure of this thesis is organized systematically to present a comprehensive research study. Chapter two conducts an extensive literature review, examining relevant documents, research articles, and journal publications to evaluate the effects of EVCSs on RDSs. Chapter three details the research methodology, including formulation of the objective function with its associated equality and inequality constraints, explanation of the optimization techniques employed, and description of the dispatch strategy for solar PV systems and BESS within the distribution network. Chapter four presents and analyzes the simulation outcomes and research findings. Finally, Chapter five summarizes the study's conclusions and proposes potential directions for future investigation in this field.

CHAPTER TWO : LITERATURE REVIEW

2.1.Introduction

EVCSs are being installing in different location of our country, Nepal that have been powered from public utility grid. Nowadays, the concept of integrating RERs for EVCSs have been in trend throughout the world through formation of DC microgrid. With the increase in the adoption rate of EVs and increasing load growth, it is crucial to enhanced the efficiency of the existing distribution network by integrating renewable source of energy with ESS so as to store the excess energy from renewable energy and grid during low demand and supply back to the grid when the generation is low during peak period. However, appropriate size selection and placement of RERs with BESS is considered to be challenging task so as to improve the distribution system performance and reliability of the system with minimizing system costs. Many researchers have used artificial intelligence method such as Genetic Algorithm, PSO, whereas others have utilized the iterative method to get the perfect size of the microgrid components (PV solar, wind, BESS). Similarly, several researchers have employed Mixed Integer Linear Programming techniques to optimize energy coordination among microgrid elements.

Chaudhari and his team put forwarded optimization model to use the ESSs with the objective of minimum operating cost of EVCS powered by PV considering real-time electricity price (Chaudhari et al., 2018). Bhatti and his team proposed the PSO model to optimize the size of the PV and BESS in grid connected EVCS with the financial model as their objective function (OF) (Bhatti et al., 2019). To maximize energy efficiency, Torreglosa and his research team advised deploying a management system that controls power distribution across a DC microgrid's components (Torreglosa et al., 2016). Janamala et al. employed the Coyote Optimization Algorithm to curtail increased power loss and voltage deviation with EV load through the optimal sizing of the PV system (Janamala et al., 2021). Scalfati et al. focused on the optimal sizing of the distributed energy resources in DC microgrid from economic point of view that determined that the optimal mix of distributed generators (DGs) and ESS considering the opportunities of load management using Mixed Integer Linear Programming (Scalfati et al., 2017). Focusing on sustainable mobility solutions, Dhaked and colleagues implemented a microgrid-powered charging station for electric two-wheelers that

synergizes solar energy, fuel cells, and conventional grid power. The system was designed to operate cost-efficiently while maintaining energy autonomy and reducing peak load grid stress (Dhaked et al., 2021). Using the PSO technique, Muthuvel's research team implemented a PV system on a DC nano-grid to power isolated residences. The system design accounted for maximum annual monthly consumption patterns, sunlight exposure, and environmental temperature, with all factors analyzed through an inclusive cost function encompassing every design parameter (Muthuvel et al., 2017). Genetic Algorithm based optimization technique, as demonstrated by (Alzahrani et al., 2019), is effective in reducing system losses with a high penetration level of solar PV through optimal BESS placement. To optimize the system's cost, three metaheuristic algorithms are employed: PSO, African Vulture Optimization, and Salp Swarm Optimization and the results exhibit that PSO offers the highest goal values, while African Vulture Optimization algorithm achieves the fastest return time (Pompern et al., 2023). A research group led by Bandyopadhyay optimized hybrid PV-battery microgrid configurations using a comprehensive techno-economic model. Their investigation of energy/power independence and financial metrics included case studies in Texas and the Netherlands, revealing how weather patterns influence optimal system dimensions (Bandyopadhyay et al., 2020).

Leonori's group proved soft computing superior to RTH methods for microgrid energy management through real-world scenario testing. They developed machine learning-based energy management strategy (EMS), created a unique energy flow visualization technique, and validated their system using Raspberry Pi hardware (Leonori et al., 2020). Meng and colleagues analyzed MGSC/EMS control objectives through the lens of microgrid hierarchical control layers. Their review focused on development methodologies, emphasizing notable application examples in existing research (Meng et al., 2016). The proposed smart energy management solution by Chaouachi and his team employ machine learning algorithms integrated with mathematical optimization techniques. By processing anticipated energy demand and renewable power availability data, the system optimally schedules resources to achieve eco-friendly and cost-efficient microgrid operation. (Chaouachi et al., 2013). Slime Mould Algorithm employed by researchers (Abdel-Mawgoud et al., 2021) to optimize PV/BESS configuration in RDS, using 24-hour active power loss minimization as OF for determining ideal system size and location.

2.2.EVCS Installation Status

The increasing global adoption of EVs has led to a significant need for effective vehicle charging infrastructure. In order to meet the energy demand of the growing fleet, not only governmental agencies but also private builders and infrastructure developers are concentrated on increasing the number of charging stations and ports. Moreover, governments throughout the world are working together with oil and gas businesses to strategically plan and construct infrastructure related to charging stations. To encourage the use of EVs so as to achieve zero-carbon emission, several countries are installing EVCS within minimal distance such that EV users won't get suffered from charging opportunities. The growing demand for public charging stations highlights the need to match the convenience of refueling traditional cars, even though most EV owners charge at home. In 2022 alone, over 900,000 new public chargers were installed, raising the global total to 2.7 million by year-end. This represents a 55% rise compared to 2021, mirroring the pre-pandemic growth rate of 50% observed between 2015 and 2019 (International Energy Agency, 2023).

The charging station of power rating less than 22 kW that can be considered as slow charger were installed more than 6,00,000 in public places throughout the world in 2022, among which China shares the greatest portion. In addition to that, the number of public fast chargers whose power rating greater than 22 kW increased by 3,30,000 globally in 2022. Consumers without dependable private charging capabilities rely on publicly accessible charging facilities. In 2023, 51 advanced FCSs for EVs were formally opened by NEA in various parts of the nation. Among them, 26 are made to charge large automobiles while remaining 25 are made to charge both small and large automobiles. Apart from that, Sajha Yatayat has installed FCS of capacity around 1.4 MW to cater the charging solution to approximately 40 EVs at a time, especially large buses and micros. More than that, various private organizations like Hyundai, Kia, BYD, MG Motor, Tata Motors, Yatri and so on are focused on setting the charging solutions for both four wheelers and two wheelers.

2.2.1. Classification of EVCS

EVCSs can be stratified according to technical specifications, with three established charging levels differentiated by power output and charging speed. While Levels 1 and 2 utilize alternating current (AC), Level 3 employs direct current (DC) for rapid charging applications (Mastoi et al., 2022).

2.2.1.1. Level 1 – Slow Charger

It is commonly found EV charger in household where the owner of an EV may conveniently recharge their vehicle in the comfort and convenience of their home and routine. With a power output of less than 1.9 kW and a regular household outlet (120 volts in the US), it is the slowest charging method and performs poorly in terms of efficiency.

2.2.1.2. Level 2 – Fast Charger

It is mostly found on work places and public locations where it can charge the vehicle a bit faster compared to Level 1 charging. It uses either 240 Volt 1-phase supply or 400 volt 3-phase supply to power the battery with power output less than 19.2 kW.

2.2.1.3. Level 3 – Rapid Charger

It is the fastest type of charging based on high-voltage DC current that can feed more than a 100 kW of power directly to the EV battery. They are generally designed to charge the vehicle up to 80% within short period of time thus, reduces the charging time drastically in contrast to charging at Levels 1 and 2.

2.3. Classification of Distribution System

Distribution infrastructure typically comprises feeders, distributors, and service mains in a hierarchical arrangement. Voltage levels determine the system classification, with primary distribution operating at higher voltages (3.3-11 kV) and secondary distribution at lower voltages (230-400 V). Connection topologies are additionally characterized as Radial, Ring Main, or Interconnected configurations (Prakash et al., 2017).

In RDS, there will be only one single path through which power is delivered to load from substation. Because of single path, power may get blocked if there any fault occurs between substation and load, thus has very low reliability. However, it has its own advantages like low initial cost, simple design and easy to plan and operate.

The load in ring main system is fed from two parallel paths from substation thus, power can be delivered to load easily if fault exist in any one of the paths. The busbar of any path has to carry double load if outage occurs in any paths. Because of the parallel paths, it has higher reliability and power availability thus, can maintain the voltage

level at the receiving end and hence, better voltage regulation. However, it is expensive and complex as compared to RDS.

In Inter-connected system, there exists multiple paths between substation and load as well as multiple substations to supply the power. These paths form mesh between substation and load thus, reliability and power availability of this system is superior. It is more efficient and low loss however, are complicated in design and operation as well as costlier.

Nepal's electrical infrastructure predominantly utilizes radial distribution configurations. This network architecture faces increasing challenges with power quality and supply reliability as consumption grows. NEA, as the exclusive regulatory body for power distribution in Nepal, is currently implementing several modernization projects such as system capacity augmentation, installation of protective devices (auto-reclosers and smart load break switches) and underground cable installation.

2.4. Electric Vehicle Charging Station in RDS

Electric Vehicle users can satisfy their demand through slow charging as well as fast charging. Slow charging is mostly preferred for residential purpose as it takes longer time to refill the battery energy. Thus, it allows distribution system operator to plan and regulate the operation of the charging system. However, the installation trend of FCS is quite impressive, as it allows better charging experience that can be comparable to the refueling time of combustion vehicles. Unlike gradual charging methods, rapid charging infrastructure introduces more significant electrical disturbances to power networks, manifesting as voltage instability, system imbalances, and harmonic pollution affecting current and voltage quality.

As per Nepal Electricity Grid Code 2080 introduced by Electricity Regulatory Commission, distribution voltage level should be maintained within $\pm 5\%$ of the rated voltage level in normal operation while the frequency should be within $\pm 2.5\%$ of the rated frequency. Thus, to maintain voltage, frequency and harmonics level within the specified limit some of the mitigating measures need to incorporate with the charging stations.

2.4.1. Smart Charging

In order to overcome FCSs's effect on voltage stability, EV users should recharge their vehicles during off-peak hour to reduce power demand on the grid. This can be

achieved by influencing the charging behavior through manipulation of electricity price.

2.4.2. Integration of RER with Energy Storage

Nowadays, the use of RERs in the power system is growing rapidly as it doesn't produce GHGs, diversify the portfolio of energy, unlimited availability however, they are intermittency in nature. In order to convert the non-dispatchable to dispatchable source of energy, they have to couple with energy storage. This approach helps minimize the impact of FCSs' high-fluctuation loads, thereby decreasing both system losses and overall power requirements. Furthermore, ESS enable effective energy management, enhance reliability, provide peak demand reduction, and contribute to grid stabilization.

2.4.3. Use of Power Electronics Devices

The integration of power electronic solutions such as FACTS devices, STATCOM, and UPFC enhances system power quality by mitigating voltage sags and power interruptions.

2.5. Load Flow Analysis in RDS

Load flow analysis serves to determine the steady state condition of the power system. It is usually performed for the improvement of the system as well as proper planning and sustainable operation of the system. The Newton-Raphson Method, Backward/Forward Sweep Method, Fast Decoupled Method, Gauss-Sidel Method, Continuation Method, Artificial Intelligence Method, and other algorithms may be used with software like NEPLAN, CYMDIST, MATLAB, DigSilent, ETAP, and so forth.

Backward/Forward Sweep method is an iterative method in which two computational steps are carried out at each iteration. The forward sweep and the reverse sweep are the two steps that make it up. In a backward sweep, voltage and current are determined from the end node to the source node using Kirchhoff's Voltage Law and Kirchhoff's Current Law. When using forward sweep, the downstream is calculated starting from the source node. Node-branch aligned data serves as the algorithm's input value. Basic data needed for the load flow are active and reactive powers with the classification of sending and receiving nodes (Deosaria et al., 2022). Because of the fast convergence capability and appropriate for RDS, this method has been adopted in this research work.

2.6.Optimization Technique

Optimization represents the process of identifying the most efficient solution when performing operations to achieve predetermined objectives. There are multiple approaches carried out in the literature to optimize the size and location of the renewable source of energy based on their specific OFs like minimization of total annual cost, power loss reduction, maximization of cost-benefits, reliability indices and so on. The optimal placement and sizing of RERs with ESS are not linear in nature, rather need to solve as non-linear optimization method. Some of the approaches for optimization of renewable energy include analytical approach, 2/3 rule, sensitivity analysis-based approach, linear and non-linear programming, dynamic programming, meta-heuristic approach, simulated annealing, Tabu search, Shuffled frog leaping, Artificial Bee Colony and so on. Among them, PSO of meta-heuristic approach has been used in this research.

Kennedy and Eberhart first introduced PSO in 1995, establishing it as a novel approach in the field of optimization techniques (Eberhart et al., 1995). PSO algorithm operates within a multidimensional value-based search space, mimicking the collective behavior of swarming organisms seeking essential resources such as food. In such swarms, individuals influence one another, enhancing both group and individual success. This biologically inspired approach enables effective optimization of Solar PV and BESS sizing and placement in the study. By leveraging randomized exploration and selection of optimal or near-optimal solutions, PSO enhances optimization efficiency, delivering robust and high-performing results.

CHAPTER THREE : RESEARCH METHODOLOGY

3.1. Research Approach

The research has been started with the identification and formulation of the problems existed in the RDS with the incorporation of the EVCS because the installation has been increasing rapidly without any technical analysis of the system. Then the review of the literature related to the research work has been carried in order to furnish the knowledge on the identified problem. The next one up is the collection of the data that includes resistance and reactance of the distribution branches, active and reactive power demand of each bus which are the major variable of the problem. The next step involves the selection of the software and algorithm to conduct optimization process. For this work, MATLAB software has been used and optimization has been performed using PSO algorithm through the use of Backward/Forward sweep algorithm as load flow analysis tool. Later, load flow of the radial feeder before and after placement of EVCS has been executed to get the bus voltage and transmission loss to analyze the impact of the EVCS placement on the feeder. Considering these variables, optimization of the OF using PSO algorithm has been performed to get possible candidate bus for the placement of the Solar PV and BESS. This approach calculates the most efficient size and placement for PV solar panels and battery storage, ensuring minimized OF and line losses. Similarly, the feeder was analyzed under load flow conditions with EV charging stations and optimally positioned PV-BESS units to validate the effectiveness of the proposed solution.

At initial, the research has been conducted on the RDS of Standard IEEE 33 test bus system on which examination of technological elements like active power loss, voltage profile and financial aspects are performed. The results obtained from the Standard IEEE 33-bus test system are cross-verified against existing literature. The same methodology is then implemented on the Byasi Radial Feeder in Bhaktapur, supplied by Bhaktapur Substation. The voltage gradient and active power loss of the feeder before and after placement of EVCS has been compared and then optimization process has been implemented for the strategic placement and sizing of the Solar PV and BESS in the system so as to reduce active power loss and improve voltage gradient of the system. EVCSs in the system have been placed at different prime location from charging point of view. The demand of each charging station has been considered 150

kW with power factor of 0.8 lagging. OF combines two key performance indicators: PLRI and VDIRI. These operate within a constrained optimization environment incorporating both equality and inequality constraints to identify optimal bus locations for solar PV and BESS integration. The selected buses serve as control variables in the optimization procedure. Subsequently, an economic analysis compares pre- and post-implementation scenarios to evaluate the financial feasibility of the proposed solution through cost-benefit assessment of energy savings and capital expenditures. The methodology adopted is presented in the flowchart below:

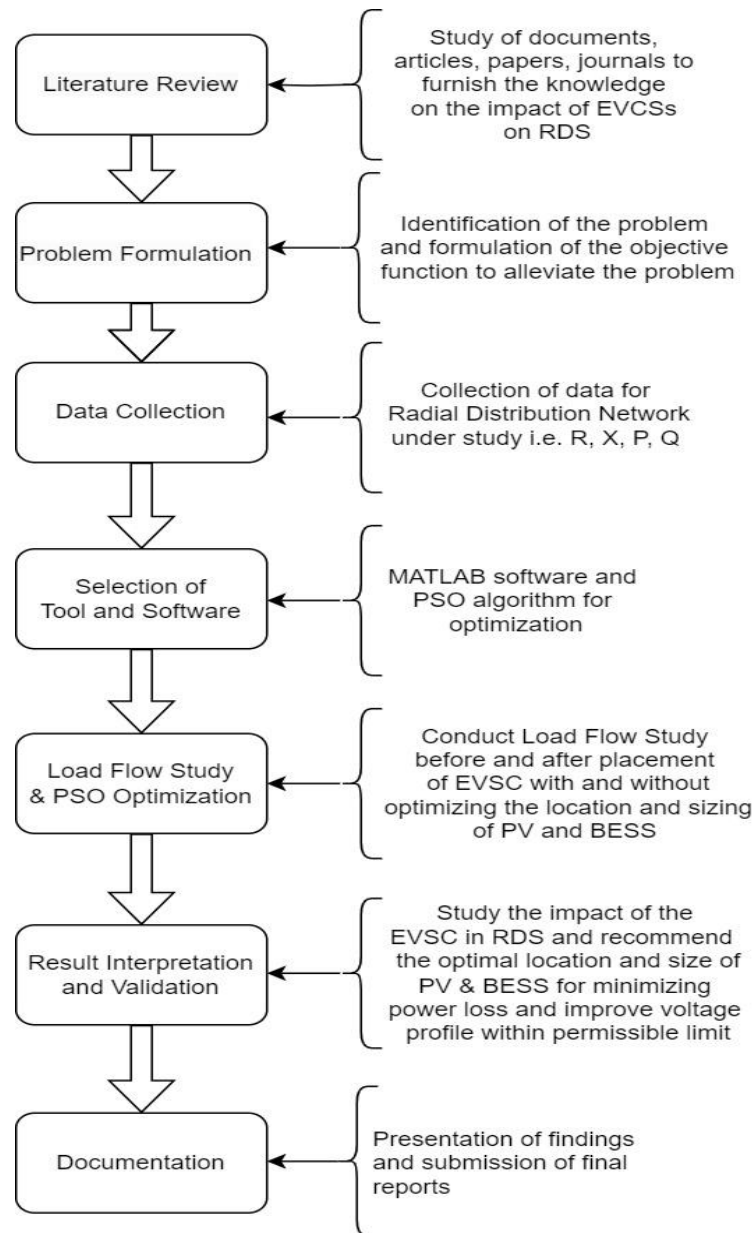


Figure 3.1: Flowchart of Research Methodology

3.2. Modelling of EVCS, Solar PV and BESS

3.2.1. EVCS Model

EV load in the network can be represent using different load model like constant current load, constant power load, constant impedance load, however neither of these models have provided evidence to support their approach. It is imperative to model the EV load precisely in the power system for realistic stability studies such that EV load varies in response to the system voltage and frequency fluctuation. In order to model the charger, it is essential to understand the charging characteristic of the charger through which battery get charged. There is numerous charging methods exist, including constant current charging (CC), constant voltage charging (CV), constant power charging (CP) and trickle charging (TC). CC charging approach maintains a fixed current flow to the battery until terminal voltage achieves a predetermined threshold. Subsequently, the system switches to CV mode, where voltage remains stable while current gradually decreases until the battery attains the designated state of charge (SOC) level. At the stating of the charging, trickle charging is provided so as to increase the voltage level of the battery at specified level before starring CC method.

