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Analysing EV Charging and DERs Effects on Microgrid Performance and A Multi-IndexApproach for Optimizing

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ABSTRACT

The growing adoption of electric vehicles (EVs) brings new challenges to electricity distribution systems, includingcareful planning of electric vehicle charging station (EVCS) installations. This paper analyzes the impacts of fixed-size Electric Vehicle Charging Stations on the microgrid's reliability and performance across four scenarios. Asystematic, simulation-based methodology was developed to assess the implications of EVCS deployment on someregard, such as voltage imbalances, losses in power, reliability of supply, and the voltage stability index. Thedevelopment of a novel index, termed MORVSL, is proposed comprising several reliability indices such as SAIFI,SAIDI, CAIDI, ENS and the active and reactive losses and the voltage stability deviation index. The analysis aimsto ascertain the effects these indices have on the microgrid and determine the optimal sites for EVCS placement. Thefull analysis is performed on the IEEE-9bus AC microgrid test system with and without istributed energy resourcesoffering new insights in the form of a Simulink 2021a model to test the placement of EVCS. This EV charginginfrastructure has significant effects on the microgrid and optimizing its configuration will contribute to the goals ofhaving more efficient and reliable systems.

Introduction: The shift from conventional internal combustion engine cars to electric vehicles (EVs) is accelerating globally dueto environmental issues and regulations aimed at addressing climate change [1]. The increasing popularity of electriccars has led to a heightened demand for electric vehicle charging stations (EVCS), hence exerting extra pressure onthe current power distribution infrastructure [2]. To guarantee the continuity, reliability, and efficiency of the powergrid, considerable consideration must be given to the integration of EVCS.

The installation of EV charging stations may lead to issues within the distribution network, including increaseddemand, voltage fluctuations, and potential system overload during peak charging periods [4]. These difficultiesmust be investigated and strategised to mitigate adverse effects on overall system performance. Improper placementor overload circumstances of EVCS can result in significant voltage drop, heightened active power losses, andcritically diminished voltage stability [5]. Enhancing the placement and dimensions of charging stations wouldcontribute to maintaining the dependability of the distribution system [6].

NithersWerkaarUndaar has chosen to explore the influence of the EVCS on several system metrics, includingvoltage stability and power flow. 7 It is understandable that there is limited scholarly study employing an integrated,multi-disciplinary strategy to concurrently analyse performance on goals. Numerous studies conducted to date areplagued with ill-posed difficulties due to their reliance on overly simplistic models that exclusively address certainphenomena—such as voltage noise, power supply losses, and other aspects of system operation in a broad sense. [8].

This research, grounded on Multi-Criterion Decision Analysis (MCDA), seeks to address existing deficiencies bydeveloping and incorporating an index function that encompasses essential aspects of a distribution system,including voltage regulation, power losses, reliability indices, and the voltage stability index as pivotal elements.The aim is to investigate various dimensions of EVCS's influence on the operational efficacy of the IEEE 9 bus ACmicrogrids,

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encompassing technical, economic, and ICT-enabled environmental systems thinking style democracy,to identify effective strategies and technologies that facilitate the integration of EV charging infrastructure withinmicrogrid systems to enhance emissions reduction objectives and system equilibrium. [9-10].

Keywords: Electric Vehicle, EVCharging station, Microgrid, Reliability, Stability, Distributed energy resources.

INTRODUCTION

Background on growth of EVs:

The shift from conventional internal combustion engine cars to electric vehicles (EVs) is accelerating globally due to environmental issues and regulations aimed at addressing climate change [1]. The increasing popularity of electric cars has led to a heightened demand for electric vehicle charging stations (EVCS), hence exerting extra pressure onthe current power distribution infrastructure [2]. To guarantee the continuity, reliability, and efficiency of the powergrid, considerable consideration must be given to the integration of EVCS.

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This research, grounded on Multi-Criterion Decision Analysis (MCDA), seeks to address existing deficiencies by developing and incorporating an index function that encompasses essential aspects of a distribution system, including voltage regulation, power losses, reliability indices, and the voltage stability index as pivotal elements. The aim is to investigate various dimensions of EVSC's influence on the operational efficacy of the IEEE 9 bus AC microgrids, encompassing technical, economic, and ICT-enabled environmental systems thinking style democracy, to identify effective strategies and technologies that facilitate the integration of EV charging infrastructure within microgrid systems to enhance emissions reduction objectives and system equilibrium. [9-10].

Importance of EV charging infrastructure in supporting EV growth:

Rapid acceptance of electric vehicles (EVs) is a result of the urgent need to lower greenhouse gas emissions and dependency on fossil fuels. Maintaining the increase as more people switch to EVs depends on reliable andconveniently available charging infrastructure. A well-developed charging network not only solves range anxiety but also increases customer trust, therefore making EV ownership more sensible and attractive. The entire potential of EV adoption—that is, reaching notable emission reductions and enhancing energy security—cannot be completely realised without a strong infrastructure.

Statement of the problem: Impact of EVCS on grid

With the rising popularity of EVs, the necessity for dependable and efficient charging infrastructure has becomemore paramount. A significant hurdle to broad EVs adoption is the absence of standards and the limited availabilityof fast-charging solutions that cater to varied customer requirements. The SAE J1772 standard establishes aframework for DC fast charging across three tiers; nevertheless, obstacles such as inadequate infrastructuredeployment, compatibility challenges, and a lack of public awareness impede its successful

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application. Failure toovercome these difficulties may impede the transition to EVs, therefore compromising efforts to diminishgreenhouse gas emissions and dependence on fossil fuels.

