

Smart Assisted Charging Station with Load Balancing for Electrical Vehicle

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ABSTRACT: The “Smart EV Charging Station with load balancing for EV along with Grid Green Power” is an innovative solution to reduce the pollution. But the Primary reason the people do not prefer E-Vehicle that is a unavailability of the charging station. Increasing in pollution and depletion of fossil fuels (petroleum, diesel, coal, etc.) has paved way of the entry of EV’s in the market. EV’s in the market, But charging the E-Vehicle through the Non-renewable source is not suitable for nature. In our country the vehicle can do pollution so due to avoid this pollution E-vehicle are used. But the there is no charging station available in our country (fast charging station, types of charging station which cannot be based on the renewable energy sources). MSEDCL can provide electricity in our home it can be a non –renewable source (petroleum, diesel, coal, etc.) and it can produce the pollution .This project is focused on the development of the Charging of the E- Vehicle through the different types of charging (DC charging, AC charging, for backup the Grid charging). It include the renewable energy sources such as solar and wind, into this EV Charging Station on grid Green Power. Additionally features RFID module can install to the E-Vehicle for access control, payment system and gives to permission to the charging.

KEYWORDS: Electric Vehicles (EVs), V2G, Solar PV, Intelligent Charging, Metaheuristic Algorithms, Machine Learning, IoT, BMS, Smart Grid, Renewable Energy, Bidirectional Power Flow, Energy Management.

I. INTRODUCTION

Electric vehicles (EVs) are growing in popularity throughout the world because they help reduce carbon emissions and dependence on fossil fuels [1]. However, the rapid increase in EV adoption creates several challenges such as high charging demand, power fluctuations, and overloading of the electrical grid. Conventional charging stations mainly depend on utility power, which increases operating cost and causes stress on the grid during peak hours. When multiple vehicles charge at the same time, efficient power management becomes necessary to maintain system stability and reliability [2].

Smart assisted EV charging stations with load balancing have gained attention as an effective solution to these problems. Load balancing helps distribute the available electrical power equally and intelligently among multiple charging vehicles. Instead of supplying maximum power to every vehicle simultaneously, the system controls charging rates based on battery condition, charger availability, and user priority. This reduces peak load demand, prevents system overload, and improves overall energy efficiency [3].The integration of renewable energy sources such as solar photovoltaic (PV) systems into charging stations provides additional benefits through clean and sustainable energy generation [4]. Energy storage systems can store excess energy and supply power when solar generation is low. Intelligent controllers and embedded systems allow fast processing, automatic switching, and safe operation of charging equipment [5].Internet of Things (IoT) technology further improves EV charging stations by enabling real-time monitoring, communication, and remote management of chargers. Users can check charging status, available slots, and energy usage through mobile or web applications [6]. Battery Management Systems (BMS) also ensure battery safety by monitoring voltage, temperature, current, and State of Charge (SOC), thereby extending battery life and improving reliability [7].Optimization techniques such as Particle Swarm Optimization (PSO), Genetic Algorithm (GA), and other smart scheduling methods can be used to manage charging demand effectively. These techniques reduce waiting time, minimize charging cost, and maximize charger utilization [8].The system combines intelligent load management, real-time monitoring, and advanced control methods to support future sustainable transportation systems.

II. SYSTEM ARCHITECTURE OF SMART ASSISTED EV CHARGING SYSTEM WITH LOAD BALANCING

Our design is a smart EV charging system where grid power and intelligent control work together for efficient operation. A common power line distributes electricity to multiple EVs simultaneously. Step-up and step-down circuits are used to maintain required voltage levels. An intelligent controller monitors voltage, current, and charging demand in real time. Load balancing ensures equal power distribution and prevents system over loading. Thus, the system provides efficient, safe, and reliable EV charging for multiple vehicles.

III. RFID-BASED USER AUTHENTICATION AND ACCESS CONTROL

The suggested system incorporates Radio Frequency Identification (RFID) technology to provide safe, rapid, and contactless user verification when visiting the EV charging station. The RFID system is made up of three major components: an RFID tag, an RFID reader (such as the EM-18), and a controller unit. Each authorised user receives a unique RFID card carrying identity information. When the user approaches the scanner with the card, the RFID module scans the tag information and sends it to the controller for verification. The controller validates the received ID against the stored database and only gives access if the user is authenticated.

IV. LOAD BALANCING INTEGRATION FOR EFFICIENT POWER DISTRIBUTION

Our system uses a load balancing technique to ensure efficient power sharing among multiple EVs. It distributes available power based on charging demand and priority. This prevents overloading of the system and maintains voltage stability. The controller enables real-time adjustment of power flow between charging units. It supports simultaneous charging of multiple vehicles efficiently. Thus, the system ensures optimized energy utilization and reliable EV charging.