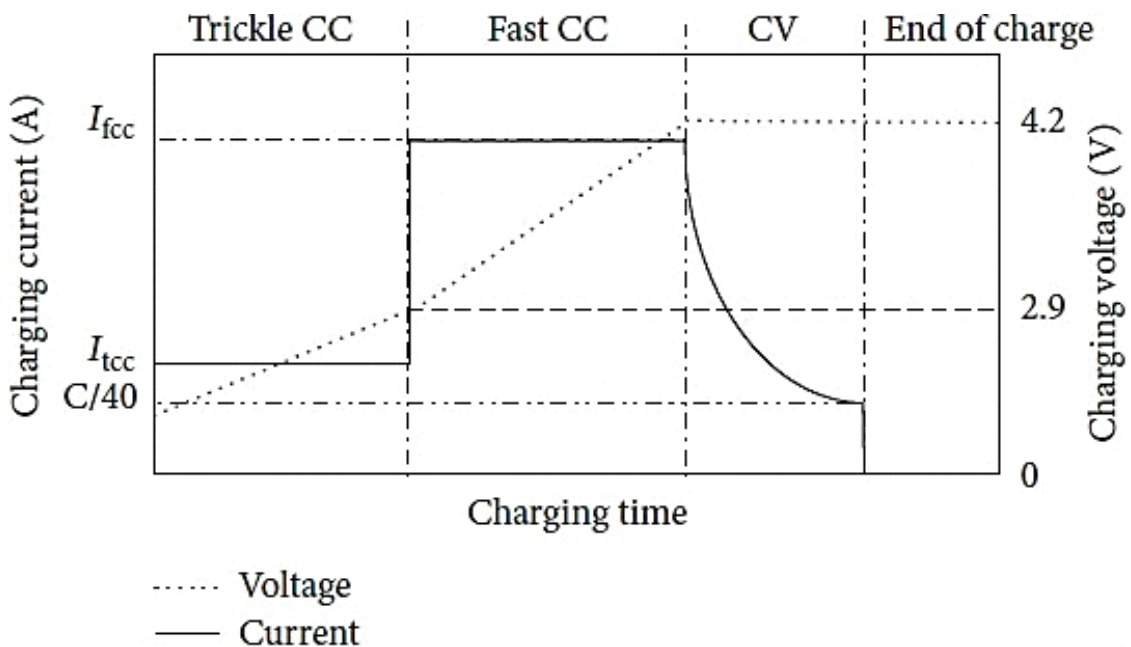


Figure 3.2: Typical Charging Process of Li-ion battery (ZIADI et al., 2015)

EV charging module usually consists of two main stages: first stage which includes rectification of the AC supply followed by power factor correction and second stage include isolated DC/DC converter. In isolated DC/DC converter, rectified AC (DC supply inverted to high frequency AC) pass-through high frequency transformer and

then rectified to DC suitable for charging battery. For safety purposes, a high-frequency transformer ensures electrical separation between the grid and EV.

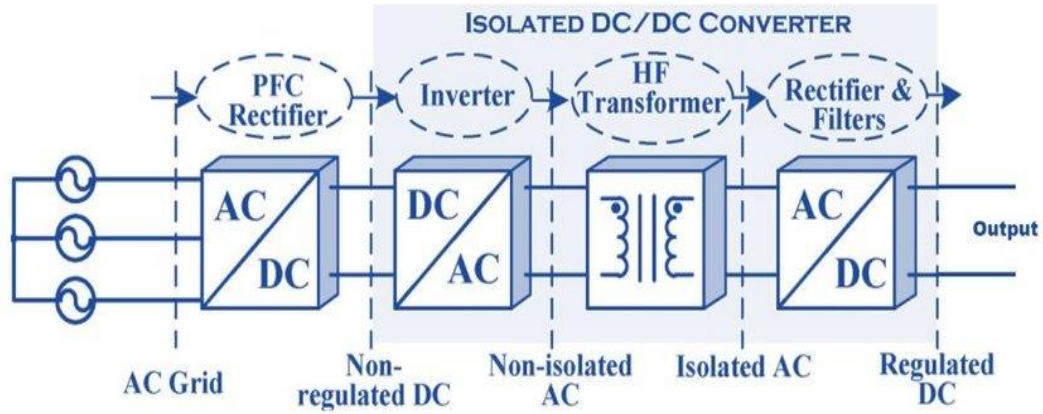


Figure 3.3: High frequency isolation-based DC fast charger solution (Bahrami, 2020)

In power system studies, EV load model is usually represented as constant current load, constant power load or as constant impedance load (Shukla et al., 2018; Tian et al., 2021). However, modern EV fast charger consists of ac-dc converter at the front end for rectification and power factor control followed by dc-dc converter at the battery end for maintaining appropriate charging current for different SOC level and cell temperature of the battery (Kilicoglu et al., 2023). Considering all of these issues, (Dharmakeerthi et al., 2012) proposed the load model of the EV charger that consists of constant power component and supply voltage dependent component as:

$$\frac{P}{P_0} = k_{cp} + k_{vd} \times \left(\frac{v}{v_0}\right)^\alpha \quad \text{Equation 3.1}$$

In order to get the values of the k_{cp} , k_{vd} and α , simulation of the charger has been done at different SOC of the battery and found that $k_{cp}=0.9061$, $k_{vd}=0.0939$ and $\alpha=-3.715$. Hence, the EV charger load model becomes:

$$\frac{P}{P_0} = 0.9061 + 0.0939 \times \left(\frac{v}{v_0}\right)^{-3.715} \quad \text{Equation 3.2}$$

where, P_0 is power consumption at the reference voltage (v_0) and P is the rated power consumption at the rated voltage (v).

3.2.2. Solar PV Model

Solar is sustainable source of energy that can be used to prevent further climate change. It is available abundantly and versatile source of energy. The pioneering work of Bell

Labs researchers Gerald Pearson, Daryl Chapin, and Calvin Fuller in 1954 led to the first practical crystalline silicon photovoltaic cell. This breakthrough invention established silicon-based technology as the dominant approach for large-scale electricity generation through solar PV. It can be used for the production of electricity in mega scale using flat plate, concentrator PV system and thermal concentrator solar power system. The PV effect serves as the foundation for the solar system's operation i.e. when the solar light that consists of well-defined energy quanta called photon interacts with specific materials, it frees electron from their atomic bond thus, creates hole with positive charge and electron with negative charge. This electron-hole pair tends to recombine that makes them stable rather than apart. Before recombining, we can generate electricity by traveling the electron through electric circuit and hence, this movement of electron called electricity.

A variety of PV cell technologies are available for converting solar energy into electrical power (Photovoltaic Energy Factsheet, 2021; Rathore et al., 2021).

Crystalline Silicon (c-Si) Solar cell: Manufactured from slender silicon slices with a specific atomic arrangement (diamond cubic structure), these represent the most common type of solar cells used in commercially produced solar panels. Crystalline silicon is of two types: monocrystalline and polycrystalline silicon. The crystal structure of monocrystalline silicon is uninterrupted and persistent throughout the bulk, up to the borders, with an efficiency of around 14–18% while polycrystalline silicon consists of many crystalline grains oriented randomly with laboratory efficiency of about 12-14%.

Thin film Solar cell: It employs significantly thinner active layers than wafer-based designs. Their production presents fewer technical challenges and yields lighter, more flexible, and cost-effective modules. However, these advantages come with trade-offs in power output and durability when benchmarked against traditional c-Si photovoltaic technology. They are also called second generation solar cell. The efficiency of thin film cell is usually 10-16%.

The key factors that influence PV system's output are solar irradiation and ambient temperature (Sufyan et al., 2020). The output power of Solar PV is given as:

$$P_{out}^{pv} = P_{STC}^{pv} \times \frac{I}{I_{ref}} \times [1 + \tau \times \{(T_{amb} + (0.0256 \times I)) - T_{ref}\}] \quad \text{Equation 3.3}$$

where, P_{out}^{pv} = power output from Solar PV

P_{STC}^{pv} = power output from Solar PV at standard test condition

I = solar irradiance at watt per meter square

I_{ref} = solar irradiance at standard test condition = 1000 W/m²

T_{ref} = temperature at standard condition (25 °C)

T_{amb} = ambient temperature of the PV surrounding

τ = constant taken as $3.7 \cdot 10^{-3}$ (1/°C)

3.2.3. BESS Model

BESS is the energy storage technology that can be used to store electrical energy. They are used to accumulate surplus energy while demand is low and release back to the system when demand is high. Thus, it helps to provide flexibility, reliability and stability of the system. In addition to that, BESS are gaining popularity in managing the intermittency of renewable source of energy like Solar, Wind. RERs coupled with energy storage are widely used for load shifting, output smoothing, network congestion management and frequency control of the system.

Based on the chemical used inside the battery, they can be classified as (Chen et al., 2012; Rakhimov et al., 2024):

Lead- Acid Battery (Pb-Acid): These rechargeable batteries are widely used because of long life, affordable and well-established technology. Although they have low efficiency, low energy density and requires higher maintenance.

Lithium-ion Battery (Li-ion): They are gaining popularity in portable electrical and electronics devices because of higher energy density. Nowadays, they are extensively used in Electric Vehicle because of higher power-to-weight ratio, higher efficiency, good temperature performance, long life and low self-discharge.

Nickel-Cadmium Battery (NiCd): It is one of the rechargeable batteries that can be used in the application where reliable and uninterrupted power supply is required over wide range of environmental condition. Although, they are bulky in size and weight, higher self-discharge rate and lower energy density.

Nickel-Metal Hydride Battery (NiMH): They are extensively used in the application where high current draining is required because of its lower internal resistance. They are widely used in hybrid electric vehicle due to its safety and abuse tolerant capability.

Table 3.1: Comparison of Battery Technology

Characteristics	Pb-Acid	Li-ion	NiCd	NiMH
Specific Energy (Wh/kg)	35-40	100-265	40-60	60-120
Energy Density (Wh/L)	80-90	250-693	50-150	140-300
Specific Power (W/kg)	180	250-340	150	250-1000
Nominal Cell Voltage (Volt)	2-2.1	2.5-5	1.2-1.3	1.2-1.35
Life time Cycle (cycles)	250-2000	100-10000	1000-5000	300-1800
Lifespan (years)	2-15	5-15	10-20	2-15
Efficiency (%)	50-95	80-95	70-90	66-92

The modelling of the battery can be represented by following equation with the assumptions of no self-discharging (Chedid et al., 2019):

In case of charging of the battery,

$$\text{SoC}(t) = \text{SoC}(t - \Delta t) + \eta_{\text{charging}} \times \frac{P_{\text{batt}(t)}}{C_{\text{batt}(t)} \times V} \Delta t \quad \text{Equation 3.4}$$

In case of discharging of the battery,

$$\text{SoC}(t) = \text{SoC}(t - \Delta t) - \frac{P_{\text{batt}(t)}}{\eta_{\text{discharging}} \times C_{\text{batt}(t)} \times V} \Delta t \quad \text{Equation 3.5}$$

where, $P_{\text{batt}(t)}$ = Power of the battery in an interval Δt

$\text{SOC}(t)$ = State of charge of the battery

η_{charging} and $\eta_{\text{discharging}}$ = charging and discharging efficiency of battery

C_{batt} = capacity of the battery

V = nominal voltage of the battery

3.3. Grid Parameters Calculation

Load flow studies compute nodal voltage magnitudes and identify active/reactive power losses throughout an electrical network under steady-state conditions. Backward/Forward sweep algorithm has been used in this research work to carry out the load flow as it is the most easy and efficient method.

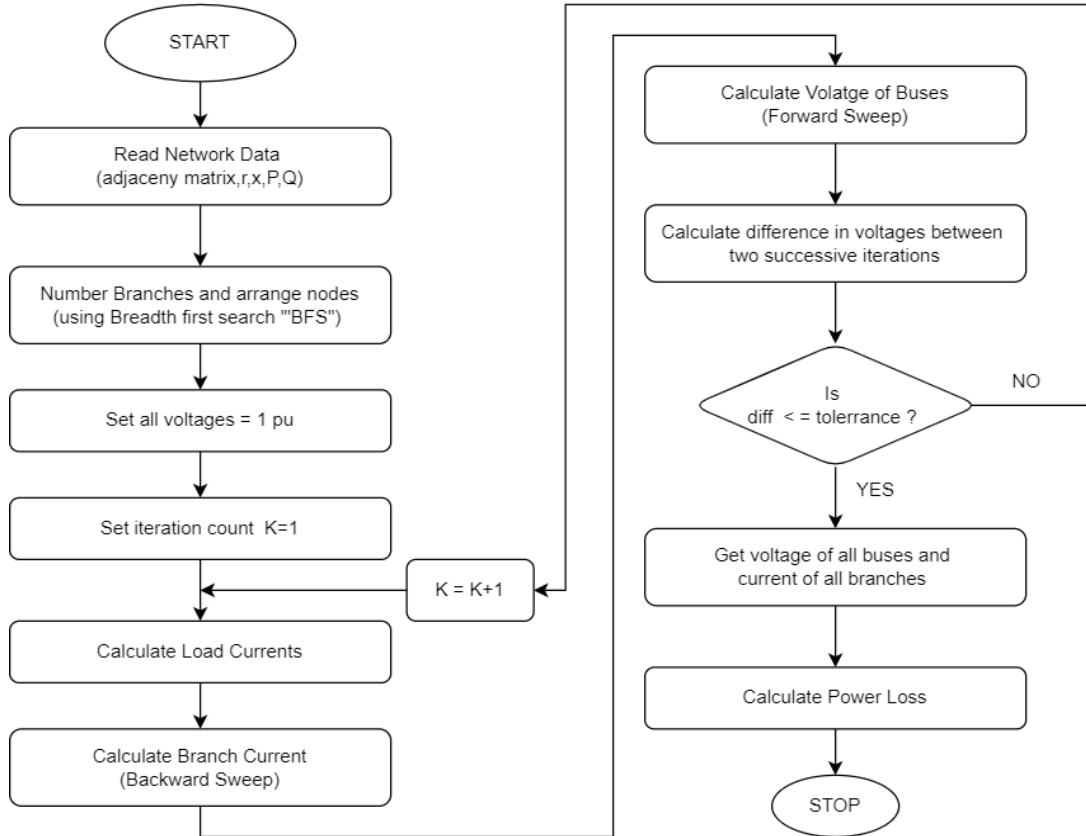


Figure 3.4: Backward/Forward Sweep Algorithm

There are two sweeps in this algorithm: backward and forward. The load flow of RDS starts with input of resistance and reactance of branches as well as active and reactive power demand of each bus. Then end nodes of the feeder are determined using breadth first search method. Now, initialize the voltage of each bus to 1 p.u. and iteration count $K=1$. Then, we calculate the load current with the initialized bus voltage and branch current using backward sweep (Deosaria et al., 2022).

$$I_i^k = \left(\frac{S_i}{V_i^k} \right)^* - y_i \times V_i^{k-1} \quad \text{Equation 3.6}$$

$$J_1^k = -I_{lr} + \sum J_{lr} \quad \text{Equation 3.7}$$

where, $i = 1, 2, 3, \dots, n$ (number of nodes)