Section 2 clarifies the computational approach for determining voltage stability, dependability, and power loss. InSection 3, the author examines the MOVRSL index and its use as an optimisation issue for determining theplacements of charging stations. Section 4 presents the findings about the impact of EVCS on microgridperformance, both with and without distributed energy resources (DERs), and identifies the ideal locations forcharging stations inside a microgrid system. Ultimately, Section 5 concludes the investigation by contemplatingpotential future endeavours.

This research examines the influence of EVCS on microgrids, the reliability of charging stations, and power qualitymeasures. The principal discoveries and contributions of this research are as follows:

i. The study assesses the influence of EVCS on microgrid reliability by analysing key reliability indicators, including SAIFI, SAIDI, ENS, active and reactive power losses, and voltage stability indices. This research is innovative since it employs comprehensive performance metrics to assess the benefits of EVCS, rather than just depending on power losses or reliance.
ii. The paper elucidates how DERs may mitigate the adverse impacts of EVCS and demonstrates their capacity to enhance stability and reliability. This paper presents a pragmatic approach to integrating EVs into contemporary power infrastructure.
iii. The research proposes an innovative strategy to mitigate the adverse effects of these power systems. The paper proposes a thorough, index-based analysis to determine the ideal deployment strategy for EVCS, therefore adversely affecting the microgrid.

LITERATURE REVIEW:

The worldwide transition to electric cars (EVs) has raised substantial problems for current power distributionnetworks, chiefly due to the considerable surge in demand for ic vehicle charging stations (EVCS), particularly forfast charging facilities. The installation of such charging stations may induce significant demand spikes on localnetworks, potentially leading to voltage collapses, degradation of power quality, and even grid breakdowns.Numerous research has concentrated on the mitigation of these issues with charging stations.Abdelaziz et al. included road and electrical limitations in the allocation of EVCS to power networks and electricroadways. This strategy seeks to reduce power loss and voltage fluctuations while enhancing system dependability [11]. Abdelaziz et al. propose a more straightforward method aimed at minimising energy loss and voltagefluctuations in the system, while improving system dependability. Pratap et al. formulated an algorithm forintegrating the positioning of EVCS with network reconfiguration and the strategic planning of DERs to minimiseactive power loss and maximise the reduction of voltage imbalance [12]. Bald et al. examined the integration ofphotovoltaic systems with electric car charging stations by implementing a two-tier optimisation to save real estateexpenses while enhancing customer experience [13]. Suresh et al. focused on developing Electric Vehicle ChargingStations (EVCS) utilising battery storage technology and solar-based distributed generation planning within theframework of multi-objective optimization [14].

The influence of EVCS is complex concerning electrical mechanical networks. The additional demand from rapidcharging sessions heightens the probability of transformers and feeds experiencing overload. Patel et al. demonstratethat exceptionally rapid charging sessions may attain up to 240 kW each session, and the prevalence of these stationsin metropolitan locales exacerbates the issue, necessitating enhancements in the network [15]. Furthermore, Wang et al. discovered that high-density electric car charging stations might induce voltage variations and instabilities,particularly during peak demand periods [17]. Real-time voltage regulation is essential to avert voltage fluctuationsand diminished system reliability, as shown by Kumar et al. Finally, Zhao et al. assert that fast charging inducesharmonic distortions, which disrupt critical equipment connected to the grid [19]. Poor charge control facilitatessignificant demand spikes that jeopardize grid infrastructure, as demonstrated by the modelling studies conducted byAhmed and Lee [20].

Various ways have been proposed throughout time to overcome these difficulties. According to Green et al. dynamic load management systems can temporally spread charging operations, mitigating peak loads whilemaintaining

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customer satisfaction [21]. Furthermore, employing EVCSs powered by solar and wind resourcesdiminish dependence on the grid and alleviates peak demand. Ma et al. [22] indicate that elevated demand periodsfrequently impact the power grid; however, energy storage systems (ESS) can mitigate part of this pressure bystoring energy during non-peak hours and delivering it during peak consumption times. Fan et al. shown that energystorage systems (ESS) might mitigate the effects of fast-charging stations on the electrical grid [23]. Liu and Zhang[24] assert that employing vehicle-to-grid (V2G) technology for bidirectional energy flow offers further advantages,since electric cars (EVs) may function as distributed energy storage systems, delivering grid functions such asfrequency regulation and load shifting. In summary, to adequately accommodate the increasing quantity of EVs,modifications to the distribution lines and transformers are necessary, representing a long-term sustainable option, asindicated by Chau et al. [25].

In summary, previous research has concentrated on reducing power losses and stabilizing voltage levels; however, there is an increasing emphasis on the integration of renewable energy sources and energy storage systems. Furtherstudy should integrate these systems to provide more complete models for improving EVCS deployment and itseffects on the operation of distribution networks.

PROPOSED METHODOLOGY:

A simulation method was employed to assess the efficacy of the microgrid system concerning the performancemetrics of various locations for EV charging stations. This section presents a succinct overview of themethodologies employed to assess power losses, voltage stability and profile, and dependability. This studyemployed MATLAB/Simulink simulation software and IEEE 9-bus benchmark microgrid test system models as itsprincipal resources.

3.1 Deviation in Voltage Stability Index

For many years, power system professionals have been concerned about voltage stability. Both when the system isworking normally and during disruptions from outside [26], the voltage levels at all system buses remain the sameand are suitable when the power system is steady. Though in some circumstances it may cause significant voltagebreakdown, particularly in microgrids, voltage stability is truly a local phenomenon. This paper analyses voltagestability using the Deviation in Voltage Stability Index (DVSI).

