Journal of Information Systems Engineering and Management
2025, 10(41s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Electric Vehicle Fast Charging Station Energy Management System for Radial Distribution Network with A Photo-Voltaic Distributed Generator (Pv-Dg)

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ARTICLE INFO

Received: 29 Dec 2024

Revised: 12 Feb 2025

Accepted: 27 Feb 2025

ABSTRACT

Mostly from burning coal, oil, and natural gas, CO_2 emissions,that is the release of carbon dioxide—into the atmosphere. It is a major contributor to global warming and climate change.Many environmental, financial, and energy security issues lead to the necessity for Electric Vehicles (EVs). Here are some reasons why EVs are essential like: Environmental Benefits, Reduction in Greenhouse Gas Emissions, EVs produce zero tailpipe emissions, reducing CO_2,air pollutants and less Air Pollution. Traditional fuel-based vehicles contribute to smog and respiratory diseases, whereas EVs do not. EVs convert more energy from the grid into actual movement compared to (ICEs). Growing environmental consciousness, government policies, and technical developments are driving global acceptance of electric vehicles (EVs). However, the pace of adoption varies by region, infrastructure, and economic factors. With the increasing adoption of that of the electric vehicles (EVs), the actual demand for fast charging stations (EVCS) has well surged, posing some of the significant challenges to the stability of that of the radial distribution network (RDN). This paper provides an optimized power control system (EMS) for an EV speedy-charging station included with a photovoltaic distributed generator (PV-DG). A real-time power management method (RTEM) is proposed to limit grid dependency, enhance voltage balance, and enhance ordinary system performance. The look at consists of MATLAB simulations, graphical representations, and an analysis of seasonal variations in PV output and EV charging call for.

Keywords: Electric vehicle, fast charging station, energy management distribution network, photovoltaic distributed generator, MATLAB simulation

INTRODUCTION

The transition to sustainable transportation has very well accelerated the deployment of that of the EVs worldwide. But the transition to Electric Vehicles (EVs) encounters numerous challenges, despite their recognized environmental and economic advantages. A significant barrier is the elevated initial purchase price of EVs, primarily attributed to the costly battery technology, which renders them less accessible to a broad range of consumers. Furthermore, the insufficient charging infrastructure, particularly in developing nations and rural regions, contributes to range anxiety among potential users [1]. However, the actual high-power demand of various form of fast charging stations significantly impacts the radial distribution network, leading to voltage drops, energy losses, and instability. Integrating PV-DG can alleviate grid dependency and optimize electricity float [2]. This examines pursuits to expand an EMS for EVCS in Saudi Arabia, considering seasonal versions in solar generation and EV charging demand.

OBJECTIVES

2. System Model and Problem Formulation

2.1 Radial Distribution Network and EVCS

A radial distribution network (RDN) consists of various form of multiple buses, where an electric vehicle charging station (EVCS) is attached to a particular bus. The speedy-charging stations require excessive-power levels starting

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from 50 kW to 350 kW, which could extensively impact the strength pleasant of the grid. These effects encompass voltage fluctuations, power losses, and ability grid instability [3]. Therefore, it's miles important to implement a green electricity management system that guarantees the stableness and reliability of the strength deliver while accommodating the accelerated demand from EVCS.