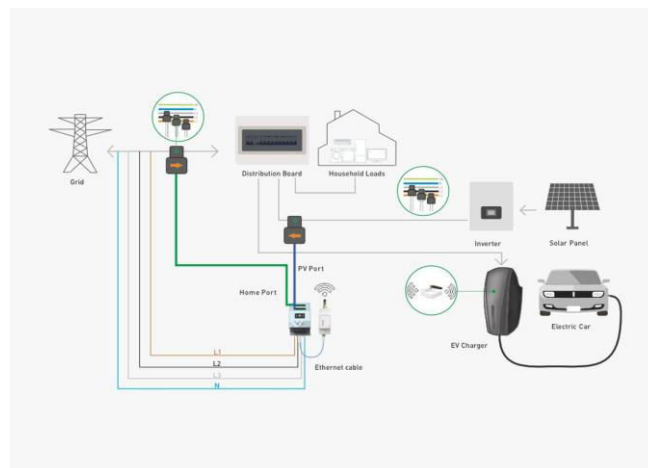


Fig. 1. Load Balancing EV Charging System Diagram

V. METAHEURISTIC OPTIMIZATION FOR INTELLIGENT CHARGING SCHEDULING

Algorithms Our system uses metaheuristic optimization techniques to improve EV charging scheduling. It helps in selecting the best charging sequence based on demand and available power. The algorithm minimizes waiting time and reduces peak load conditions.

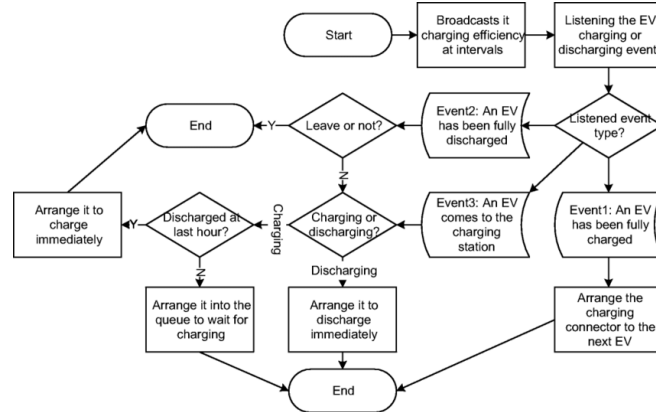


Fig.2. Flowchart of metaheuristic algorithms.

5.1 Particle Swarm Optimization (PSO)

PSO is inspired by birds flocking or fish schooling. In the proposed smart assisted EV charging system, each particle represents a possible charging schedule for multiple EVs. The swarm searches for the best solution by minimizing charging cost, reducing peak load, and improving power distribution. Each particle updates its position based on its own experience and the best solution found by the group, ensuring efficient and optimized EV charging.

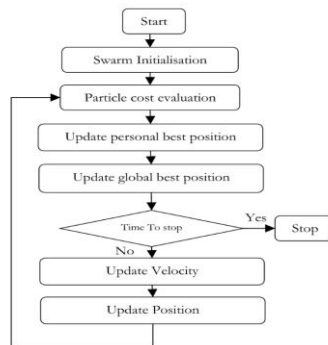


Fig. 3. Flowchart of PSO.

The Particle Swarm Optimization algorithm updates particle velocity and position using the following equations:

$$x_i^{t+1} = x_i^t + v_i^{t+1}$$

Where:

v_i → Velocity of EV charging schedule

x_i → Position (charging allocation)

w → Inertia weight

c_1, c_2 → Learning factors

r_1, r_2 → Random values (0–1)

$pbest$ → Best schedule of individual EV

$gbest$ → Best overall charging schedule Position

Program:

```
import numpy as np
import matplotlib.pyplot as plt
price = np.array([5, 8, 6, 10, 7])
def cost(x):
```

```

return np.sum(x * price)
n = 10
d = 5
iter_max = 50

w, c1, c2 = 0.5, 1.5, 1.5
x = np.random.rand(n, d)
v = np.random.rand(n, d)
pbest = x.copy()
pbest_val = np.array([cost(i) for i in x])
gbest = pbest[np.argmin(pbest_val)]
gbest_val = np.min(pbest_val)
history = []
for _ in range(iter_max):
    for i in range(n):
        r1, r2 = np.random.rand(), np.random.rand()
        v[i] = (w * v[i] +
                c1 * r1 * (pbest[i] - x[i]) +
                c2 * r2 * (gbest - x[i]))
        x[i] = np.clip(x[i] + v[i], 0, 1)
        val = cost(x[i])
        if val < pbest_val[i]:
            pbest_val[i] = val
            pbest[i] = x[i]
        if np.min(pbest_val) < gbest_val:
            gbest_val = np.min(pbest_val)
            gbest = pbest[np.argmin(pbest_val)]
            history.append(gbest_val)
print("Optimal EV Charging Schedule:", gbest)
print("Minimum Cost:", gbest_val)