This study uses the voltage stability index (VSI) introduced by Eminoglu et al. [27]. The mathematical representationof the VSI is illustrated by a fundamental 2-bus system, as seen in Figure 1. The representation of the same is detailed in Equations (1) to (8).

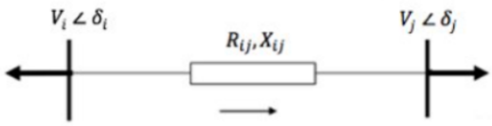

Figure 1: 2-Bus System

Figure 3 depicts the single line diagram of a two-bus system, with i and j representing the two bus system. Vi∟δi and Vj∟δj represent the voltages at bus i and bus j, respectively. I represent the current passing the branch with resistance R and impedance X.

$$I = \frac{V_i - V_j}{R + JX} \quad (1)$$

$$P_j - JQ_j = V_j^* I \quad (2)$$

Further simplification produces Equation (3) by putting the I value into Equation (2) and equating the real parts.

$$V_j^4 + 2V_j^2(P_jR + Q_jX) - V_i^2V_j^2 + (P_j^2 + Q_j^2)|Z|^2 = 0 \quad (3)$$

Equation (3) states that the transferable active power and reactive power may be represented by Equations (4) and (5), respectively.

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$$P_j = \frac{L \pm \sqrt{M}}{|Z|} \tag{4}$$

Where, $L = -Cos\theta_z V_j^2$, and $M = Cos^2\theta_z V_j^4 - V_j^4 - |Z|^2 Q_j^2 - 2V_j^2 Q_j X + V_i^2 V_j^2$

$$Q_j = \frac{A \pm \sqrt{B}}{|Z|} \tag{5}$$

Where, $A = -Sin\theta_z V_j^2$, and $B = Sin^2\theta_z V_j^4 - V_j^4 - |Z|^2 P_j^2 - 2V_j^2 P_j R + V_i^2 V_j^2$

Hence, the necessary conditions for the transfer of reactive and active power are given by Equation (6):

$$M \geq 0 \text{ and } B \geq 0 \tag{6}$$

Simply plugging in the real values of N and Q allows one to determine the system's stability criterion.

$$VSI = 2V_i^2 V_j^2 - 2V_j^2 (P_j R + Q_j X) - |Z| (P_j^2 + Q_j^2) \geq 0 \tag{7}$$

$$DVSI = 1 - VSI \tag{8}$$

Equation (7) is referred to as VSI. This functions as a criterion for assessing voltage stability. The VSI will diminish as active power increases. Exceeding a certain limit of active power will compromise system stability. This study employs the deviation in VSI (DVSI), as delineated in equation (8), to ascertain the ideal site for the EVCS.

3.2 Reliability:

The reliability assessment of the electricity system has emerged as a critical domain of inquiry. Reliability refers to the probability that a system will perform satisfactorily for a certain period under established operating parameters. The reliability analysis of the power system concentrates on the dependability of generation, transmission, and distribution. The microgrid's dependability is closely associated with consumer satisfaction levels [28].To evaluate the dependability metrics of the microgrid, statistical information on failure rate, repair rate, average outage duration, and the customer count at the buses or load points of the distribution network is essential [29].

The reliability indices of the distribution network are categorised into two primary types: customer-oriented and energy-oriented dependability indices. SAIFI, SAIDI, and CAIDI are the three principal categories of dependability indices centred on client orientation. The energy-focused dependability indices can be further classified as ENS and AENS. A comprehensive description and the formulae for several customer- and energy-oriented dependability indicators are presented in Equations (9-13).

$$SAIFI = \frac{\sum \lambda_i N_i}{\sum N_i} \tag{9}$$

$$SAIDI = \frac{\sum U_i N_i}{\sum N_i} \tag{10}$$

$$CAIDI = \frac{\sum \lambda_i N_i}{\sum \lambda_i N_i} \tag{11}$$

$$ENS = \sum L_i U_i \tag{12}$$

$$AENS = \frac{\sum L_i U_i}{\sum N_i} \tag{13}$$

3.2.1 Failure Rate Adjustments

The base failure rate calculation: The base failure rate base is often supplied for each line or system component in [30].

Calculation of load effect factor: The integration of a 300 kW EVCS at a designated bus allows for the estimation of increased electrical current across associated lines utilising Ohm's Law, as shown in equation (14):

$$I = \frac{P}{V * Cos\theta} \tag{14}$$

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Where: P represents the supplementary load, V denotes the operational voltage at the bus, and Cos signifies the power factor.

Incremental Current on Each Line: Supplementary current traverses each line linked to the bus where the EVCS is incorporated.

Adjustment of stress factors: Failure rates escalate with elevated electrical and thermal stress.

$$\lambda_{new} = \lambda_{base}\left(1 + \frac{K*\Delta I}{I_{base}}\right) \quad (15)$$

3.3 Power Losses

The formula for determining the cumulative real and reactive power losses in a microgrid system is shown in Equation (16-17).

$$P_{loss} = \sum_{i=1}^{n} I_i^2 R \quad (16)$$

$$Q_{loss} = \sum_{i=1}^{n} I_i^2 X \quad (17)$$

In distribution systems, line losses lower system efficiency; lower power supplied to consumers, increase energy prices, and may cause voltage fluctuations, therefore compromising the dependability and quality of the power supply.