S_i = power output at node i

V_i = voltage at node i

y_i = shunt admittance at node i

$l = b, b-1, \dots, 1$

I_{lr} = current injection of node lr calculated from step 1

$\sum J_{lr}$ = current in branches originated from node lr

$lr = 1, 2, 3, \dots, b$ (number of branches)

The, voltage at each bus is calculated with the branch current using forward sweep method.

$$V_{lr}^k = V_{ls}^k - Z_l \times J_l^k \quad \text{Equation 3.8}$$

where, ls and lr represent sending and receiving end of branch l

Z_l = series impedance of branch l

This iterative method will be continuous and check convergence criteria i.e. voltage difference between two successive iterations at each bus. If the convergence criteria are within the specified tolerance limit, then the voltage of each bus and branch current are saved. Based on these saved values, transmission loss at individual branch as well total losses is evaluated. The total losses are the summation of the branch losses while the branch loss is calculated using following formula:

$$P_l = \sum \frac{P_i^2 + Q_i^2}{V_i^2} \times R_i \quad \text{Equation 3.9}$$

$$Q_l = \sum \frac{P_i^2 + Q_i^2}{V_i^2} \times X_i \quad \text{Equation 3.10}$$

where, P_i and Q_i are the total active and reactive power injected through i^{th} node

R_i = resistance of i^{th} branch

X_i = reactance of i^{th} branch

The total active and reactive power loss of the network is given by

$$TPL = \sum_{i=1}^{n-1} P_i \quad \text{Equation 3.11}$$

$$TQL = \sum_{i=1}^{n-1} Q_i \quad \text{Equation 3.12}$$

3.4. Objective Function

The inclusion of EVCSs into radial distribution networks degrades voltage stability and increases technical losses. To mitigate these issues, this study proposes a weighted multi-objective optimization framework. The approach optimally sizes and positions solar PV systems coupled with battery storage, while simultaneously minimizing a composite performance index that combines both voltage deviation and power loss reduction metrics.

$$\text{Min \{OF\}} = (w_1 \times \text{PLRI}) + (w_2 \times \text{VDIRI}) \quad \text{Equation 3.13}$$

where, w_1 and w_2 represent user-defined weighting coefficients for PLRI and VDIRI, respectively. These weights must satisfy two conditions:

1. Each weight must range between 0 and 1 ($0 \leq w_1, w_2 \leq 1$).
2. Their sum must equal unity ($w_1 + w_2 = 1$).

Power Loss Reduction Index (PLRI): It defined as the percentage of system active power loss following PV-BESS deployment as compared to system active power loss prior to placement.

$$\text{PLRI} = \frac{P_{\text{loss}}^{\text{DG}}}{P_{\text{loss}}} \quad \text{Equation 3.14}$$

Voltage Deviation Index Reduction Index (VDIRI): It is defined as the percentage of voltage deviation index following PV-BESS deployment as compared to the voltage deviation index prior to placement.

$$\text{VDIRI} = \frac{\text{VDI}^{\text{DG}}}{\text{VDI}^{\text{woDG}}} \quad \text{Equation 3.15}$$

Voltage Deviation Index (VDI) quantifies system-wide voltage variations by calculating the sum of squared differences between actual bus voltages and their nominal values.

$$\text{VDI} = \sum_{i=1}^n |V_n - V_i|^2 \quad \text{Equation 3.16}$$

where, n represents the system's total bus quantity, V_n denotes the standardized nominal voltage, V_i corresponds to the real-time voltage measurement at the i^{th} bus.

During optimization process, some equality and inequality constraints need to be considered which are presented as follow:

3.4.1. Equality Constraints

The power from substation, Solar PV and BESS at any time 't' must match with the power demanded by system load and losses exit in the system as:

$$P_s + \sum_{i=1}^{N_{pv+bess}} P_{PV+BESS}(i) = \sum_{j=1}^{N_{bus}} P_{load}(j) + \sum_{k=1}^{N_{br}} P_{loss}(k) \quad \text{Equation 3.17}$$

$$Q_s = \sum_{j=1}^{N_{bus}} Q_{load}(j) + \sum_{k=1}^{N_{br}} Q_{loss}(k) \quad \text{Equation 3.18}$$

where, P_s = Active power supplied from substation,

Q_s = Reactive power supplied from substation,

$P_{PV+BESS}$ = Power supplied from Solar PV and BESS,

P_{load} = Active Power demanded by load,

Q_{load} = Reactive Power demanded by load,

P_{loss} = Active Power loss in the branches,

Q_{loss} = Reactive Power loss in the branches,

$N_{pv+bess}$ = Total number of Solar PV modules and battery bank,

N_{bus} = Total number of buses,

N_{br} = Total number of branches.

3.4.2. Inequality Constraints

System Voltage Limit

The system's voltage levels must be regulated within the allowed range to mitigate risks of overvoltage and undervoltage.

$$V_{min} \leq V_j \leq V_{max}$$

where, V_{min} = minimum voltage of bus, 0.95 p. u., V_{max} = maximum voltage of bus, 1.05 p. u., and V_j = voltage of j^{th} bus.

Solar PV with BESS sizing Limit

The constraints for sizing PV and BESS are given as below:

$$0 \leq P_{PV} \leq 50\% \text{ of } P_{\text{Total}},$$

$$0 \leq P_{\text{BESS}} \leq 30\% \text{ of } P_{\text{Total}},$$

$$E_{\text{BESS}}^{\min} \leq E_{\text{BESS}}^t \leq E_{\text{BESS}}^{\max}$$

$$E_{\text{BESS}}^{\min} = (1-\text{DOD}) \times S_{\text{BESS}} \quad \text{Equation 3.19}$$

where, P_{Total} = sum of the total active power of the system,

P_{PV} = total active power of PV system,

P_{BESS} = total active power of BESS,

E_{BESS}^{\min} = minimum energy of the battery bank

E_{BESS}^{\max} = maximum energy of battery bank,

E_{BESS}^t = energy of the battery bank at any time 't',

S_{BESS} = nominal capacity value of battery bank,

DOD = depth of discharge of battery bank.

3.5. Optimization using PSO Algorithm

PSO algorithm navigates n-dimensional solution space where each particle maintains (Gad, 2022; Eberhart et al., 1995; Maleki et al., 2015):

- Position vector: $X_i = (X_{i1}, X_{i2}, \dots, X_{in})$
- Velocity vector: $V_i = (V_{i1}, V_{i2}, \dots, V_{in})$

The velocity update incorporates three fundamental components:

1. Cognitive influence (c_1): Attracts particles toward their personal best positions (Pbest)
2. Social influence (c_2): Guides particles toward the swarm's global best position (Gbest)
3. Inertia weight (w): Preserves a percentage of the particle's previous velocity

Algorithm Dynamics:

Particles explore the search space by continuously updating their velocities and positions using the relation:

$$v_j^{k+1} = w^k \times v_j^k + c_1 \times r_1 \times (P_{\text{best}}^k - x_j^k) + c_2 \times r_2 \times (G_{\text{best}}^k - x_j^k) \quad \text{Equation 3.20}$$

$$x_j^{k+1} = x_j^k + v_j^{k+1} \quad \text{Equation 3.21}$$

where r_1 and r_2 are random numbers in $[0,1]$ that introduce stochasticity.

The inertia weight is updated using following formula:

$$\omega = \frac{\omega_{\max} - \omega_{\min}}{\max_iteration} \times \text{iteration}_{\text{number}} \quad \text{Equation 3.22}$$

The proposed work uses a population size of 250 and limits the iterations to 200, $w_{\max} = 0.9$ and $w_{\min} = 0.4$.

Particle Swarm Optimization Implementation Steps:

1. Initialization Phase:
 - a. Randomly generate particle population within search space boundaries
 - b. Assign random initial positions and velocities to all particles
2. Fitness Evaluation:
 - a. Calculate OF values for each particle
 - b. Initialize Pbest with starting configurations
 - c. Identify Gbest from particle with minimum OF value
3. Iterative Optimization:
 - a. Update particle velocities and positions using governing equations (Eq. 3.20 and 3.21)
 - b. Apply constraint handling:
 - Revert particles exceeding feasible boundaries to prior valid positions
 - c. Re-evaluate OF values for updated positions
 - d. Update Pbest and Gbest records when improved solutions are found
4. Termination Check:
 - a. Verify stopping criteria satisfaction
 - b. If met: Output Gbest as optimal Solar PV/BESS configuration
 - c. Else: Repeat steps 3(a)-3(d) until convergence (Eberhart et al., 1995).

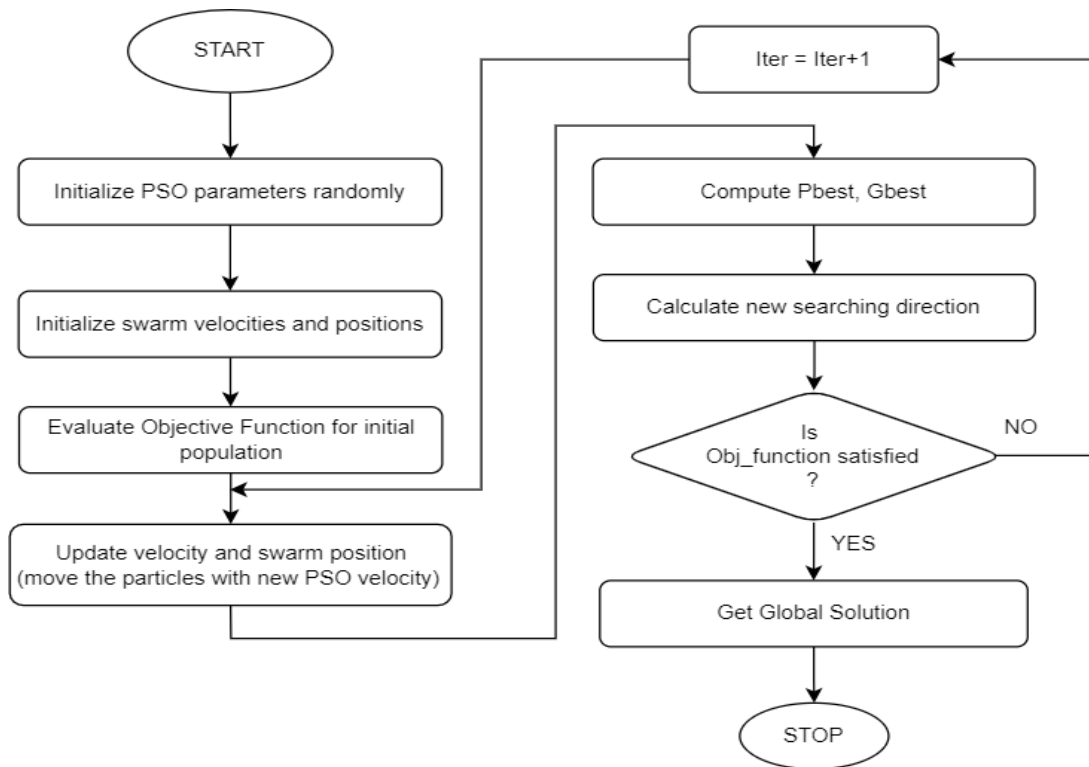


Figure 3.5: Flowchart of PSO

3.6.Solar PV and BESS Dispatching Approach

Renewable sources of energy like Wind, Solar PV are non-dispatchable source of energy. The output these resources cannot be changed according to the load demand. Thus, the energy produced from these resources during low demand period will be wasted out, consequently, the energy cost will be higher enough. Hence, these resources need to integrate with some energy storing devices like batteries, thermal or mechanical system. In this research work, solar PV has been coupled with battery such that excess energy from PV during day time will be stored and that energy will be release back to the system during peak time.

The threshold power has been defined based on the average demand of the grid so as to maintain the total load of the system below its average demand value. The power flow between the battery storage and grid is dynamically regulated according to solar PV generation, overall system load, and battery storage capacity. The energy from solar will only charge the battery if it is sufficient to meet the difference of demand and threshold power during day time. The battery will only be discharge if the solar energy isn't able to meet the load above threshold value during off peak time however, during

peak time, battery will be discharge up to its maximum capacity to supply the demand. This enables to shift the load as well to shave the peak demand of the system.

3.6.1. Algorithm

- i. *Initialize Variables:*
 - *Define the threshold power (P_{th}).*
 - *Set the initial state of charge (SoC) of BESS.*
 - *Load system demand (P_d).*
 - *Set the PV output (P_{pv}).*
 - *Set time $t = 1$ (start of the dispatch period).*
- ii. *Main Loop:*
 - *Repeat the following steps for $t = 1$ to 24 hours (daily dispatch loop)*
- iii. *If grid power < 0 , go to step vii, otherwise continue*
- iv. *Calculate Power Difference:*
 - *Compute the demand power above threshold power of the system: $P_{\Delta} = P_d - P_{th}$.*
 - *Check if $P_{\Delta} \leq 0$ (system demand is below the threshold power; no urgency to discharge the battery).*
- v. *If $P_{\Delta} \leq 0$:*
 - *Check if $P_{pv} > 0$ (there is PV generation):*
 - *If SoC $< 100\%$, charge the BESS and supply remaining PV power to the load.*
 - *Else, supply complete PV power to the load.*
 - *If $P_{pv} = 0$ and demand is not meet, draw the remaining power from grid*
- vi. *If $P_{\Delta} > 0$:*
 - *Check if $P_{pv} > 0$ (there is PV generation):*
 - *Calculate $P_{diff} = P_{pv} - P_d$.*
 - *If $P_{diff} > 0$, check the state of BESS:*
 - *If SoC $< 100\%$, charge the BESS and supply remaining PV power to the load; else supply complete PV power to load*
 - *If $P_{diff} < 0$, check the state of BESS:*
 - *If SoC $> 20\%$, discharge the BESS along with PV power to the load; else supply only PV power to load*
 - *If $P_{pv} = 0$, check the state of BESS:*
 - *If SoC $> 20\%$, discharge the BESS*

- *If demand is not meet, draw the remaining power from grid*
- vii. *If $P_{pv} > 0$ (there is PV generation):*
 - *Calculate $P_{diff} = P_{pv} - P_d$.*
 - *If $P_{diff} > 0$, check the state of BESS:*
 - *If $SoC < 100\%$, charge the BESS and supply remaining PV power to load; else supply required PV power to load*
 - *If $P_{diff} < 0$, check the state of BESS:*
 - *If $SoC > 20\%$, discharge the BESS along with PV power to the load; else supply only PV power to load*
- viii. *If $P_{pv} = 0$, check the state of BESS:*
 - *If $SoC > 20\%$, discharge the BESS upto 20%*
- ix. *End of Loop:*
 - *Increment t by 1 hour.*
 - *Check if $t = 24$ (end of the day):*
 - *If yes, the algorithm ends.*
 - *If no, go back to step iii.*

This algorithm outlines the dispatch process for PV and BESS. It is structured to handle the energy management between PV generation, BESS charging/discharging, and grid power supply. The algorithm operates over a 24-hour cycle, checking the state of charge (SoC) of the BESS, PV output, and load demand of the system, as shown in the flowchart representation in Fig 3.6.