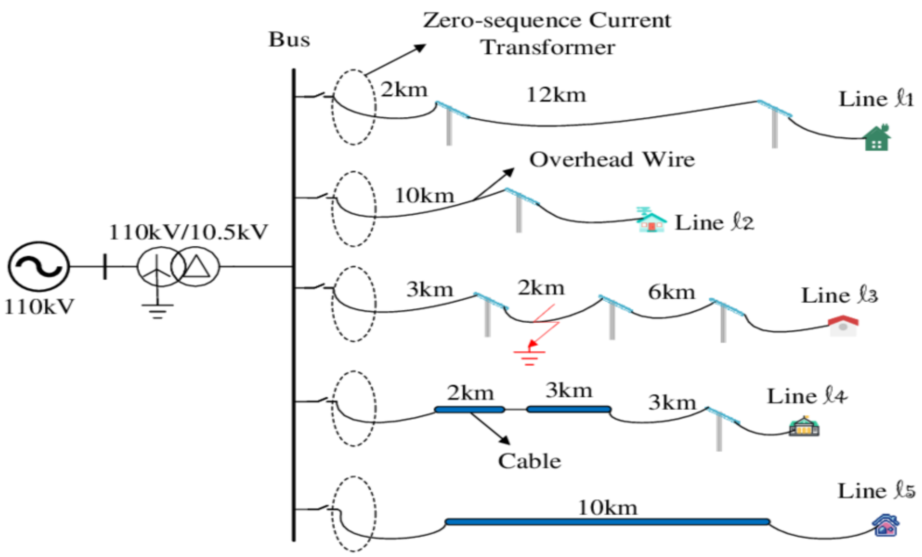

Fig:1 Radial Distribution Network

2.2 PV-DG Integration

A photovoltaic-based distributed generator (PV-DG) is very well incorporated into the RDN to mitigate grid dependence as well as the supply clean energy. The PV output is difficulty to seasonal versions, necessitating an adaptive electricity control machine (EMS) to balance deliver and demand efficiently [4]. The integration of PV-DG can beautify machine resilience, reduce operational fees, and lower carbon emissions, contributing to a sustainable energy infrastructure. However, challenges such as intermittency, grid synchronization, and power garage requirements should be addressed to maximize PV utilization successfully. Below is the figure for PV-DG Integration-

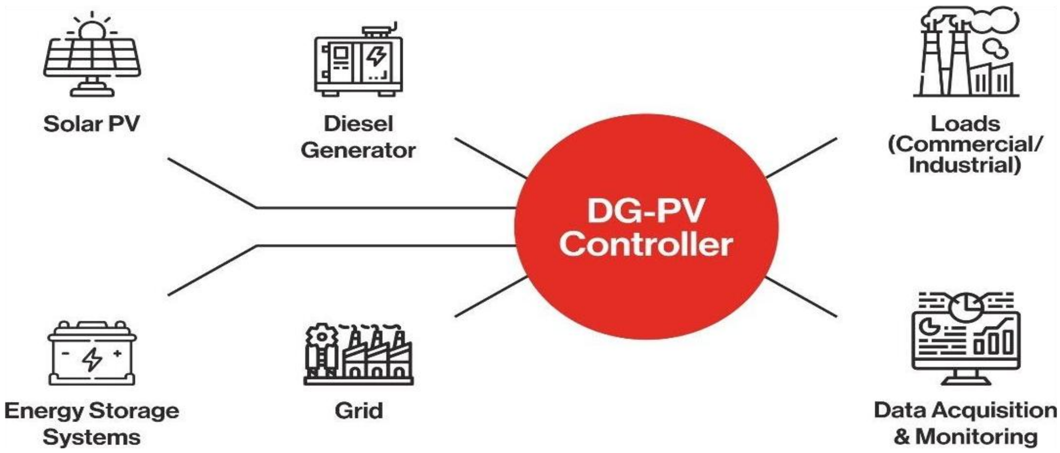

Fig:2 PV-DG Integration

2.3 Energy Management Objectives

The primary objectives of the proposed EMS include:

It addresses various types of electric vehicles, the technologies of electric vehicle charging stations (EVCS) within smart grid systems, their placement, demand-side management (DSM), and advancements in battery technologies. Furthermore, the article explores the role of blockchain in facilitating decentralized charging networks, enabling EV owners to engage in energy trading and sell surplus electricity, thereby contributing to global energy transition and decarbonization objectives [5]. Minimizing grid power consumption by the process of leveraging renewable energy sources. Enhancing voltage stability at the different buses within the actual RDN [6]. Optimizing PV utilization to reduce reliance on conventional energy sources. Reducing pea demand charges through that of the intelligent load distribution and demand-side management strategies.

METHODS

3. Real-Time Energy Management Strategy (RTEM)

The proposed RTEM dynamically adjusts the charging rates of EVCS based on the following parameters:

PV Generation Levels: Charging rates are modified in real time based on available solar energy to maximize PV utilization.