3.4 Statistical Approachfor assessing the impact of EVCS on microgrid.

Microgrids and EVCS are essential in the future energy framework, offering solutions to meet the rising electricity demand from electric cars and enabling the incorporation of DERs. In this context, it is crucial to examine the influence of EV charging station load and the incorporation of DERs on key operational parameters of the microgrid under different scenarios regarding the location of EV charging stations.

Figure 2 delineates the methods adopted in this research toanalyse the influence of EVCS load and DER integration on the microgrid.

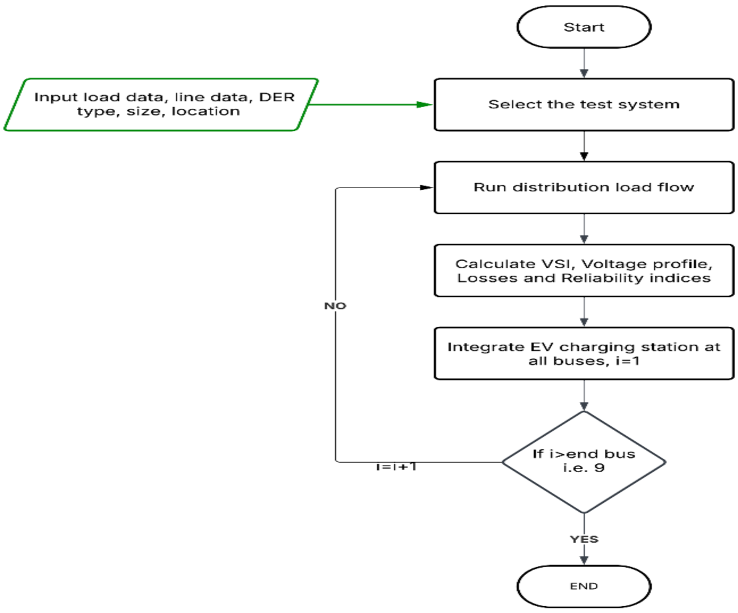

Figure 2. Flowchart for computation of different MG performance indices.

3.5 Multi Objective VRSL Index (MOVRSL):

Likewise, to power system studies, there is a deficiency of indices in microgrid analysis that comprehensively convey information on the three fundamental operational parameters: voltage stability, dependability, and power

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losses. This research introduces a unique multi-objective indicator termed the Reliability, Voltage Stability, and Line Losses (MORVSL) index.

This index offers insights into three fundamental characteristics that regulate the functioning of the microgrid after any disruption. This index is relevant for:

- Ideal placement of EVCS and DERs.
- Distribution network and microgrid planning using distributed generators.
- Reconfiguration of distribution networks.

This subsection demonstrates the numerical computation of the MORVSL index via Equations (18) to (21):

$$\mathrm{MORVSL} = \mathrm{Min}\ \{\alpha X + \beta Y + \omega Z\} \quad (18)$$

$$\text{Where, } X = \frac{\mathrm{DVSI_i}}{\mathrm{DVSI_{base}}} \quad (19)$$

$$Y = \beta_1 \frac{\mathrm{SAIFI_i}}{\mathrm{SAIFI_{base}}} + \beta_2 \frac{\mathrm{SAIDI_i}}{\mathrm{SAIDI_{base}}} + \beta_3 \frac{\mathrm{CAIDI_i}}{\mathrm{CAIDII_{base}}} + \beta_4 \frac{\mathrm{ENS_i}}{\mathrm{ENS_{base}}} \quad (20)$$

$$Z = \omega_1 \frac{\mathrm{RPL_i}}{\mathrm{RPL_{base}}} + \omega_2 \frac{\mathrm{QPL_i}}{\mathrm{QPL_{base}}} \quad (21)$$

The primary objective of the EVCS placement problem is to determine the optimal locations for EVCS inside the distribution network, minimizing their impact on network operations. The MORVSL index was framed as the objective function for the EVCS location problem due to its capacity to encompass power losses, voltage stability, and dependability simultaneously.

Figure 3 illustrates a flowchart depicting the optimal location of the EVCS according to the MORVSL index. The EVCS is initially modelled, followed by the simulation of test scenarios.A comprehensive analysis of the effects of reliability, stability, and power losses is conducted across all testing situations. A comparative investigation of the influence of EVCS loads on the designated features is conducted to allocate suitable weights to all elements of the MORVSL index. The allocation of weights to the different indices of the MOVRSL index is determined by integrating the load from EVCS. The criterion most adversely impacted is given the most weight, as seen in Table 1.

Table 1: input parameter

Parameter	**Value**
α	0.2
β	0.5
ω	0.3
β_1	0.1
β_2	0.1
β_3	0.1
β_4	0.2
ω_1	0.2
ω_2	0.1

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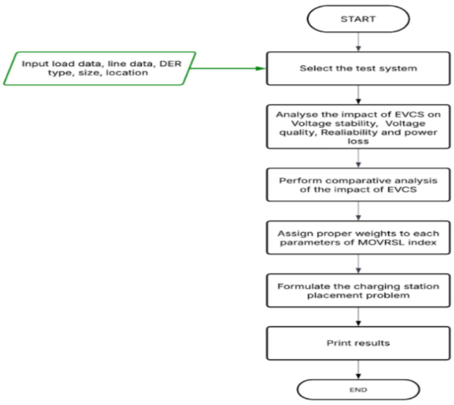

Figure: 3Flowchart for EVCS placement based on MOVRSL index.

4. SIMULATION RESULTS:

The substantial influx of EVs increases load demand, hence compromising the operating parameters of the microgrid. This paper includes a statistical approach of the impact of EVCS on the dependability, voltage stability, and line losses of the microgrid under various conditions. A EVCS placement strategy based on the proposed index is introduced. This section delineates the findings of the analyses performed.