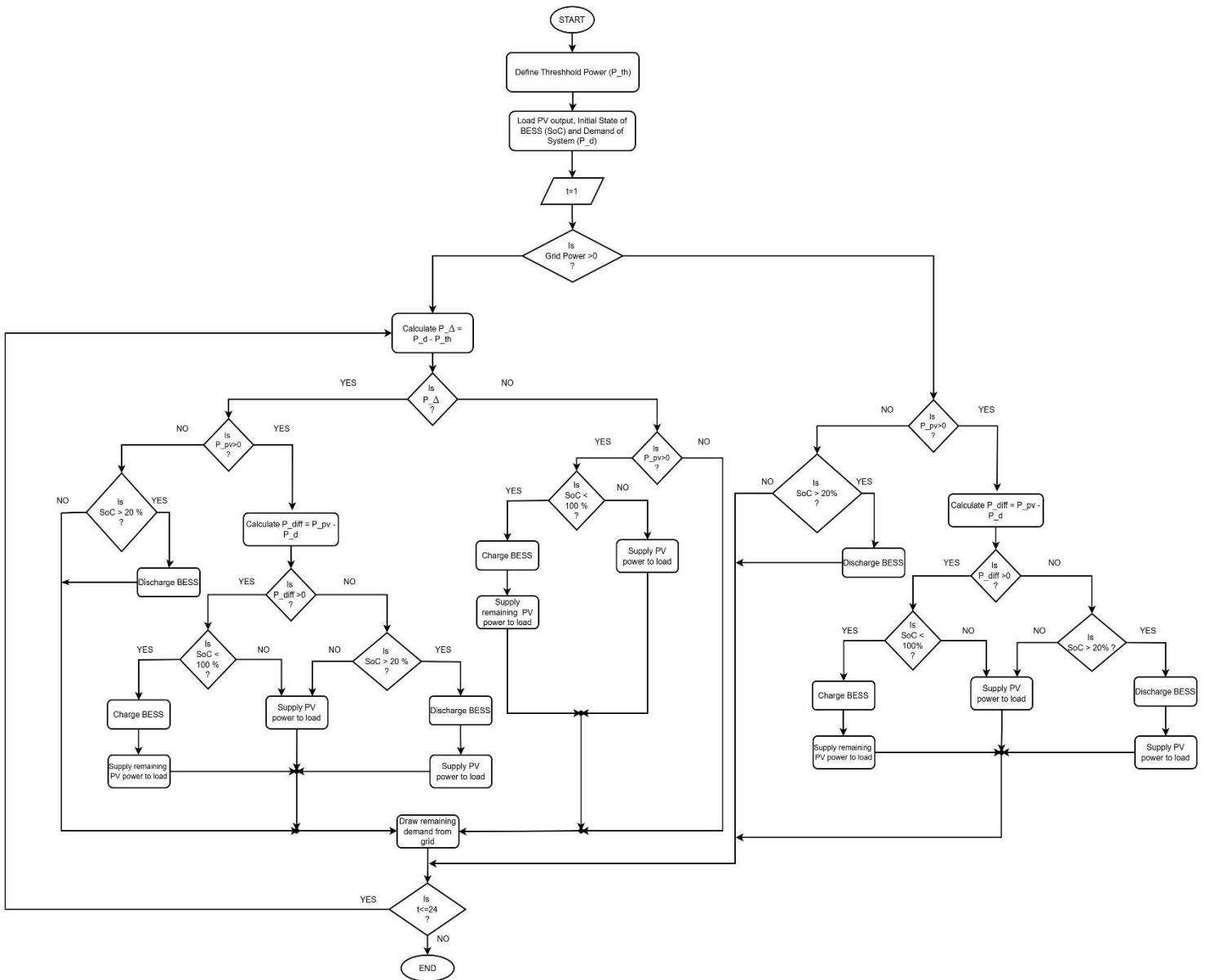


Figure 3.6: Solar PV and BESS dispatching flowchart

3.7. Financial Analysis of the Proposed System

Before spending investment to any project, it is equally essential to analyze the financial viability of the project in order to ensure that investment is recoverable within the lifespan of the project with satisfiable rate of return. In this research work, Solar PV and BESS has been integrated with grid thus, to reduce the losses in the system as well to improve the voltage profile of the feeder. There will be enough capital cost for the Solar PV and BESS along with the recurring cost of the BESS replacement. In addition to this, there will be operational and maintenance cost of the PV-BESS. However, this system will recover investment through the generation of Solar energy and saving of power loss in the distribution system. A detailed tabulation presents the

system's engineering characteristics, installation costs, O&M expenditures, economic variables, and solar PPA pricing structure in appendix 10 (Poudyal et al., 2021; Shrestha, 2023).

The total cost of the project can be represented by following formula:

$$\text{Total Cost (TC)} = \text{Installation cost of Solar PV and BESS} + \text{Battery Replacement Cost} + \text{operation \& maintenance cost of Solar PV and BESS} \quad \text{Equation 3.23}$$

$$\text{Installation cost of Solar PV} = 65,000 \times \text{size of Solar PV in kW} \quad \text{Equation 3.24}$$

$$\text{Installation cost of BESS} = 20,000 \times \text{capacity of battery in kWh} \quad \text{Equation 3.25}$$

$$\text{Battery Replacement Cost} = 10,000 \times \text{capacity of battery in kWh} \times \left(\frac{1}{(1+i)^7} + \frac{1}{(1+i)^{14}} \right) \quad \text{Equation 3.26}$$

$$\text{O \& M cost of Solar PV} = 1.5\% \times \text{Installation cost of Solar PV} \quad \text{Equation 3.27}$$

$$\text{O \& M cost of BESS} = 1.5\% \times (\text{Installation cost of Battery} + \text{Battery Replacement Cost}) \quad \text{Equation 3.28}$$

$$\text{Cost of energy Saving per year} = \text{demand cost per month} \times \text{demand saved} \times 12 + \text{per unit cost of energy} \times (\text{Power loss with EVCS} - \text{Power loss with Solar PV \& BESS}) \times \text{loss of load factor} \times 8760 \quad \text{Equation 3.29}$$

Loss of load factor indicates the proportion of load loss between the average and maximum levels in the system. It is given by

$$\text{Loss of load factor (LLF)} = k \times L_f + (1-k) \times L_f^2 \quad \text{Equation 3.30}$$

where, L_f is load factor and $k = 0.2$

$$\text{Cost of Solar energy generation per year} = \text{per unit cost of Solar energy} \times \text{size of Solar PV in kW} \times \text{number of sunny days} \quad \text{Equation 3.31}$$

$$\text{Total recovered cost per year (TR)} = \text{Cost of energy saving per year} + \text{Cost of Solar energy generation per year} \quad \text{Equation 3.32}$$

Discounted payback period is defined as the number of years after which the cumulative discounted cash inflows take to recover the initial investment.

$$\text{Discounted Payback period (in years)} = \frac{\text{TC}}{\text{Discounted TR}} \quad \text{Equation 3.33}$$

3.8. System Under Consideration

In this research work, integration of EVCS of size 150 kW @ 0.85 lagging power factor has been done at four different prime locations followed by the optimal placement and sizing of Solar PV and BESS in the same system to reduce transmission loss and improve voltage profile.

The time horizon of a day is splitted into 24 sections. The temperature and solar irradiance on which output of the Solar PV depends is depicted in Fig 3.7. The load curve of the EVCS of Ratnapark Station within NEA premise is taken for this research.

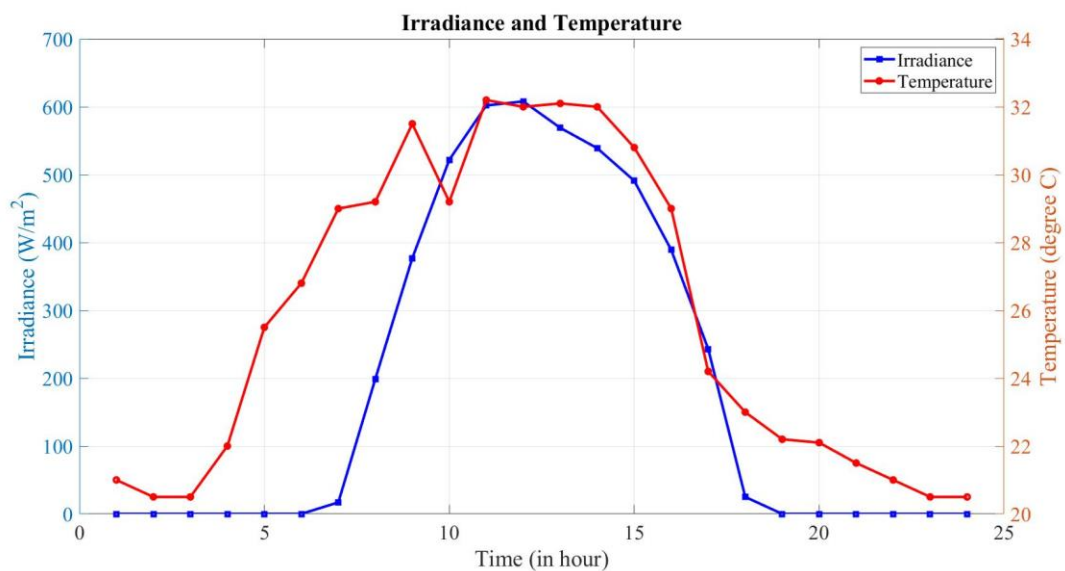


Figure 3.7: Solar Irradiance and temperature versus time

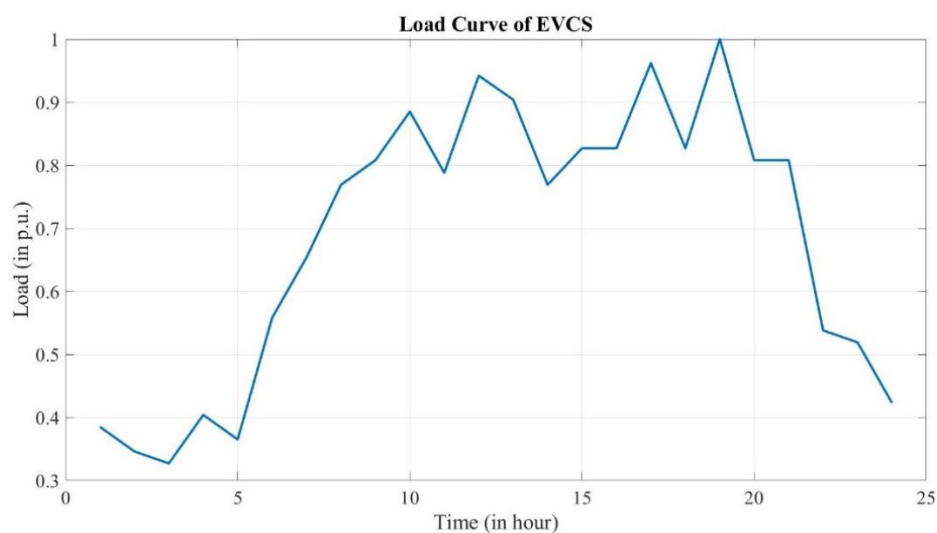


Figure 3.8: Load curve of Ratnapark charging station, NEA

For the test of the research work, IEEE 33 test bus system has been used as it is well documented and the related data are easily available in the internet thus, easy to analysis the research work. Then this work is replicated to real bus system i.e. Byasi feeder and analysis has been done from different perspective. The load curves of the Byasi Feeder of three consecutive days are depicted in Fig 3.9.

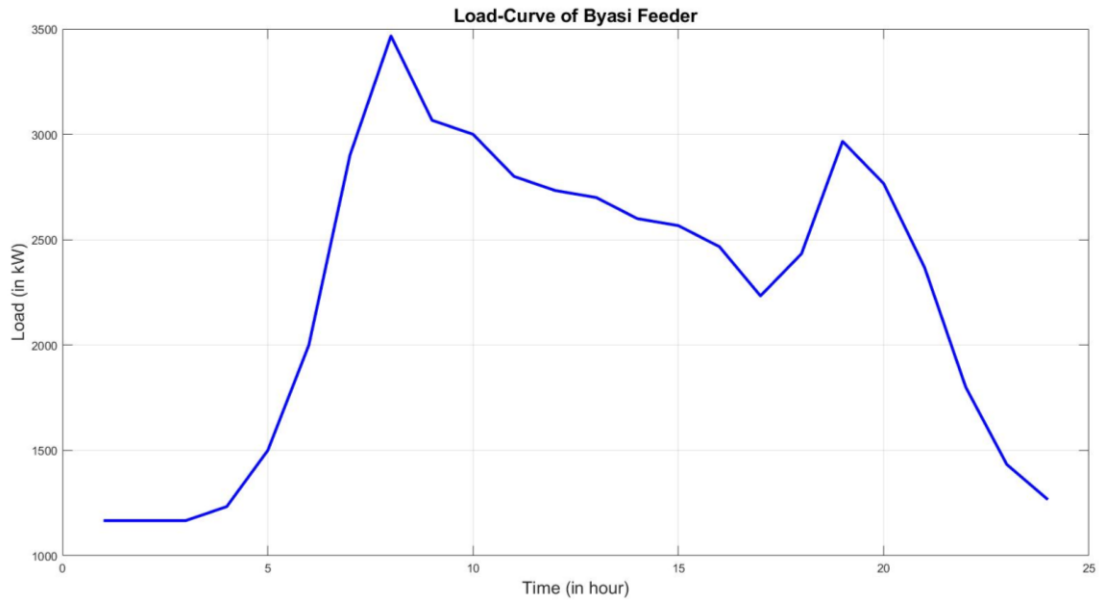


Figure 3.9: Load Curve of Byasi Feeder

3.9. Tools and Software

MATLAB which stands for “MATrix LABoratory”, is a numeric computing tool in the form of matrix introduced by MathWorks. It can be used to perform multiple tasks like matrix manipulations, algorithm implementations, user interface design as well as simulation of electrical, mechanical, control system and so on. Electrical tasks like electrical circuit design, load flow analysis, fault analysis, PID tuning and many more can be carried out in this platform.

In this research, the proposed algorithm was programmed in MATLAB (R2021a) and executed for testing and debugging on a PC with an Intel® Core™ i5-7200U processor (2.50 GHz base, 2.70 GHz max) and 4 GB of memory.

CHAPTER FOUR : RESULTS AND DISCUSSION

This study aims to reduce active power losses and improve the voltage profile in an EVCS – integrated RDS through the optimal placement and sizing of Solar PV and BESS. The research begins by analyzing the IEEE 33-bus test system under four distinct scenarios.

- **Case I:** A load flow analysis is conducted on the standard IEEE 33-bus system to determine baseline active power losses and voltage profiles.
- **Case II:** The system is re-evaluated after integrating 150 kW EVCS (@ 0.85 lagging power factor) at four different prime locations, with subsequent observations on power loss and voltage behavior.
- **Case III:** PSO algorithm is employed to determine the optimal sizing and placement of Solar PV and BESS, followed by load flow analysis to assess their impact on system performance.
- **Case IV:** The optimized size of Solar PV and BESS configurations are obtained after placing them at the same locations as the EVCSs and comparative analysis has been performed with the above case.

Additionally, an energy management strategy is implemented to regulate power flow among Solar PV, BESS, and load demand—including EVCS consumption. After validating the results on the IEEE 33-bus system, the same methodology is applied to the Byasi feeder for further verification.

Finally, a financial analysis is performed to assess the project's economic feasibility, along with an evaluation of how weighting factors in the multi-objective function influence the optimal solution.

4.1.IEEE 33 Test Bus System

The rated line voltage of the system is 12.66 kV, and the base power is 100 MVA. The total active load of the system is 3715 kW, and the reactive load is 2300 kVAR distributed along 33 buses (Santoso et al., 2018).

4.1.1. Base Case Scenario validation

Load flow analysis has been done in MATLAB using backward/forward sweep algorithm. After analysis, it is observed that there is active power loss of 202 kW with the minimum voltage of 0.9134 p.u. at bus 18 shown in Fig 4.1. which is exactly with the result of (Mohamed Imran et al., 2014). It shows that the network parameters considered in this work matches with that of reference.

4.1.2. With EVCSs at prime locations

In this case, EVCSs of 150 kW @0.85 lagging pf has been placed at four different prime locations of bus no. 4, 8, 12 and 26 then load flow analysis has been carried out. After load flow, it is observed that the integration of EVCSs in the systems increased the active power loss to 281 kW which is 39.11% higher as compared to base case of 202 kW and voltage of the minimum bus i.e. bus 18 further decreased to 0.8954 p.u. which is 1.97% lower as that of base case. It is clear from the Fig 4.1 that the voltage magnitude has been decreasing gradually from bus 2 to bus 18 and then from bus 19 to bus 33.

4.1.3. With Optimal Size of Solar PV and BESS at Optimal Locations

Addition of EVCSs in the radial distribution feeder further degrades the voltage profile of the system as well as increase the power loss in the system. To maintain the voltage within the permissible limit, integration of Solar PV with BESS has been done. The optimal placement and sizing have been determined through the use of PSO algorithm and found to be 473 kW, 506 kW, 430 kW, 498 kW of Solar PV and 323 kW, 266 kW, 282 kW, 294 kW of BESS at bus no. 6, 8, 14, 31 respectively. The study has been done for battery coupled Solar PV system, that's the reason why the location is same for both Solar PV and BESS. With their integration, the voltage of the minimum bus rises to 0.9757 p.u. at bus 30 and total active power loss reduces to 94 kW. This shows that the minimum voltage of the system has been improved by 8.98% while the active power loss of the system has been decreased saved by 66.55% as compared to second case.