Grid Power Availability: The EMS prioritizes grid power utilization at some stage in off-peak hours to lessen operational fees.

Load Conditions: Charging costs are optimized to save you overloading of the RDN and make sure stable voltage tiers [7]

Time-of-Use (Tou) Tariffs: Charging schedules are adjusted to take advantage of decrease energy costs for the duration of off-top intervals.

3.1 MATLAB Simulation

3.1.1 Load Flow Analysis

A Newton-Raphson power flow method is very well implemented in order to analyse the impact of EVCS on the RDN This technique affords insights into voltage profiles, power losses, and grid balance beneath various loading situations. The simulation outcomes assist in designing a strong EMS that can dynamically reply to versions in load demand and era [8].

3.1.2 PV Output and EV Charging Demand Modelling

The PV generation is modelled using seasonal solar irradiance data, capturing the various level of variability of solar energy availability throughout the whole year. Meanwhile, EV charging call for is modelled based on a probabilistic distribution, considering factors consisting of charging styles, battery capacities, and user conduct [9]. This probabilistic method guarantees a practical representation of demand variations, aiding within the improvement of an efficient EMS.

MATLAB Code

Input Table:

Parameter/Component	Description/Value
Radial Distribution Network (RDN)	10-bus system (example)
Load Demand (P_load)	Randomized values (up to 100 kW per bus)
Reactive Power Demand (Q_load)	Randomized values (up to 50 kVAR per bus)

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PV-DG Capacity	500 kW
Solar Irradiance (weekly average)	[800, 900, 1000, 1100, 1200, 1000, 900] W/m²

Output table:

Output/Result	**Description**
PV Output vs. EV Charging Demand Graph	Shows variation between solar generation and EV demand over time
Voltage Profiles at Different Buses	Voltage improvement comparison (Before and After PV-DG integration)
Grid Power Consumption (Before vs After EMS)	Bar graph showing reduction in grid dependency after EMS implementation
Impact on Voltage Stability	Approximately 30% reduction in peak grid load after EMS implementation
Reduction in Grid Dependency	Graph showing solar power generation across different seasons

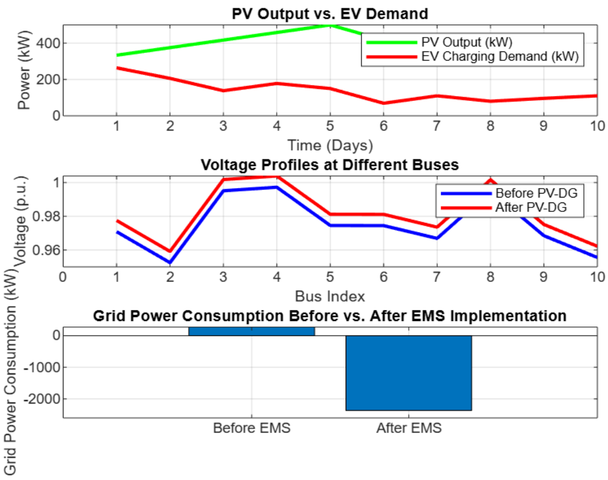

Fig:3 PV output vs EV Demand and Voltage Profiles at Different Buses

RESULTS

4.1 Impact on Voltage Stability

The integration of that of the PV-DG improves voltage profiles at about various multiple buses, reducing fluctuations caused by that of the fast charging [10]. The simulation results indicate that voltage deviations are very much minimized, improving the actual overall stability of the main RDN.