4.1 Test System Description and Analysis Scenarios

The suggested statistical analysis was conducted to analyse the simulation findings and ascertain the importance of EVCS sites on the IEEE 9-bus AC microgridbenchmark system. This produces a radial network, as seen in Figure 4. The network has 9 buses and 8 branches, each linked to a constant RL load of 7.302 MW and a reactive power of 1.528 MVAr, respectively. The line data, load data, locations and allocations of DERs, as well as data pertaining to reliability indices, are detailed in [30]. The microgrid is equipped with three photovoltaic systems, totalling 5600 kW, and two induction generator-based wind turbines, totalling 1300 kW.

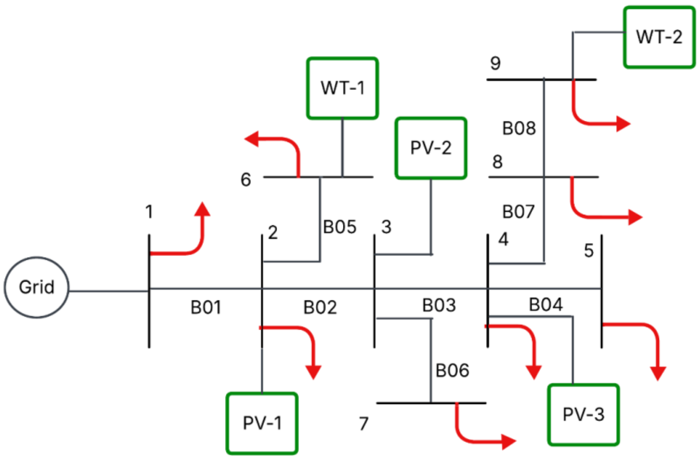

Figure 4: IEEE 9 bus AC microgrid Test System [30]

The 300kW DC EVCS demand is simulated and incorporated into the AC microgrid using a 12-pulse inverter, which is regulated using pulse-width modulation techniques. The research involved assessing several scenarios to identify optimal sites for EVCS to evaluate the efficacy of DERs inside the microgrid system, as shown below:

Scenario 1: Microgrid System without DERs and EVCS

Scenario 2: Microgrid System with EVCS but Without DERs

Scenario 3: Microgrid System with DERs and No EVCS

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Scenario 4: Microgrid System with EVCS and DERs.

scenario 1 is the initial situation chosen for further examination. Scenario 2 has 9 distinct examples with a 300 kW EVCS, which is supplied from bus 1 to bus 9, to demonstrate the impact of EVCS on microgrid performance. In scenario 3, three solar systems are linked to buses 2, 3, and 4, while two induction generator-based wind turbines are connected to buses 6 and 9. Subsequently, certain components of the EVC are integrated with DER-enabled microgrids to demonstrate the efficacy of DERs in enhancing system performance and addressing the challenges associated with EVCS.

4.2 Impact of EV charging station on microgrid

This paragraph discusses the study's findings about the effects of electric car charging station load on voltage stability, reliability, and power losses in the microgrid across all scenarios outlined.

4.2.1 Impact of EVCS on VSI

This section examines VSI in several scenarios to demonstrate the impact of EVCS on microgrids and how the integration of DERs may enhance system stability. In Scenario 1, the average VSI is 0.973 pu, signifying that the system operates effectively under standard conditions. In Scenario 3, the integration of the MG with DERs results in a significant increase in the average VSI to 0.999 pu, indicating enhanced system stability due to the DERs. Nevertheless, when EVCS are incorporated (Scenario 2) without supplementary voltage support systems such as DERs, the VSI declines markedly in all instances.

The comparison presented in Table 2 of VSI at various PCC sites throughout Scenario 1, Scenario 2, and Scenario 4 underscores the effects and enhancements in voltage stability: In Scenario 2, VSI decreases at all PCC locations relative to Scenario 1. The minimal decrease was seen at PCC 3 (-0.10%), indicating that EVCS will perform optimally at this site relative to others. This area endures little voltage stress and has greater resilience to EVCS integration. In scenario 4, VSI values have increased at all PCC locations, indicating an enhancement in voltage stability following DER integration. The most notable enhancement is shown at PCC @ 4, 5, and 7 (from 0.972 to 0.987), indicating that this site derives the most advantage from DERs.

Table 2: average VSI at different cases (Scenario 3 vs Scenario 4)

PCC Location	VSI in Scenario 1 (Base Case)	VSI in Scenario 2 (EVCS Impact)	% Deviation due to EVCS	VSI in Scenario 4 (EVCS + DER)	% Recovery due to DER
PCC @ 2	0.973	0.959	↓ 1.44%	0.972	↑ 1.35%
PCC @ 3	0.973	0.972	↓ 0.10%	0.987	↑ 1.54%
PCC @ 4	0.973	0.944	↓ 2.98%	0.978	↑ 3.60%
PCC @ 5	0.973	0.940	↓ 3.39%	0.970	↑ 3.19%
PCC @ 6	0.973	0.965	↓ 0.82%	0.967	↑ 0.21%
PCC @ 7	0.973	0.952	↓ 2.15%	0.991	↑ 4.09%
PCC @ 8	0.973	0.950	↓ 2.36%	0.978	↑ 2.94%
PCC @ 9	0.973	0.948	↓ 2.57%	0.977	↑ 3.06%

Under typical conditions, the system shows a steady operation in Scenario 1 with an average voltage near to 0.99 pu, therefore indicating little stress. As the graphic shows, voltage varies at different buses depending on where the EVCS PCC is placed when EVCS is included to the microgrid (Scenario 2 Cases). Similarly Bus 5 from 0.9891 pu to 0.9728pu, showing the maximum amount of voltage deterioration due to EV charging; voltage at Bus 4 declines from 0.9896 pu (Base Case) to 0.99774 pu, similarly. Observing the most notable voltage declines at Buses 4, 5, 8, and 9 indicates that these buses are more susceptible to variations in EV charging demand.