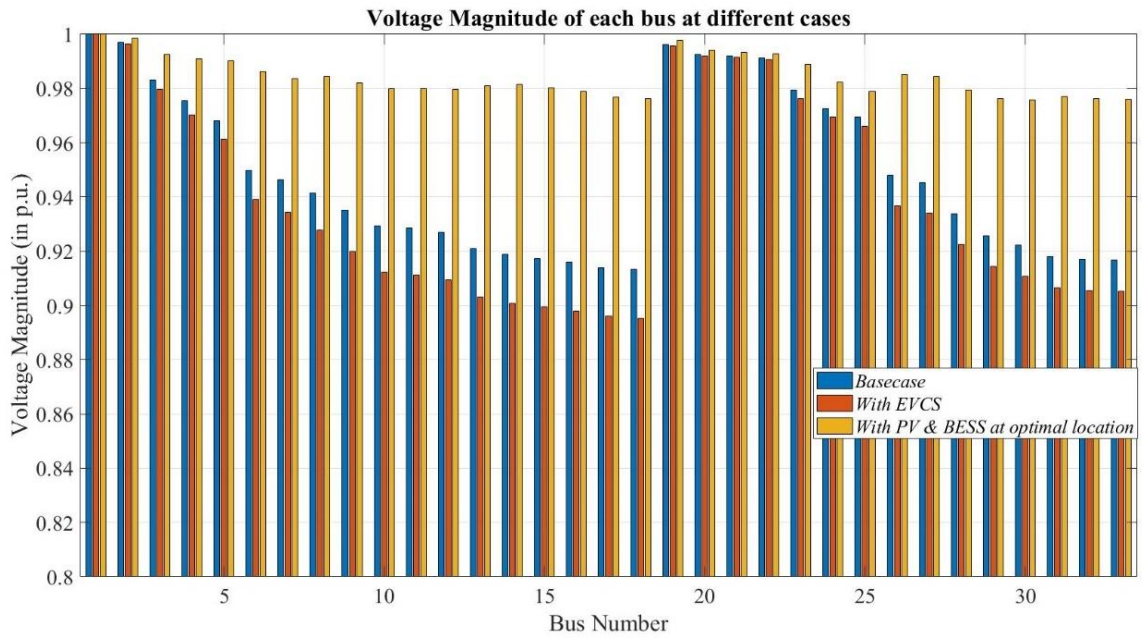


Figure 4.1: Voltage profile of IEEE 33 test bus system with Solar PV and BESS at optimal locations

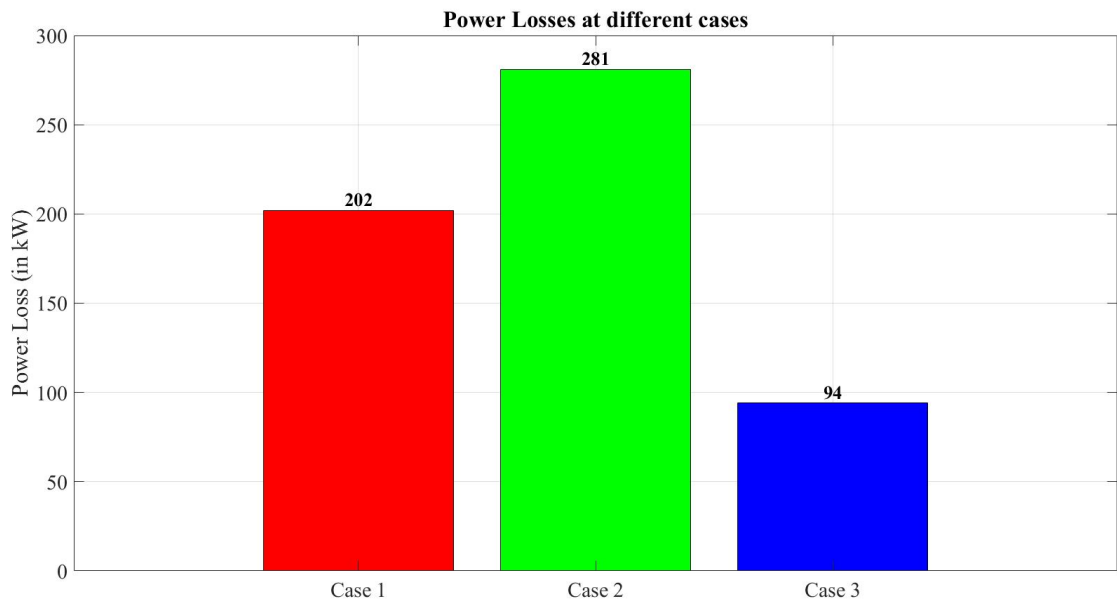


Figure 4.2: Power Loss Comparison of IEEE 33 test bus system with Solar PV and BESS at optimal locations

With the incorporation of Solar PV and battery, not only the power loss reduces and voltage profile improves but also there is peak shaving and shifting of load in the system. For this system, the duration of battery has been taken as four hours that leads to the capacity of the battery becomes 1511 kWh, 1244 kWh, 1319 kWh and 1375 kWh which sums to 5449 kWh of battery capacity and 1906 kW of Solar PV in the grid. These optimized configurations help manage demand-side energy usage while

improving grid stability. The peak load of the system is 4315 kW at 7 PM. With the dispatching of the solar PV and battery as per algorithm mentioned earlier, the peak load of the system at 7 PM reduces to 3205 kW i.e. 25.72% reduction. This depicts that the proposed system is successful in shifting and curtailing the load of the system.

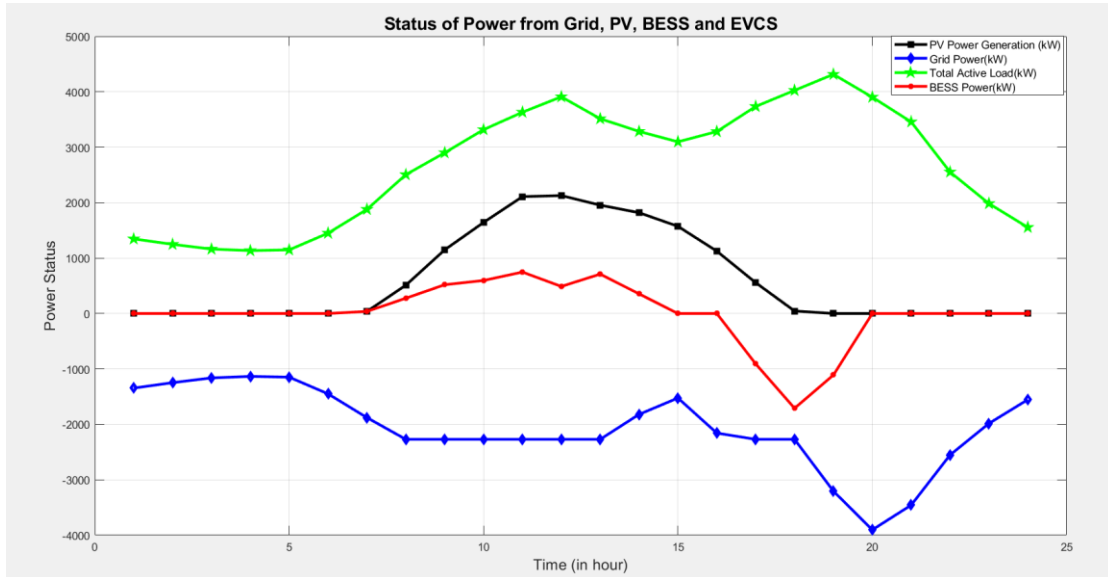


Figure 4.3: Load Management with Solar PV and BESS in IEEE 33 Bus

4.1.4. With Optimal Size of Solar PV and BESS at EVCSs Locations

In the present scenario, integration of renewable source of energy for assisting the grid connected charging station has been increasing drastically as they possess numerous advantages and are financially viable. However, while integrating these resources, regardless the loading condition of the feeder, they usually placed at the points of the EVCS. The analysis of this trend has been done in this research work whether it is beneficial or not from grid perspective. For this, we have fixed the battery coupled Solar PV in the same locations as that of EVCSs and then optimization algorithm has been implemented to get the optimal size. From this, the optimal sizes of Solar PV are 541 kW, 541 kW, 541 kW and 541 kW i.e. the maximum allowable size of the Solar PV and 325 kW, 325 kW, 325 kW, 325 kW of battery at locations of bus 4, 8, 12 and 26 respectively. This sums the total size of Solar PV becomes 2164 kW and that of BESS becomes 1299 kW which are 13.54% and 11.40% greater as compared to that of Solar PV and Battery at optimal locations respectively. Despite of increase in the size

of PV-BESS, the active power loss is still higher i.e. 106 kW and minimum bus voltage is 0.9535 p.u. at bus 33.

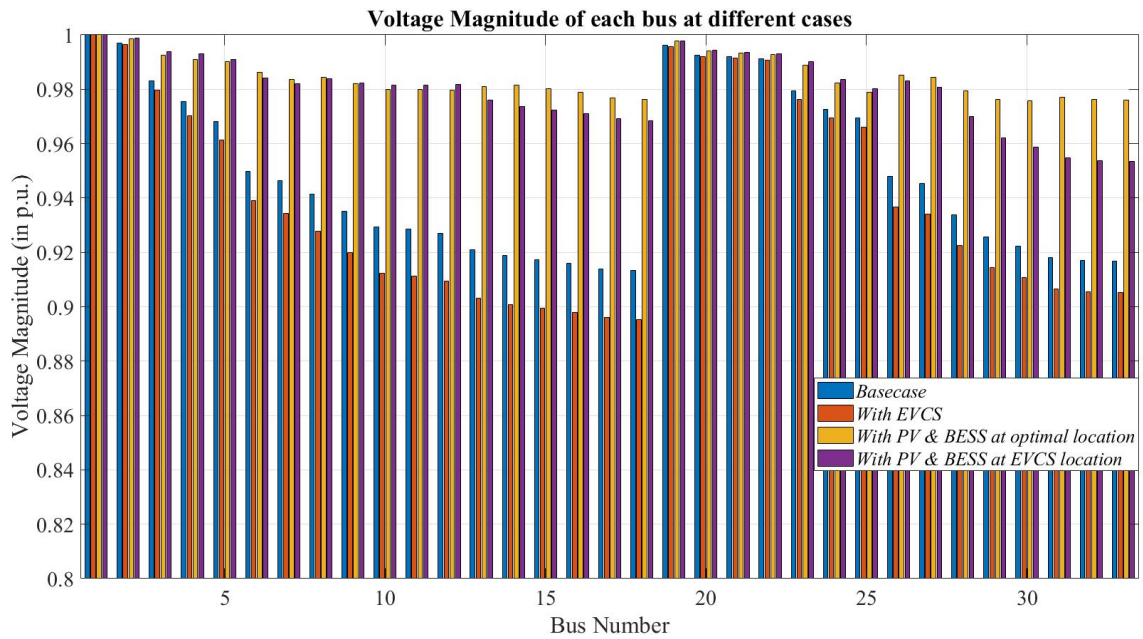


Figure 4.4: Voltage profile of IEEE 33 test bus with Solar PV and BESS at EVCSs' locations

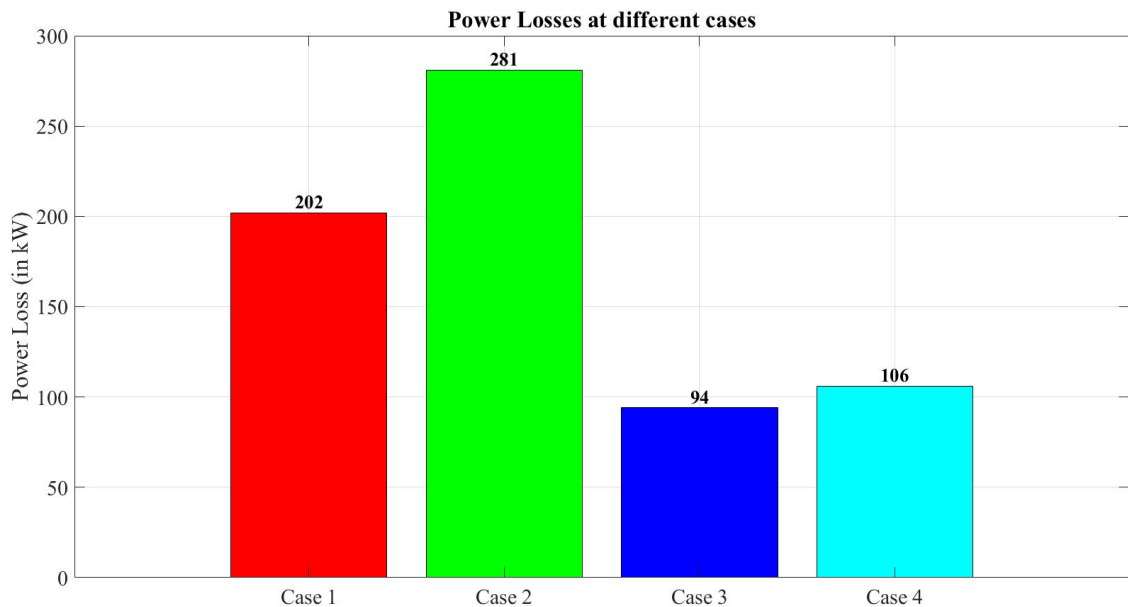


Figure 4.5: Power Loss Comparison of IEEE 33 test bus system at different cases

From the analysis, it is clear that the placement of the renewable source of energy should be based on the loading condition of the feeder rather than the charging location in order to achieve technical benefits.

4.2. Byasi Feeder

4.2.1. Base Case

The active power loss of the Byasi feeder without any placement of EVCSs is 416 kW while the minimum bus voltage is 0.9442 p.u. at bus 28.

4.2.2. With EVCSs at prime locations

The placement of EVCSs of 150 kW @0.85 lagging pf at four different prime locations at bus no. 4, 8, 12 and 26 further degrades the bus voltage while increased the active power loss of the system. After load flow, it is found that the integration of EVCSs in the systems increased the active power loss to 477 kW which is 14.66% higher as compared to base case of 416 kW while voltage of the minimum bus is 0.9404 p.u. at bus 28 which is 1.98% lower as that of base case. It is clear from the Fig 4.6 that the voltage magnitude has been decreasing gradually from bus 2 to bus 14 and then from bus 15 to bus 30.

4.2.3. With Optimal Size of Solar PV and BESS at Optimal Locations

The ideal placement and sizing of PV-BESS maintains the voltage of each bus within the limit and reduces the power loss of the system. The optimal placement and sizing for Byasi feeder are found to be 717 kW, 567 kW, 730 kW, 562 kW of Solar PV and 217 kW, 143 kW, 435 kW, 516 kW of BESS at bus no. 8, 18, 22, 29 respectively. With their integration, the voltage of the minimum bus rises to 0.9646 p.u. at bus 28 and total active power loss reduces to 209 kW. This improves the voltage of the minimum bus by 2.57% while the active power loss of the feeder has been saved by 56.18% as compared to second case.

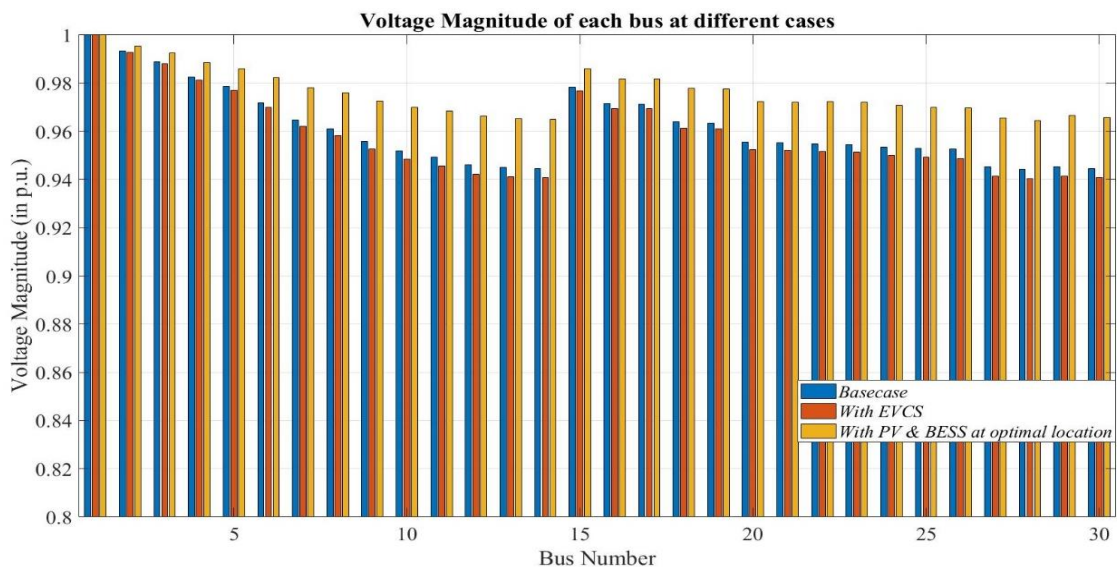


Figure 4.6: Voltage profile of Byasi Feeder with Solar PV and BESS at optimal locations

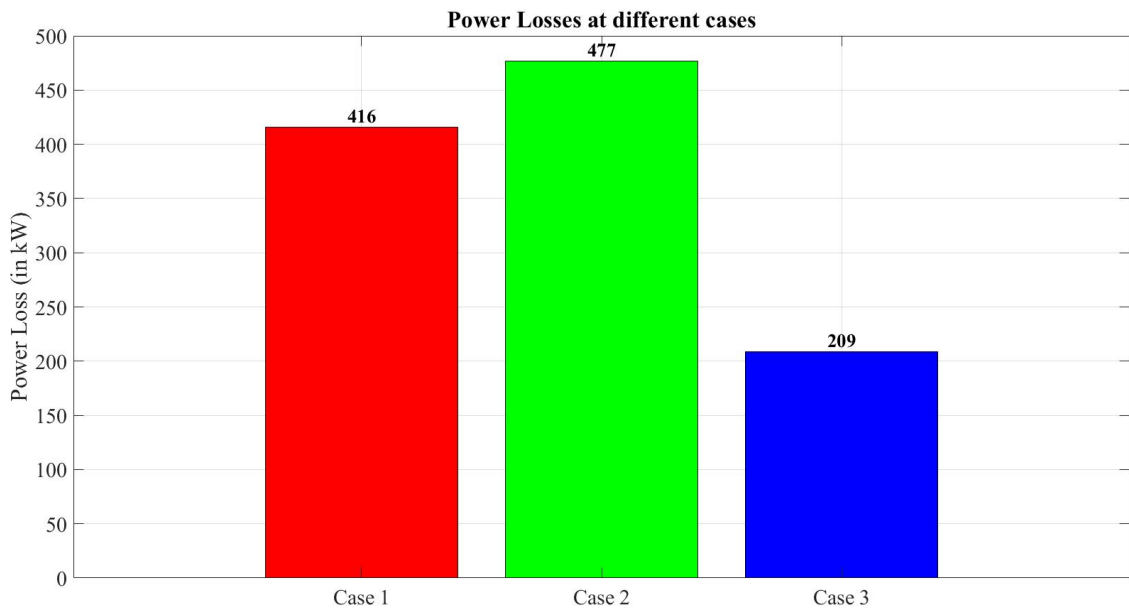


Figure 4.7: Power Loss Comparison of Byasi feeder with Solar PV and BESS at optimal locations

After the integration of Solar PV of size 717 kW, 567 kW, 730 kW and 562 kW which sums to 2576 kW and battery of capacity 1015 kWh, 669 kWh, 2035 kWh and 2414 kWh which sums to 6133 kWh at locations 8, 18, 22 and 29 respectively, the highest load of the system reduces to 3272 kW at 8 AM i.e. 17.4% reduction while the peak load of the system at 7 PM reduces to 2283 kW i.e. 38.3% reduction. Thus, the proposed system assists in shaving and shifting the load of the system.