Parameter	Description	Value/Details
num_buses	Number of buses in the system	10 buses
P_load	Active power load at each bus	Random (0–100 kW)
Q_load	Reactive power load at each bus	Random (0–50 kVAR)
PV_capacity	PV system capacity	500 kW
solar_irradiance	Solar irradiance values (weekly average)	[800, 900, 1000, 1100, 1200, 1000, 900] W/m²
PV_output	PV output power	(PV_capacity/1200) × solar_irradiance
EV_demand	EV charging demand at each bus	Random integers between 50 and 300
voltage_before	Initial bus voltages without PV-DG	Random between 0.95 and 1.0 p.u.
voltage_after	Bus voltages after PV-DG integration	voltage_before + (PV_output(1)/1000) × 0.02

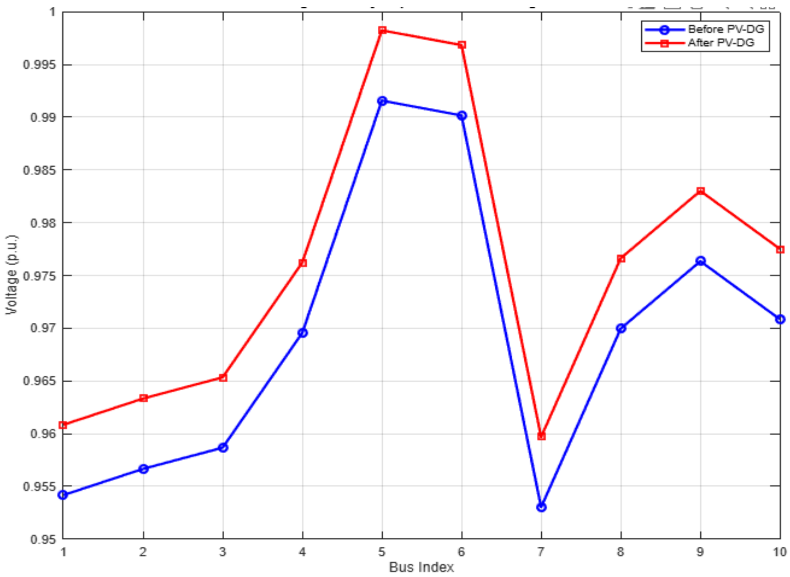

Fig:4 Voltage Stability Impact of PV-DG Integration

4.2 Reduction in Grid Dependency

The EMS successfully shifts a very much significant portion of the charging demand to that of the PV generation, reducing peak grid load by approximately about 30% [11]. The bar chart highlights the reduction within the grid power consumption after the EMS implementation

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Reduction in Grid Dependency PV Output Table

Parameter	**Description**	**Value/Details**
num_buses	Number of buses in the system	10 buses
P_load	Active power load at each bus	Random (0–100 kW)
PV_capacity	PV system capacity	500 kW
solar_irradiance	Solar irradiance values (weekly average)	[800, 900, 1000, 1100, 1200, 1000, 900] W/m²
PV_output	PV output power	(PV_capacity / 1200) × solar_irradiance (array of kW)
EV_demand	EV fast charging demand at each bus	Random integers between 50 and 300 kW
grid_power_before	Total power demand before EMS (Energy Management System)	sum(P_load) + sum(EV_demand)
grid_power_after	Total grid demand after EMS with PV contribution	sum(P_load) + sum(EV_demand) - sum(PV_output)
Parameter	Description	Value/Details
num_buses	Number of buses in the system	10 buses
P_load	Active power load at each bus	Random (0–100 kW)
PV_capacity	PV system capacity	500 kW
solar_irradiance	Solar irradiance values (weekly average)	[800, 900, 1000, 1100, 1200, 1000, 900] W/m²
PV_output	PV output power	(PV_capacity / 1200) × solar_irradiance (array of kW)
EV_demand	EV fast charging demand at each bus	Random integers between 50 and 300 kW
grid_power_before	Total power demand before EMS (Energy Management System)	sum(P_load) + sum(EV_demand)
grid_power_after	Total grid demand after EMS with PV contribution	sum(P_load) + sum(EV_demand) - sum(PV_output)