Figures 5 and 6 show over several buses the voltage profile for Scenario 3 and Scenario 4. For most buses, voltage levels in S3 stay always high—almost 0. 999 pu—indicating that the system runs in a steady condition free from EVCS integration. Some buses show clear voltage decreases when EVCS integration is used instead of the baseline

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scenario.These areas are more sensitive to EV charging demands; voltage at bus 4 reduces from 0.9993 pu to 0.9824 pu, bus 5 falls from 0.9988 pu to 0.9819 pu, and bus 9 lowers from 0.9987 pu to 0.9788 pu.

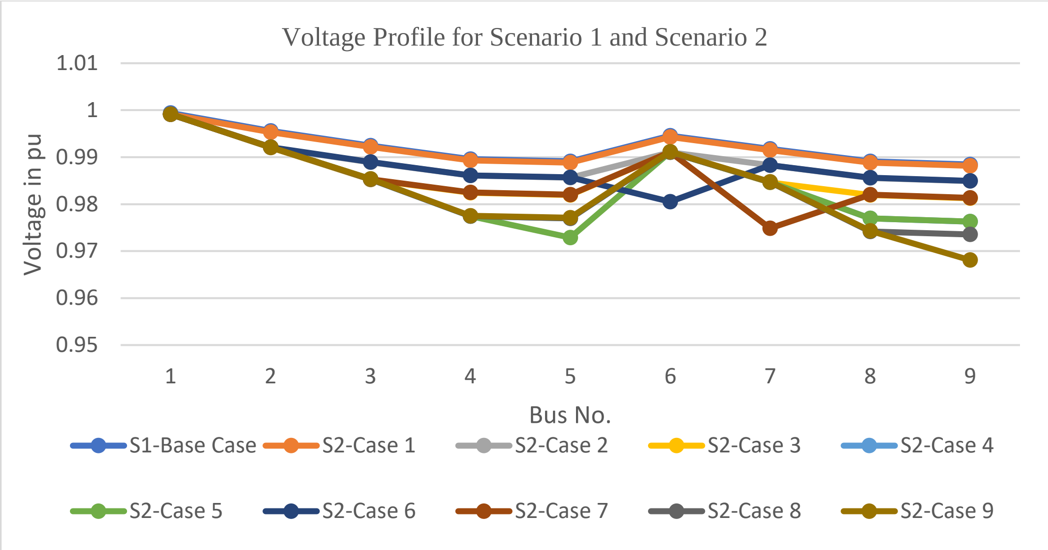

Figure 5: Impact of EVCs on voltage profile of microgrid without DERs (Scenario 1 and 2)

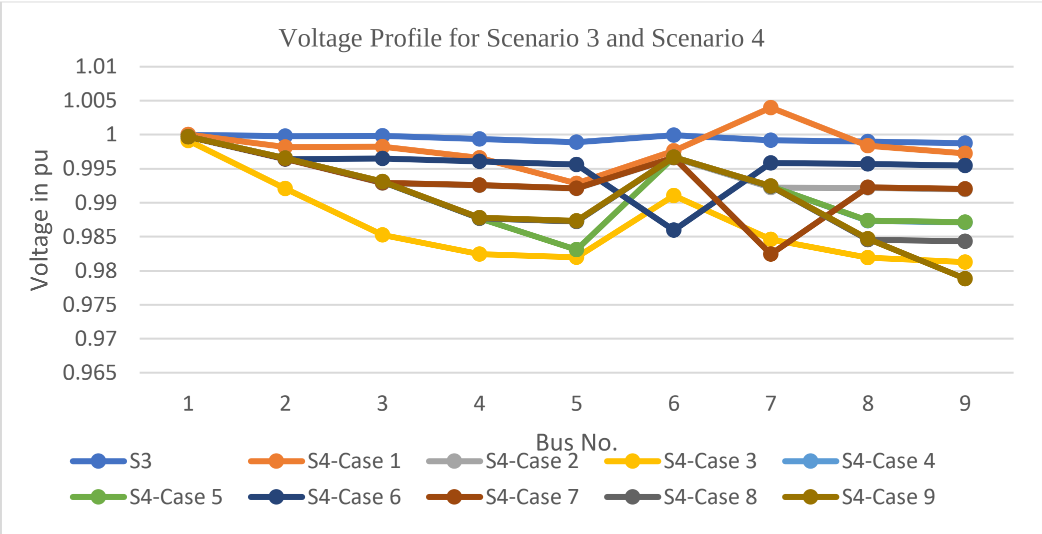

Figure 6: Impact of EVCs on voltage profile of microgrid with DERs (Scenario 3 and 4)

4.2.2 Impact of EVCS on Reliability

The influence of EVCS load on the adaptability of the microgrid was examined across all scenarios. This sub-section presents the outcomes of the analysis. The failure rate, repair rate, and outage length of the system under heightened load demand were calculated using the unitary technique [30].