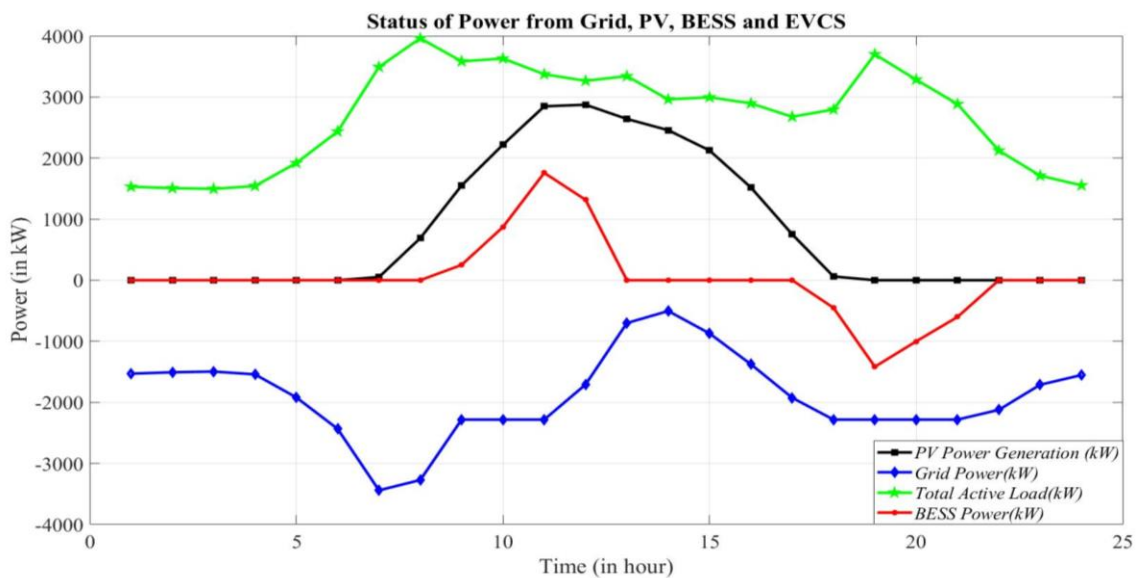


Figure 4.8: Load Management with Solar PV and BESS in Byasi Feeder

4.2.4. With Optimal Size of Solar PV and BESS at EVCSs Locations

If we integrate the Solar PV of size 539 kW, 1081 kW, 787 kW, 301 kW and BESS of size 225 kW, 424 kW, 526 kW, 274 kW obtained from the optimization algorithm in the same location as that of EVCSs, the active power loss of the system reduces to 212 kW while voltage of the minimum bus improves to 0.9646 p.u. at 28. The total size of Solar PV for this case is 2708 kW and that of BESS is 1449 kW which is 5.12% and 10.53% higher respectively. Although the increase in the size of PV-BESS, power loss in the system is still higher compared to case 3. Thus, the placement of PV-BESS for any EVCS in radial feeder should be done after examining the loading status of the feeder.

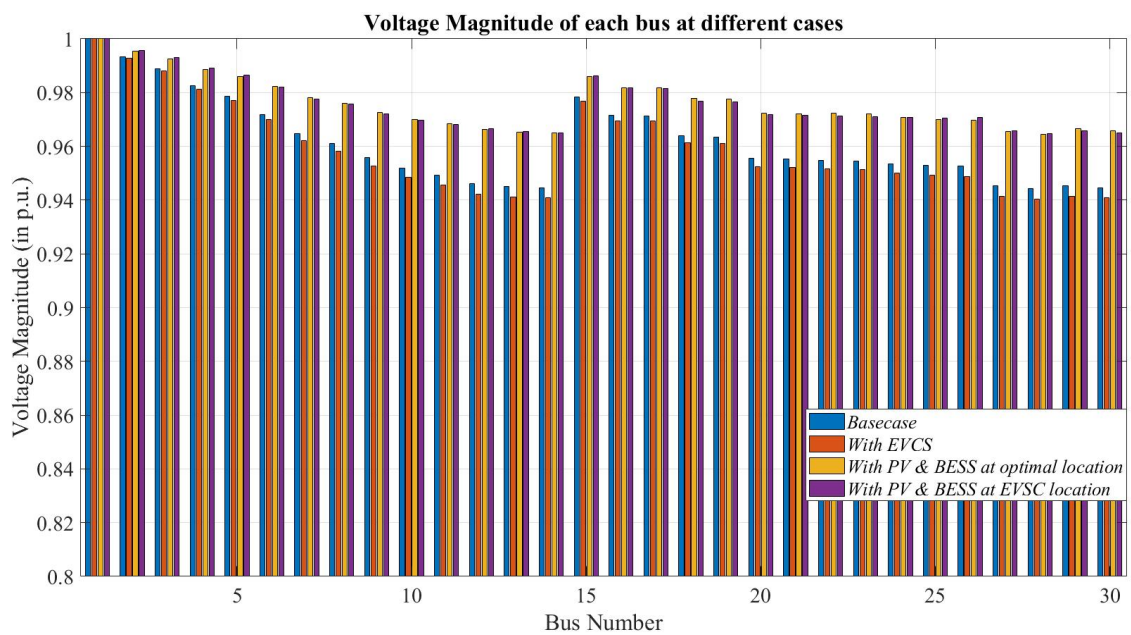


Figure 4.9: Voltage profile of Byasi Feeder with Solar PV and BESS at EVCSs' locations

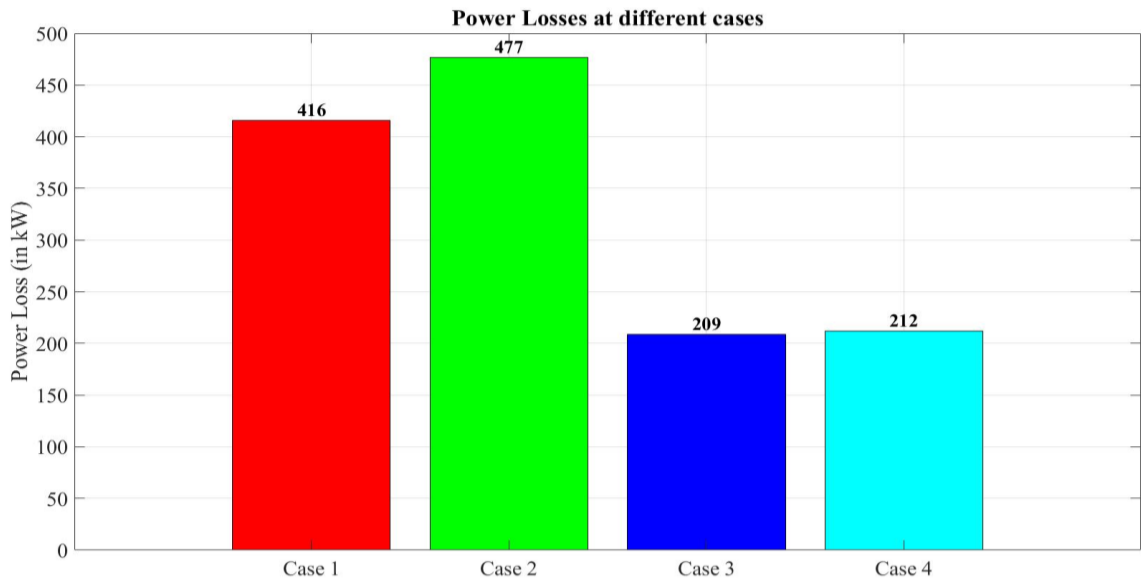


Figure 4.10: Power Loss Comparison of Byasi feeder at different cases

4.2.5. Financial Analysis of the proposed system in Byasi Feeder

The incorporation of the battery-coupled Solar PV system increases the financial burden; however, we can return our investment through the energy saving cost as well as the cost of the energy produced by Solar PV. The cash flow diagram of the proposed system is shown in Fig 4.11.

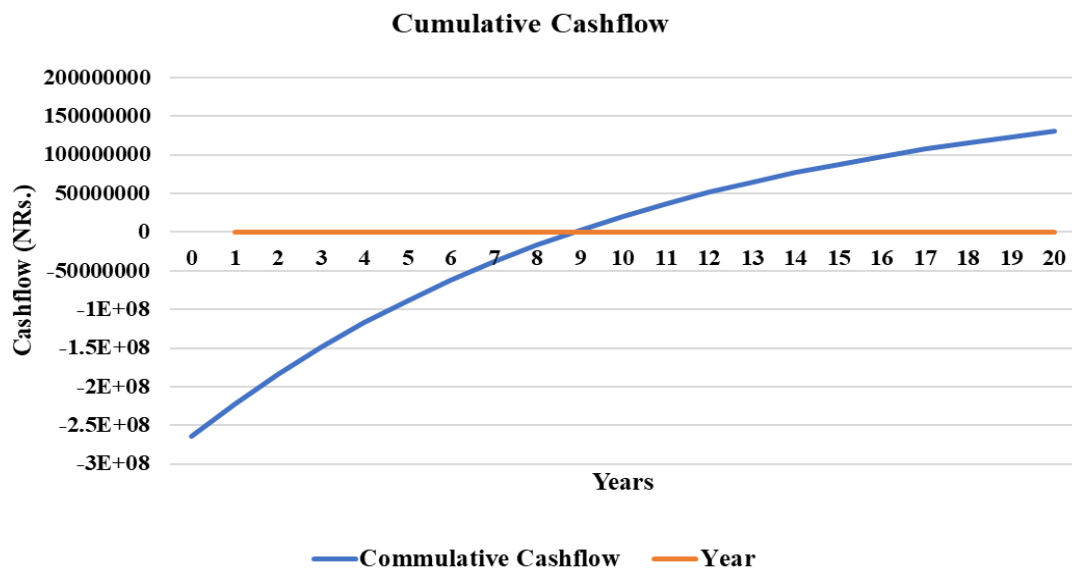


Figure 4.11: Cumulative Cashflow of proposed system in Byasi Feeder

From the above cumulative cashflow diagram, the discounted payback period of the proposed system considering installation cost, battery replacement cost, O &M cost, energy saving cost and cost of energy generated by Solar PV is approximately 9 years.

Thus, the system is financially viable as it generates adequate rate of return on the investment.

The Cumulative cashflow table is shown in appendix K.

4.2.6. Impact Assessment of weighting factors: w1 and w2

The objective function of the study is presented in equation no:3.13.

The weighting factors in a multi-objective function play a crucial role in shaping the final solution by defining the priority of different objectives. These weights influence the optimization process, causing it to favor certain variables over others, thereby defining what constitutes an "optimal" solution based on their assigned values.

When consolidating multiple single-objective functions into a unified framework, weighting factors enable the creation of a composite objective function. This facilitates the identification of a balanced solution that accounts for the relative importance of each objective. However, when objectives hold similar priority, even slight adjustments to these weights can lead to significant shifts in the optimal outcome.

Since the chosen weights reflect the preferences and goals of the decision-maker, their selection requires careful consideration of the underlying objectives and operational context (Chatterjee et al., 2024; Togo et al., 2022).

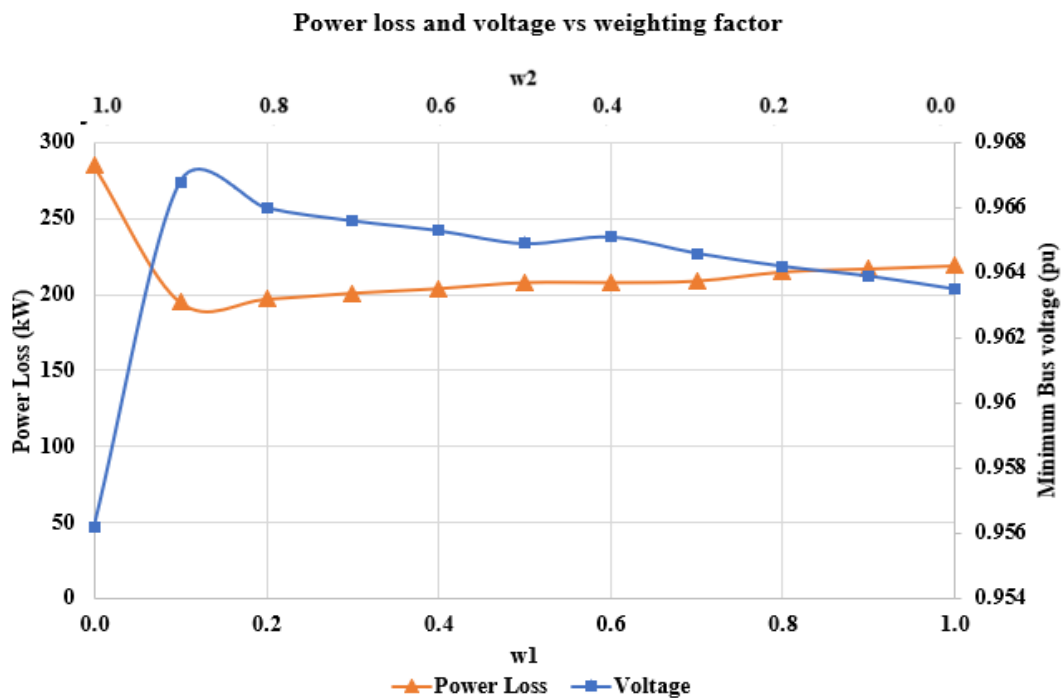


Figure 4.12: Power Loss and minimum bus voltage vs weighting factors

The presented Fig 4.12 illustrates the inverse correlation between power loss minimization and voltage regulation. At maximum power loss ($w_1=0$), voltage levels are minimized, whereas optimal voltage conditions ($w_1=0.1$) correspond to the greatest reduction in power loss. This inverse relationship indicates that w_1 and w_2 probably serve as weighting parameters in an optimization framework designed to reconcile voltage enhancement with power loss mitigation in distribution networks. By modifying these weighting coefficients, the optimization process can be tuned to emphasize either voltage stability or efficiency improvement, depending on the operational priorities and technical limitations of the power network.

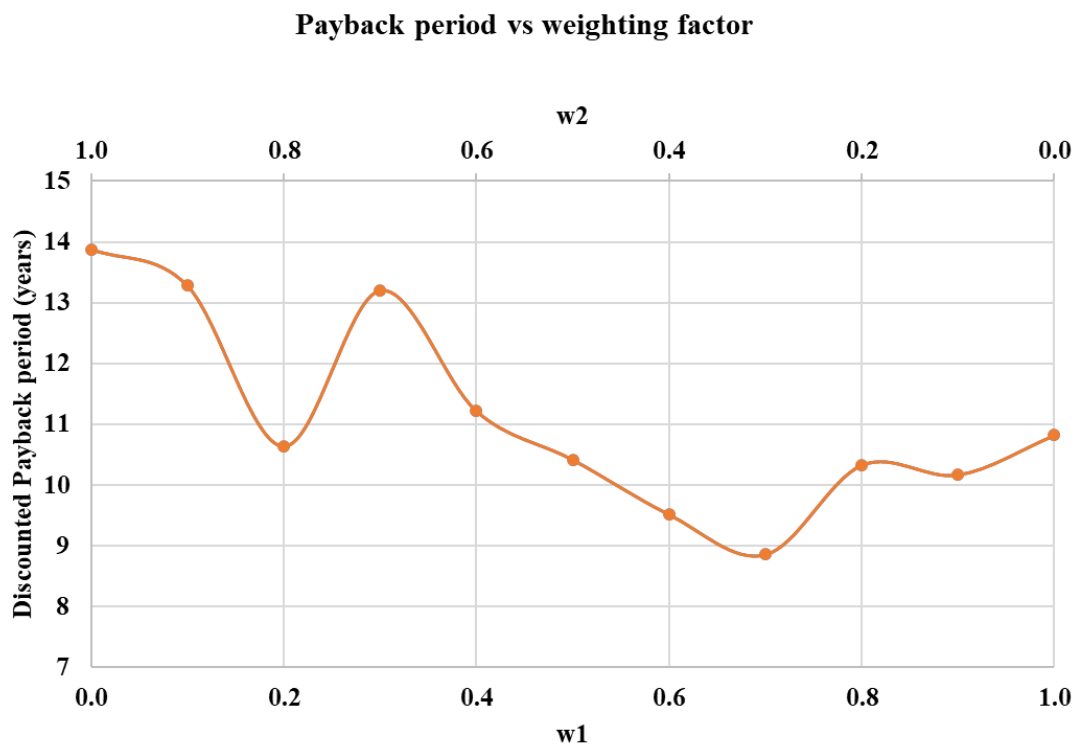


Figure 4.13: Discounted Payback period vs weighting factors

Figure 4.13 reveals the significant influence of weighting factors on the discounted payback period. The analysis shows the most favorable payback duration of approximately 8.9 years occurs when w_1 and w_2 are weighted at 0.7 and 0.3 respectively. This optimal weighting combination enhances investment recovery efficiency, while the nonlinear relationship demonstrates that disproportionate weight allocations at either extreme result in substantially extended payback durations.