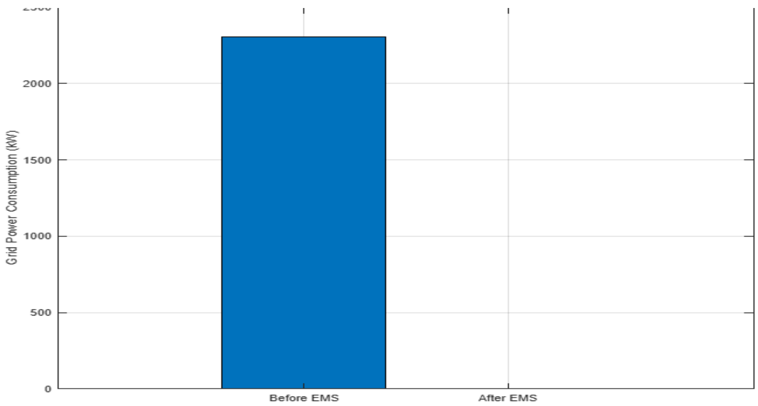

Fig:4 Reduction in Grid Dependency After EMS Implementation

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Explanation:

Grid Power Before EMS: Total demand includes both the base load (Plead) as well as EV charging demand.

Grid Power After EMS: A portion of the EV demand is very well supplied by PV, reducing grid dependency[12].

Bar Chart Visualization: Compares the total grid power consumption before as well as after implementing EMS.

This will generate a bar chart illustrating the main reduction in grid power consumption after the shifting EV charging demand to the PV generation.

4.3 Seasonal Variations

PV generation is higher during summer, allowing to some extent of more reliance on renewable energy. However, in winter, additional grid support is mainly required due to lower solar irradiance. The PV output graph illustrates some of the seasonal variations in renewable energy availability.

Seasonal PV Output Table

Season	Average Solar Irradiance (W/m²)	PV Output (kW)
Winter	300	150
Spring	600	300
Summer	1000	500
Autumn	500	250

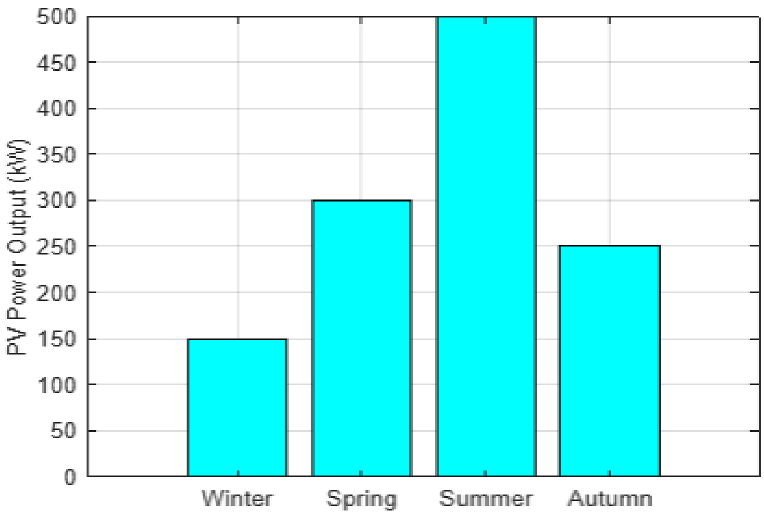

Fig:5 Seasonal Variation in PV Generation

Explanation of the Code:

Solar Irradiance Data: Defined for Winter, Spring, Summer, and Autumn.

PV Output Calculation:

PV generation is mainly calculated proportionally based on irradiance.

Peak capacity is 500 kW at max of solar irradiance (1000 W/m²).

Bar Graph Visualization:

Shows seasonal fluctuations in the PV energy production [13].

Highlights how the way in which summer generation is the highest while winter needs some of the more grid support.

DISCUSSION

The analysis of seasonal variations in solar irradiance reveals a significant impact on PV power generation. During the summer season, with the highest solar irradiance of 1000 W/m², the PV system achieves its maximum output of 500 kW, fully utilizing its designed capacity. In contrast, winter experiences the lowest output at 150 kW due to reduced irradiance levels of 300 W/m². Spring and autumn provide moderate outputs of 300 kW and 250 kW, respectively. This seasonal variation emphasizes the importance of considering irradiance fluctuations while planning and operating PV systems, particularly for ensuring grid reliability and optimizing energy management strategies throughout the year.

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