Table 3 establishes the foundational value of all recommended dependability indices from scenario 1. The incorporation of EVCS significantly affects microgrid dependability. In scenario 2, the incorporation of EVCS at bus 5 represents the most detrimental situation, significantly elevating the risk by augmenting SAIFI from 0.2412 to 0.252, SAIDI from 5.18 to 5.655, and ENS from 37321.97 kWh to 40441.007 kWh. Following the incorporation of DERs in scenario 4, all reliability indices exhibit considerable enhancement, indicating increased microgrid dependability through reduced outage frequency, optimised load balancing, and minimised Energy Not Supplied (ENS). The statistical study indicates that, with bus 1 as a slack bus, the integration of EVCS into bus 3 results in the least increase in outage frequency, length, and ENS compared to all other buses.

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Cases	SAIFI	SAIDI	CAIDI	ENS
Scenario 1	0.2412	5.18	22	37321.97
Scenario 2 –case1	0.241	5.31	22	42505.968
Scenario 2 –case2	0.249	5.557	22	40789.5
Scenario 2 –case3	0.245	5.495	22	40785.9
Scenario 2 –case4	0.249	5.591	22	40223.272
Scenario 2 –case5	0.252	5.655	22	40441.007
Scenario 2 –case6	0.247	5.566	22	40810
Scenario 2 –case7	0.249	5.591	22	39991
Scenario 2 –case8	0.252	5.653	22	40548
Scenario 2 –case9	0.255	5.685	22	40713
Scenario 3	0.193	3.19	17.6	23886.06
Scenario 4-case 1	0.1930	3.397	17.6	27203.82
Scenario 4-case 2	0.1951	3.520	17.6	25664.75
Scenario 4-case 3	0.1973	3.561	17.6	26157.04
Scenario 4-case 4	0.1994	3.578	17.6	25742.89
Scenario 4-case 5	0.2016	3.619	17.6	25882.24
Scenario 4-case 6	0.1973	3.562	17.6	26118.4
Scenario 4-case 7	0.1994	3.578	17.6	25594.36
Scenario 4-case 8	0.2016	3.595	17.6	25734.90
Scenario 4-case 9	0.2037	3.616	17.6	25840.66

4.2.3 Impact of EVCS on Power loss

This section computes and presents the effect of EVCS on real and reactive power losses inside the microgrid across all situations. Figure 7 illustrates the power losses resulting from the integration of EVCS inside the microgrid. The incorporation of EVCS in scenario 2 markedly elevates power losses relative to scenario 1. In Case 9, where the EVCS interfaces with bus 9, the losses are maximised. In scenario 3, the incorporation of DERs results in a remarkable reduction in both actual and reactive power losses, diminishing from 43.82 kW to 1.62 kW and from 55.258 kVAr to 1.71 kVAr, respectively. Incorporating EVCS into scenario 4 for the microgrid with DERs in examples 3 and 7 yields minimal loss, underscoring the significance of thoughtful EVCS placement.

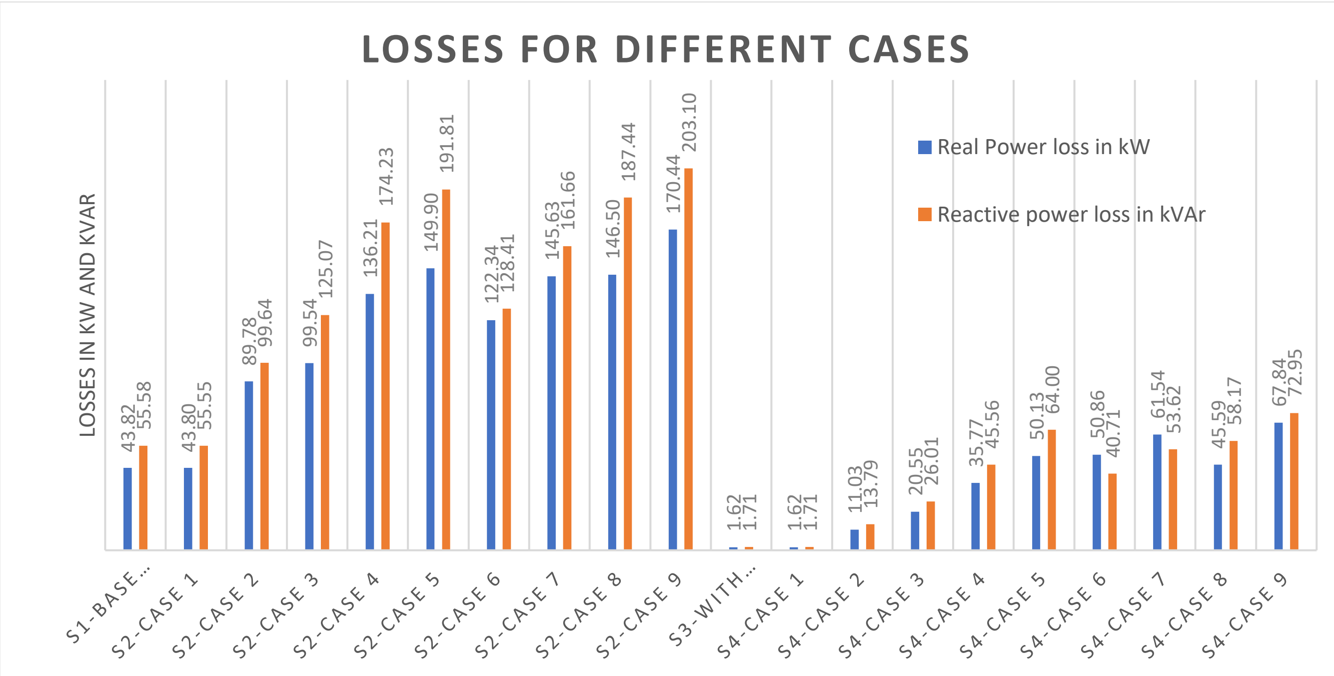

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Figure 7: Power losses of microgrid for all the scenarios.