CHAPTER FIVE : CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The study demonstrates that the expanding deployment of EV charging infrastructure within RDS creates substantial operational challenges, including voltage fluctuations that may surpass the $\pm 5\%$ threshold specified by IEEE standards, may increase energy dissipation, and possible grid instability concerns. To address these issues, this study introduces an innovative PV – BESS system solution that employs PSO techniques to determine optimal placement and sizing, offering superior results compared to conventional co-installation approaches with charging stations. Implementation results show remarkable improvements across test cases: in the IEEE 33-bus configuration, power losses saved by 66.55% (from 281 kW to 94 kW) through the installation of 1,907 kW of solar capacity combined with 1,165 kW of battery storage, accompanied by an 8.98% voltage profile enhancement (increasing from 0.8953 to 0.9757 p.u.). Similar benefits were observed in the Byasi feeder system, where losses saved by 56.18% (from 477 kW to 209 kW) using 2,576 kW of solar PV and 1,311 kW of battery capacity, while voltage levels improved by 2.57% (from 0.9404 to 0.9646 p.u.). The implemented energy management framework successfully reduced maximum system demand of the Byasi feeder by 17.4% (from 3,961 kW to 3,272 kW) and achieved a 38.3% decrease in evening peak load (from 3,700 kW to 2,283 kW) at 7 PM along with the reshaping of the load curve of the feeder. Financial assessments indicate the solution offers attractive economic viability, with a calculated payback period of nearly nine years under discounted cash flow analysis. Furthermore, the examination of multi-objective function parameters highlights their importance in achieving optimal trade-offs between system performance characteristics and financial considerations for renewable energy integration projects. These findings provide valuable insights for utilities planning grid modernization initiatives to accommodate growing EV adoption while maintaining network reliability and efficiency.

5.2. Recommendations

From this study, following points have been recommended for future research:

- Dynamic load modelling can be adopted to assess variable EV demand and renewable intermittency in RDS

- Hybrid optimization algorithms that combine the advantages of ant colony optimization and the GA with PSO can be investigated to provide more reliable and effective results.
- During the dispatching of Solar PV and BESS, linear charging/discharging characteristics of the battery system has been considered, however it's not justifiable. The characteristics of the battery which seems more realistic can be taken into consideration.
- With the penetration of charging stations in the grid, the power quality of the system may further deteriorate which can be considered.

REFERENCES

- Abdel-Mawgoud, H., Kamel, S., Rezk, H., Khurshaid, T., & Rhee, S. B. (2021). Optimal Implementation of Photovoltaic and Battery Energy Storage in Distribution Networks. *Computers, Materials and Continua*, *69*(2), 1463–1481. doi: 10.32604/cmc.2021.017995
- Alzahrani, A., Alharthi, H., & Khalid, M. (2019). Minimization of power losses through optimal battery placement in a distributed network with high penetration of photovoltaics. *Energies*, *13*(1), 1–16. doi: 10.3390/en13010140
- Bahrami, A. (2020). *EV Charging Definitions, Modes, Levels, Communication Protocols and Applied Standards*. doi: 10.13140/RG.2.2.15844.53123/11
- Bandyopadhyay, S., Mouli, G. R. C., Qin, Z., Elizondo, L. R., & Bauer, P. (2020). Techno-Economical Model Based Optimal Sizing of PV-Battery Systems for Microgrids. *IEEE Transactions on Sustainable Energy*, *11*(3), 1657–1668. doi: 10.1109/TSTE.2019.2936129
- Bhatti, A. R., Salam, Z., Sultana, B., Rasheed, N., Awan, A. B., Sultana, U., & Younas, M. (2019). Optimized sizing of photovoltaic grid-connected electric vehicle charging system using particle swarm optimization. *International Journal of Energy Research*, *43*(1), 500–522. doi: 10.1002/er.4287
- Chaouachi, R., Kamel, M., Andoulsi, R., & Nagasaka, K. (2013). Multiobjective Intelligent Energy Management for a Microgrid. *IEEE Transactions on Industrial Electronics*, *60*(4), 1688–1699. doi: 10.1109/TIE.2012.2188873
- Chatterjee, S., & Chakraborty, S. (2024). A study on the effects of objective weighting methods on TOPSIS-based parametric optimization of non-traditional machining processes. *Decision Analytics Journal*, *11*, 100451. doi: <https://doi.org/10.1016/j.dajour.2024.100451>
- Chaudhari, K., Ukil, A., Kumar, K. N., Manandhar, U., & Kollimalla, S. K. (2018). Hybrid Optimization for Economic Deployment of ESS in PV-Integrated EV Charging Stations. *IEEE Transactions on Industrial Informatics*, *14*(1), 106–116. doi: 10.1109/TII.2017.2713481

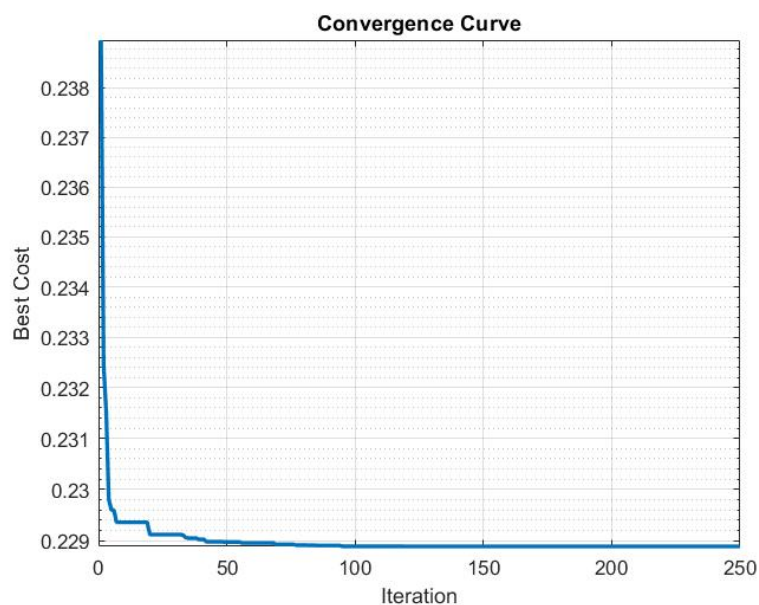
- Chedid, R., & Sawwas, A. (2019). Optimal placement and sizing of photovoltaics and battery storage in distribution networks. *Energy Storage*, 1(4). doi: 10.1002/est2.46
- Chen, X., Shen, W., Vo, T., Cao, Z., & Kapoor, A. (2012). An overview of lithium-ion batteries for electric vehicles. In 10th International Power and Energy Conference, IPEC 2012. doi: 10.1109/ASSCC.2012.6523269
- Deosaria, T., Choudhary, S., & Meena, T. (2022). Load flow analysis using Forward and Backward sweep, and minimising power losses using Genetic Algorithm. *International Journal of Advances in Engineering and Management (IJAEM)*, 4(5), 763–772. doi: 10.35629/5252-0405763772
- Dhaked, D. K., & Birla, D. (2021). Microgrid Designing for Electrical Two-Wheeler Charging Station Supported by Solar PV and Fuel Cell. *Indian Journal of Science and Technology*, 14(30), 2517–2525. doi: 10.17485/IJST/v14i30.224
- Dharmakeerthi, C. H., Mithulananthan, N., & Saha, T. K. (2012). Modeling and planning of EV fast charging station in power grid. *2012 IEEE Power and Energy Society General Meeting*, 1–8. doi: 10.1109/PESGM.2012.6345008
- Eberhart, R., & Kennedy, J. (1995). A New Optimizer Using Particle Swarm Theory. *MHS'95. Proceedings of the Sixth International Symposium on Micro Machine and Human Science*, 39–43. doi: 10.1109/MHS.1995.494215
- Gad, A. G. (2022). Particle Swarm Optimization Algorithm and Its Applications: A Systematic Review. *Archives of Computational Methods in Engineering*, 29(5), 2531–2561. doi: 10.1007/s11831-021-09694-4
- International Energy Agency. (2023). Global EV Outlook 2023: Catching up with climate ambitions. In International Energy Agency, IEA. Retrieved from www.iea.org
- Janamala, V., & Sreenivasulu Reddy, D. (2021). Coyote optimization algorithm for optimal allocation of interline –Photovoltaic battery storage system in islanded electrical distribution network considering EV load penetration. *Journal of Energy Storage*, 41, 1–10. doi: 10.1016/j.est.2021.102981

- Kilicoglu, H., & Tricoli, P. (2023). Technical Review and Survey of Future Trends of Power Converters for Fast-Charging Stations of Electric Vehicles. *Energies*, *16*(13), 1–19. doi: 10.3390/en16135204
- Leonori, S., Martino, A., Frattale Mascioli, F. M., & Rizzi, A. (2020). Microgrid Energy Management Systems Design by Computational Intelligence Techniques. *Applied Energy*, *277*. doi: 10.1016/j.apenergy.2020.115524
- Maleki, A., Ameri, M., & Keynia, F. (2015). Scrutiny of multifarious particle swarm optimization for finding the optimal size of a PV/wind/battery hybrid system. *Renewable Energy*, *80*, 552–563. doi: 10.1016/j.renene.2015.02.045
- Mastoi, M. S., Zhuang, S., Munir, H. M., Haris, M., Hassan, M., Usman, M., Bukhari, S. S. H., & Ro, J. S. (2022). An in-depth analysis of electric vehicle charging station infrastructure, policy implications, and future trends. *Energy Reports*, *8*, 11504–11529. doi: 10.1016/j.egy.2022.09.011
- Meng, L., Sanseverino, E. R., Luna, A., Dragicevic, T., Vasquez, J. C., & Guerrero, J. M. (2016). Microgrid supervisory controllers and energy management systems: A literature review. *Renewable and Sustainable Energy Reviews*, *60*, 1263–1273. doi: 10.1016/j.rser.2016.03.003
- Mohamed Imran, A., Kowsalya, M., & Kothari, D. P. (2014). A novel integration technique for optimal network reconfiguration and distributed generation placement in power distribution networks. *International Journal of Electrical Power and Energy Systems*, *63*, 461–472. doi: 10.1016/j.ijepes.2014.06.011
- Muthuvel, P., Arul Daniel, S., & Paul, S. K. (2017). Sizing of PV array in a DC nano-grid for isolated households after alteration in time of consumption. *Engineering Science and Technology, an International Journal*, *20*(6), 1632–1641. doi: 10.1016/j.jestch.2017.12.006
- NEA. (2023). *Vidyut*. Kathmandu. Retrieved from <https://www.scribd.com/document/705621913/Vidyut-Bhadra-2080>
- Photovoltaic Energy Factsheet*. (2021). Retrieved from <https://css.umich.edu/publications/factsheets/energy/photovoltaic-energy-factsheet>

- Pompern, N., Premrudeepreechacharn, S., Siritaratiwat, A., & Khunkitti, S. (2023). Optimal Placement and Capacity of Battery Energy Storage System in Distribution Networks Integrated With PV and EVs Using Metaheuristic Algorithms. *IEEE Access*, *11*, 68379–68394. doi: 10.1109/ACCESS.2023.3291590
- Poudyal, R., Loskot, P., & Parajuli, R. (2021). Techno-economic feasibility analysis of a 3-kW PV system installation in Nepal. *Renewables: Wind, Water, and Solar*, *8*(1), 1–18. doi: 10.1186/s40807-021-00068-9
- Prakash, K., Lallu, A., Islam, F. R., & Mamun, K. A. (2017). Review of Power System Distribution Network Architecture. *Proceedings - Asia-Pacific World Congress on Computer Science and Engineering 2016 and Asia-Pacific World Congress on Engineering 2016, APWC on CSE/APWCE 2016*, 124–130. doi: 10.1109/APWC-on-CSE.2016.030
- Rakhimov, E., Khoshimov, D., Sultonov, S., Jamoldinov, F., Imyaminov, A., & Omonov, B. (2024). Battery technologies: Exploring different types of batteries for energy storage. *BIO Web of Conferences*, *84*. doi: 10.1051/bioconf/20248405034
- Rathore, N., Panwar, N. L., Yettou, F., & Gama, A. (2021). A comprehensive review of different types of solar photovoltaic cells and their applications. In *International Journal of Ambient Energy* (Vol. 42, Issue 10, pp. 1200–1217). Taylor and Francis Ltd. doi: 10.1080/01430750.2019.1592774
- Ritchie, H. (2020). Cars, planes, trains: where do CO₂ emissions from transport come from? In *Our World in Data*.
- Santoso, D. B., Sarjiya, S., & Sakti, F. P. (2018). Optimal Sizing and Placement of Wind-Based Distributed Generation to Minimize Losses Using Flower Pollination Algorithm. *JTERA (Jurnal Teknologi Rekayasa)*, *3*(2), 167–176. doi: 10.31544/jtera.v3.i2.2018.167-176
- Scalfati, D., Iannuzzi, M. F., & M. Roscia. (2017). Optimal sizing of distributed energy resources in smart microgrids: A mixed integer linear programming formulation. *IEEE 6th International Conference on Renewable Energy Research and Applications (ICRERA)*, 568–573.

- Shrestha, N. (2023). Financial Analysis of Utility Scale Photovoltaic System with Battery Energy Storage System in Nepal [Institute of Engineering, IOE]. In Tribhuvan University. Retrieved from <https://elibrary.tucl.edu.np/JQ99OgQIizUxyjI9nB0on9OyLkqsGI4/api/core/bitstreams/66a5ca72-2d7d-4966-824b-08f893f540bc/content>
- Shukla, A., Verma, K., & Kumar, R. (2018). Voltage-dependent modelling of fast charging electric vehicle load considering battery characteristics. *IET Electrical Systems in Transportation*, 8(4), 221–230. doi: 10.1049/iet-est.2017.0096
- Sufyan, M., Rahim, N. A., Muhammad, M. A., Tan, C. K., Raihan, S. R. S., & Bakar, A. H. A. (2020). Charge coordination and battery lifecycle analysis of electric vehicles with V2G implementation. *Electric Power Systems Research*, 184. doi: 10.1016/j.epsr.2020.106307
- Tian, H., Tzelepis, D., & Papadopoulos, P. N. (2021). Electric vehicle charger static and dynamic modelling for power system studies. *Energies*, 14(7), 1–16. doi: 10.3390/en14071801
- Togo, H., Asanuma, K., Nishi, T., & Liu, Z. (2022). Machine Learning and Inverse Optimization for Estimation of Weighting Factors in Multi-Objective Production Scheduling Problems. *Applied Sciences*, 12(19). doi: 10.3390/app12199472
- Torreglosa, J. P., García-Triviño, P., Fernández-Ramírez, L. M., & Jurado, F. (2016). Decentralized energy management strategy based on predictive controllers for a medium voltage direct current photovoltaic electric vehicle charging station. *Energy Conversion and Management*, 108, 1–13. doi: 10.1016/j.enconman.2015.10.074
- ZIADI, Y., & Hassan, Q. (2015). A High Efficiency Li-Ion Battery LDO-Based Charger for Portable Application. *Active and Passive Electronic Components*, 2015, 1–9. doi: 10.1155/2015/591986

APPENDIX A: Convergence Curve of the optimization process



APPENDIX B: Parameters of IEEE 33 Test Bus System ($V_{base} = 12.66$ kV; $S_{base} = 100$ MVA)