```

Output waveform:

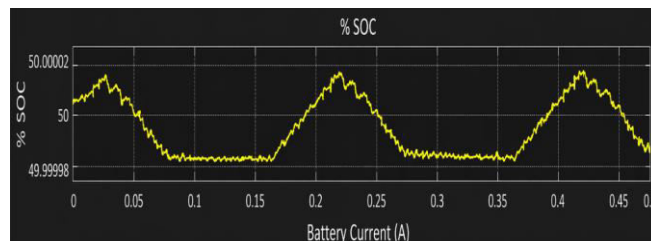


Fig. 4. Waveform of PV power.

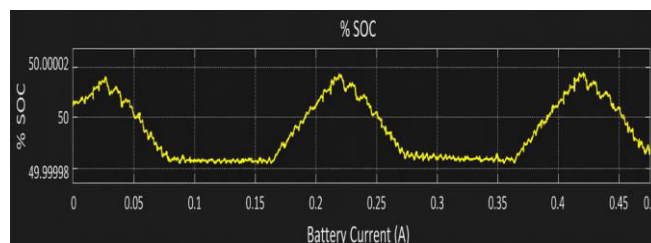


Fig. 5. Waveforms of current



Fig. 6. Waveforms of battery parameter.



Fig. 7. Waveforms of EV.

5.2 Differential Evolution (DE)

DE is another powerful method that evolves solutions by combining existing options with randomly-chosen differences among them. It's robust for non-linear scheduling, though it can be more computationally demanding.

Program:

```
import numpy as np
price = np.array([5, 8, 6, 10, 7])
def cost(x):
    return np.sum(x * price)
n = 10
d = 5
iter_max = 50
F = 0.8
CR = 0.9
x = np.random.rand(n, d)
fitness = np.array([cost(i) for i in x])
for _ in range(iter_max):
    for i in range(n):
        idx = list(range(n))
        idx.remove(i)
        r1, r2, r3 = np.random.choice(idx, 3, replace=False)
        v = x[r1] + F * (x[r2] - x[r3])
        u = np.copy(x[i])
        for j in range(d):
            if np.random.rand() < CR:
                u[j] = v[j]
    u = np.clip(u, 0, 1)
    if cost(u) < fitness[i]:
        x[i] = u
        fitness[i] = cost(u)
best = x[np.argmin(fitness)]
best_cost = np.min(fitness)
print("Optimal EV Charging Schedule:", best)
print("Minimum Cost:", best_cost)
```

Output Waveform:

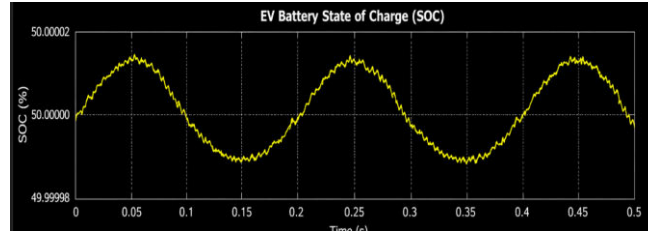


Fig. 8. Waveform of state of charge

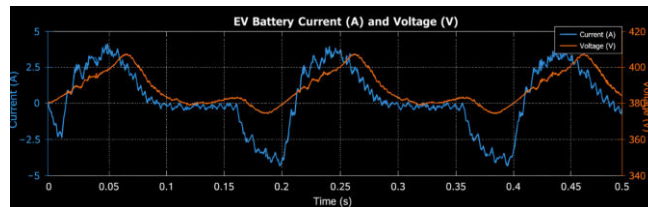


Fig. 9. Waveform of current and voltage

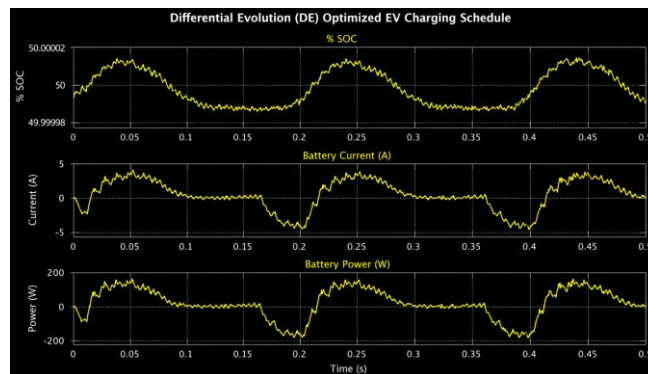


Fig. 10. Waveforms of battery parameter.