4.3 Placement of EVCS based on PRSL index and Comparative analysis of different parameters

A comparative analysis was conducted on the influence of EVCS on several operational characteristics of the system, including voltage stability deviation, power loss, and reliability, with results graphically shown in Figures 8 and 9. The metrics for SAIFI, SAIDI, ENS, Ploss, Qloss, and MORVSL in scenario 1 act as a standard for assessing the effects of EVCS installation.

The picture presents a comparative examination of the impact of EVCS on several indices of the microgrid across different scenarios. S2-Case 9 is the most unfavourable scenario, exhibiting the highest APL and RPL indices of 0.778 and 0.365, respectively, alongside a significant MOVRSL value of 2.062, rendering it the least advantageous site for EVCS installation. Among all locations, bus 3 has the minimal influence on dependability indices (SAIFI = 0.102 and SAIDI = 0.106), although it increases the APL and RPL indices by 0.454 and 0.225, respectively, resulting in a fitness value of 1.413.

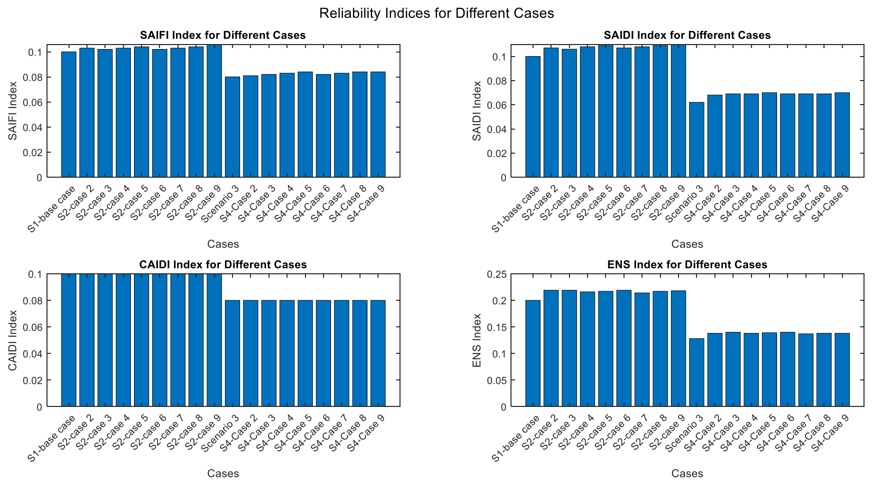

Figure 8: Impact of EVCS on Reliability indices of microgrid

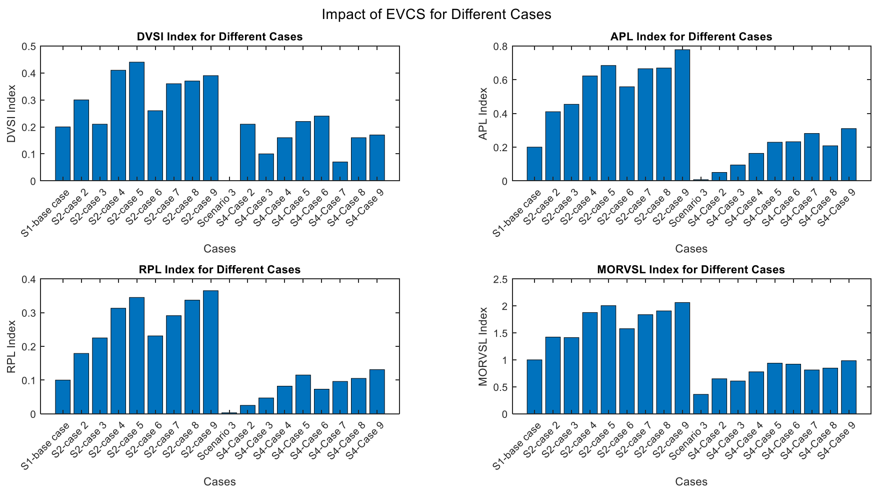

Figure 9: Impact of EVCS on DVSI, APL, RPL and MORVSL of microgrid

The new suggested multi-objective fitness function MORVSL has the lowest value at bus 3 in scenarios 2 and 4, which is 1.414 and 0.608, based on the aforementioned discusses and simulation experiments. This is the lowest value among all the locations. Consequently, bus 3 is the best spot to put the 300 kW EVCS; buses 9 and 5 are the worst places.

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Conclusion

EVs are a beneficial choice for mitigating emissions in the transportation industry. The increasing prevalence of EVs has resulted in the creation of charging stations; nevertheless, the adverse effects of the ensuing EVCS load on the microgrid cannot be overlooked. This study rigorously examined the effects of EVCS loads on voltage stability, reliability indices, and power losses inside the IEEE standard microgrid test system. The statistical research indicates that the incorrect positioning of EVCS might adversely impact system performance. In the absence of DERs, EVCS exacerbate power losses and diminish voltage stability. The incorporation of DERs mitigates these adverse effects, enhancing the system's stability beyond the baseline scenario. This study introduced a novel MORVSL index for the positioning of the EVCS within the microgrid. Bus 3 is the most advantageous site for EVCS installation, guaranteeing dependability, efficiency, and sustainability. Future research should concentrate on real-time adaptive control solutions for EVCS-DER cooperation to augment microgrid resilience.

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