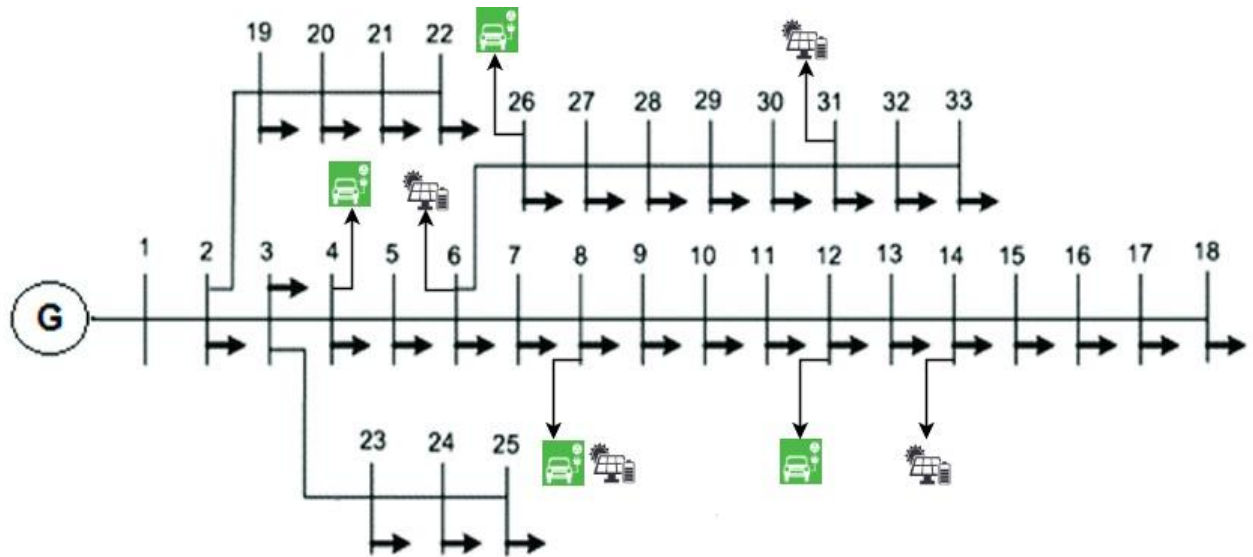
Sending Bus	Receiving Bus	R (Ohm)	X (Ohm)	Load at Receiving Bus	
				P _L (kW)	Q _L (kVAr)
1	2	0.0922	0.0470	100	60
2	3	0.4930	0.2511	90	40
3	4	0.3660	0.1864	120	80
4	5	0.3811	0.1941	60	30
5	6	0.8190	0.7070	60	20
6	7	0.1872	0.6188	200	100
7	8	0.7114	0.2351	200	100
8	9	1.0300	0.7400	60	20
9	10	1.0440	0.7400	60	20
10	11	0.1966	0.0650	45	30
11	12	0.3744	0.1238	60	35
12	13	1.4680	1.1550	60	35
13	14	0.5416	0.7129	120	80
14	15	0.5910	0.5260	60	10
15	16	0.7463	0.5450	60	20
16	17	1.2890	1.7210	60	20

17	18	0.7320	0.5740	90	40
2	19	0.1640	0.1565	90	40
19	20	1.5042	1.3554	90	40
20	21	0.4095	0.4784	90	40
21	22	0.7089	0.9373	90	40
3	23	0.4512	0.3083	90	50
23	24	0.8980	0.7091	420	200
24	25	0.8960	0.7011	420	200
6	26	0.2030	0.1034	60	25
26	27	0.2842	0.1447	60	25
27	28	1.0590	0.9337	60	20
28	29	0.8042	0.7006	120	70
29	30	0.5075	0.2585	200	600
30	31	0.9744	0.9630	150	70
31	32	0.3105	0.3619	210	100
32	33	0.3410	0.5302	60	40

APPENDIX C: Solar Irradiation and Temperature of a day

Time (in hour)	Solar Irradiation (W/m²)	Temperature (°C)	Time (in hour)	Solar Irradiation (W/m²)	Temperature (°C)
1	0	21	13	569	32.1
2	0	20.5	14	539	32
3	0	20.5	15	491	30.8
4	0	22	16	389	29
5	0	25.5	17	243	24.2
6	0	26.8	18	25	23
7	17	29	19	0	22.2
8	199	29.2	20	0	22.1
9	377	31.5	21	0	21.5
10	522	29.2	22	0	21
11	602	32.2	23	0	20.5
12	608	32	24	0	20.5

APPENDIX D: SLD of IEEE 33 Test Bus System integrated with EVCSs, Solar PV and BESS



APPENDIX E: Bus Voltages of IEEE 33 Test Bus System

Bus Number	At Base Case	With EVCS	With Solar PV and Battery at Optimal Location	With Solar PV and Battery at EVCSs' Location
1	1.0000	1.0000	1.0000	1.0000
2	0.9970	0.9965	0.9985	0.9987
3	0.9830	0.9798	0.9925	0.9938
4	0.9755	0.9703	0.9910	0.9930
5	0.9682	0.9613	0.9903	0.9911
6	0.9498	0.9390	0.9861	0.9841
7	0.9463	0.9344	0.9837	0.9820
8	0.9415	0.9277	0.9844	0.9838
9	0.9352	0.9199	0.9820	0.9824
10	0.9294	0.9124	0.9800	0.9815
11	0.9286	0.9113	0.9799	0.9815
12	0.9271	0.9093	0.9798	0.9818
13	0.9210	0.9031	0.9811	0.9760
14	0.9187	0.9008	0.9816	0.9738
15	0.9173	0.8994	0.9802	0.9724
16	0.9160	0.8980	0.9789	0.9711

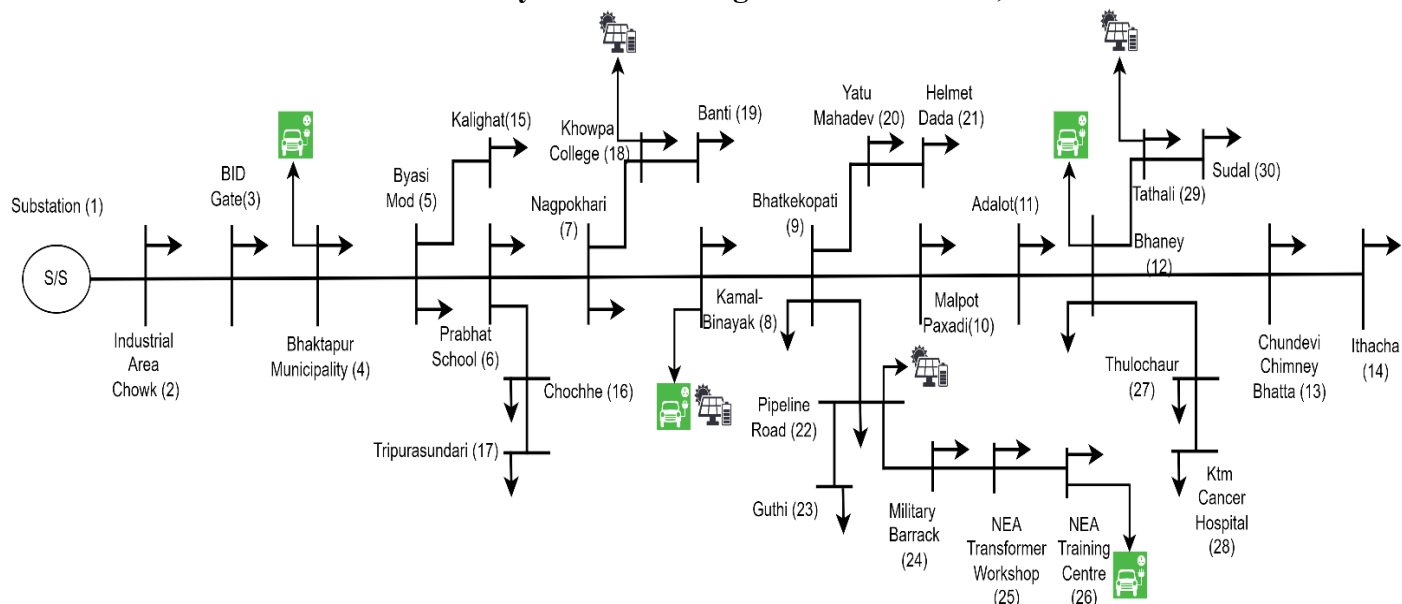
17	0.9140	0.8960	0.9769	0.9691
18	0.9134	0.8954	0.9763	0.9685
19	0.9962	0.9957	0.9977	0.9979
20	0.9926	0.9921	0.9941	0.9943
21	0.9919	0.9914	0.9934	0.9936
22	0.9913	0.9908	0.9928	0.9930
23	0.9794	0.9762	0.9889	0.9902
24	0.9727	0.9695	0.9823	0.9836
25	0.9694	0.9661	0.9790	0.9803
26	0.9479	0.9368	0.9852	0.9831
27	0.9453	0.9342	0.9843	0.9807
28	0.9339	0.9227	0.9794	0.9699
29	0.9257	0.9144	0.9762	0.9621
30	0.9222	0.9108	0.9757	0.9588
31	0.9180	0.9066	0.9771	0.9547
32	0.9171	0.9056	0.9762	0.9538
33	0.9168	0.9053	0.9759	0.9535

APPENDIX F: Parameters of Byasi Feeder ($V_{base} = 11 \text{ kV}$; $S_{base} = 100 \text{ MVA}$)

					XLPE 150 Sq.mm AL conductor		R(ohm/km)	0.259
							X(ohm/km)	0.075
Bus No.	Bus ID	Sending Bus	Receiving Bus	Branch (km)	R (Ohm)	X (Ohm)	Load at Receiving End	
							PL (kW)	QL (kVAr)
1	Substation		1				0.00	0.00
2	Industrial Area Chowk	1	2	0.3	0.078	0.022	422.40	228.00
3	BID Gate	2	3	0.2	0.052	0.015	211.20	114.00
4	Bhaktapur Municipality	3	4	0.3	0.078	0.022	246.40	133.00
5	Byashi Mod	4	5	0.2	0.052	0.015	246.40	133.00

6	Prabhat School	5	6	0.35	0.091	0.026	140.80	76.00
7	Nagpokhari	6	7	0.4	0.104	0.030	633.60	342.00
8	Kamal Binayak	7	8	0.25	0.065	0.019	422.40	228.00
9	Bhatkekopati	8	9	0.4	0.104	0.030	633.60	342.00
10	Malpot Paxadi	9	10	0.55	0.142	0.041	422.40	228.00
11	Adalot	10	11	0.45	0.117	0.034	211.20	114.00
12	Bhaney	11	12	0.6	0.155	0.045	281.60	152.00
13	Chundevi Chimney Bhattaa	12	13	0.7	0.181	0.052	281.60	152.00
14	Ithacha	13	14	0.6	0.155	0.045	281.60	152.00
15	Kalighat	5	15	0.3	0.078	0.022	281.60	152.00
16	Chochhe	6	16	0.6	0.155	0.045	140.80	76.00
17	Tripurasundari	16	17	0.25	0.065	0.019	140.80	76.00
18	Khowpa College	7	18	0.4	0.104	0.030	352.00	190.00
19	Banti	18	19	0.3	0.078	0.022	457.60	247.00
20	Yatu Mahadev	9	20	0.35	0.091	0.026	211.20	114.00
21	Helmet Dada	20	21	0.65	0.168	0.048	140.80	76.00
22	Pipeline Road	9	22	0.3	0.078	0.022	140.80	76.00
23	Guthi	22	23	0.15	0.039	0.011	457.60	247.00
24	Military Barrack	22	24	0.6	0.155	0.045	281.60	152.00
25	NEA Transformer Workshop	24	25	0.55	0.142	0.041	281.60	152.00
26	NEA Training Centre	25	26	0.35	0.091	0.026	211.20	114.00
27	Thulochaur	12	27	0.6	0.155	0.045	211.20	114.00
28	Ktm Cancer Hospital	27	28	1.4	0.363	0.104	281.60	152.00
29	Tathali	12	29	0.37	0.096	0.028	281.60	152.00
30	Sudal	29	30	0.63	0.163	0.047	457.60	247.00
				13.7			8764.80	4731

APPENDIX G: SLD of Byasi Feeder integrated with EVCSs, Solar PV and BESS



APPENDIX H: Load Profile of Byasi Feeder

Time	2/29/2024	3/1/2024	3/2/2024	Time	2/29/2024	3/1/2024	3/2/2024
1	1300	1200	1000	13	2800	2700	2600
2	1300	1200	1000	14	2500	2700	2600
3	1300	1200	1000	15	2500	2600	2600
4	1300	1300	1100	16	2400	2600	2400
5	1700	1400	1400	17	2100	2300	2300
6	2100	2000	1900	18	2300	2500	2500
7	3100	2900	2700	19	3100	2900	2900
8	3500	3600	3300	20	2800	2700	2800
9	3100	3000	3100	21	2400	2200	2500
10	3100	2900	3000	22	1800	1700	1900
11	2900	2800	2700	23	1400	1400	1500
12	2700	2800	2700	24	1300	1200	1300

APPENDIX I: Bus Voltages of Byasi Feeder

Bus Number	At Base Case	With EVCS	With Solar PV and Battery at Optimal Location	With Solar PV and Battery at EVCSs' Location
1	1	1	1	1
2	0.993	0.993	0.9955	0.9957
3	0.989	0.988	0.9927	0.993
4	0.983	0.981	0.9886	0.9891
5	0.979	0.977	0.9861	0.9864
6	0.972	0.97	0.9822	0.9821
7	0.965	0.962	0.9781	0.9777
8	0.961	0.958	0.9761	0.9758
9	0.956	0.953	0.9727	0.972
10	0.952	0.949	0.97	0.9697
11	0.949	0.946	0.9683	0.9682
12	0.946	0.942	0.9664	0.9666
13	0.945	0.941	0.9654	0.9656
14	0.945	0.941	0.9649	0.9651
15	0.978	0.977	0.9859	0.9862
16	0.972	0.97	0.9818	0.9817
17	0.971	0.969	0.9817	0.9816
18	0.964	0.961	0.978	0.9768
19	0.964	0.961	0.9776	0.9765
20	0.956	0.952	0.9724	0.9717
21	0.955	0.952	0.9721	0.9715
22	0.955	0.952	0.9723	0.9713
23	0.955	0.951	0.9721	0.9711
24	0.954	0.95	0.9709	0.9707
25	0.953	0.949	0.97	0.9705
26	0.953	0.949	0.9697	0.9707
27	0.945	0.942	0.9656	0.9658
28	0.944	0.94	0.9646	0.9646
29	0.945	0.942	0.9666	0.9659

30	0.945	0.941	0.9658	0.9651
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APPENDIX J: Technical and Financial Parameters of the study

Parameters	Values
PV System	
Installation Cost (Millions. NRs. /MW)	35
Operation and Maintenance cost (%/year)	1.5 %
Life Span (years)	20
PPA rates (NRs.)	5.94
BESS System	
Installation Cost (NRs. /kWh)	20,000
Replacement Cost (NRs. /kWh)	10,000
Operation and Maintenance cost (%/year)	1.5 %
Life Span (years)	7
Depth of Discharge (%)	90%
BESS duration (hours)	4
Round trip efficiency (%)	95
Cycles per day	1
Other Parameters	
Energy cost (NRs. /kWh)	11.50
Demand cost (NRs. /kVA/month)	240
Discount rate (%/year)	10%
Load factor (Lf)	0.576

APPENDIX K: Cumulative Cashflow of the proposed system for Byasi Feeder

Year	Cashflow	Discounted Cashflow	Cumulative Cashflow
0	-264,348,724.62	-264,348,724.62	-264,348,724.62
1	46,352,490.60	42,138,627.82	-222,210,096.80
2	46,352,490.60	38,307,843.47	-183,902,253.33
3	46,352,490.60	34,825,312.25	-149,076,941.08
4	46,352,490.60	31,659,374.77	-117,417,566.31

5	46,352,490.60	28,781,249.79	-88,636,316.52
6	46,352,490.60	26,164,772.54	-62,471,543.98
7	46,352,490.60	23,786,156.85	-38,685,387.13
8	46,352,490.60	21,623,778.96	-17,061,608.18
9	46,352,490.60	19,657,980.87	2,596,372.69
10	46,352,490.60	17,870,891.70	20,467,264.39
11	46,352,490.60	16,246,265.18	36,713,529.57
12	46,352,490.60	14,769,331.98	51,482,861.56
13	46,352,490.60	13,426,665.44	64,909,527.00
14	46,352,490.60	12,206,059.49	77,115,586.48
15	46,352,490.60	11,096,417.72	88,212,004.20
16	46,352,490.60	10,087,652.47	98,299,656.67
17	46,352,490.60	9,170,593.16	107,470,249.83
18	46,352,490.60	8,336,902.87	115,807,152.70
19	46,352,490.60	7,579,002.61	123,386,155.31
20	46,352,490.60	6,890,002.37	130,276,157.68

APPENDIX L: Impact analysis of weighting factors: w1 and w2

Objective function	w1	w2	Power Loss (kW)	Voltage of Minimum Bus (Bus 28)	PV size (kW)	BESS size (kWh)	Payback Period (yrs)
Min {OF} = (w1×PLRI) + (w2×VDIRI)	0.0	1.0	285	0.9562	1317	5556	13.88
	0.1	0.9	195	0.9668	2415	8971	13.28
	0.2	0.8	197	0.966	2555	7433	10.64
	0.3	0.7	201	0.9656	2249	8460	13.2
	0.4	0.6	204	0.9653	2378	7428	11.22
	0.5	0.5	208	0.9649	2347	6805	10.42
	0.6	0.4	208	0.9651	2721	6823	9.52
	0.7	0.3	209	0.9646	2576	6133	8.86
	0.8	0.2	215	0.9642	2245	6499	10.33
	0.9	0.1	217	0.9639	2505	6839	10.17
1.0	0.0	219	0.9635	2147	6570	10.82	

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