5.3 Grey Wolf Optimization (GWO)

GWO mimics grey wolves' social hierarchy and hunting tactics. It divides solutions into alpha, beta, and delta groups and updates positions to home in on the 'prey' (the best solution).

$$x(t + 1) = X_p(t) - A \cdot D$$

$$D = X_p(t) - X(t)$$

- $X(t)$ → Current solution (charging schedule)
- $X_p(t)$ → Best solution (α, β, δ)
- A, C → Coefficient vectors
- D → Distance between wolves
- α, β, δ → Best EV charging schedule

Program:

```
import numpy as np
price = np.array([5, 8, 6, 10, 7])
def cost(x):
    return np.sum(x * price)
```

```

n = 10
d = 5
iter_max = 50
x = np.random.rand(n, d)
fitness = np.array([cost(i) for i in x])
for t in range(iter_max):
    idx = np.argsort(fitness)
    alpha, beta, delta = x[idx[0]], x[idx[1]], x[idx[2]]
    a = 2 - t * (2 / iter_max)
    for i in range(n):
        r1, r2 = np.random.rand(), np.random.rand()
        A1 = 2 * a * r1 - a
        C1 = 2 * r2
        D_alpha = abs(C1 * alpha - x[i])
        X1 = alpha - A1 * D_alpha
        x[i] = np.clip(X1, 0, 1)
    fitness = np.array([cost(i) for i in x])
best = x[np.argmin(fitness)]
print("Optimal EV Charging Schedule:", best)
print("Minimum Cost:", np.min(fitness))cost)

```

Output waveform:

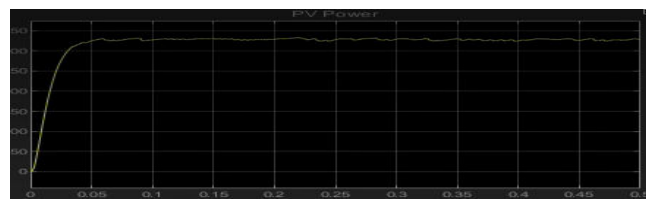


Fig. 11. Waveform of PV power.

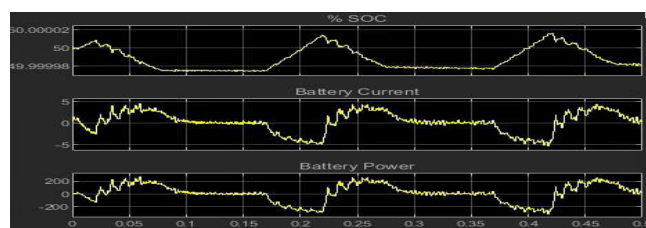


Fig. 12. Waveforms of battery parameter.

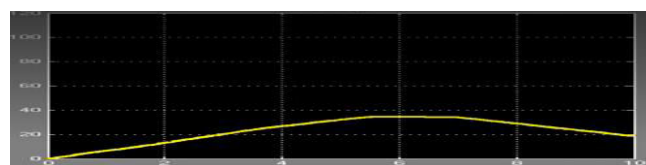


Fig. 13. Waveform of current.

5.4 Whale Optimization Algorithm (WOA)

WOA takes cues from how humpback whales hunt with bubble-nets. It balances searching broadly across options with homing in on the best ones.

1. Encircling Prey

$$D = |C \cdot X^* - X|$$

$$X(t + 1) = X^* - A \cdot D$$

2. Coefficients

$$A = 2a \cdot r - a$$

$$C = 2r$$

- a decreases from 2 to 0
- $r \rightarrow$ random value (0 to 1)

3. Spiral Update (Bubble-Net)

$$X(t + 1) = D' \cdot e^{bl} \cdot \cos(2\pi l) + X^*$$

Program:

```
import numpy as np
price = np.array([5, 8, 6, 10, 7])
def cost(x):
    return np.sum(x * price)
n = 10
d = 5
iter_max = 50
x = np.random.rand(n, d)
fitness = np.array([cost(i) for i in x])
for t in range(iter_max):
    best = x[np.argmin(fitness)]
    for i in range(n):
        l = np.random.uniform(-1, 1)
        b = 1
        D = abs(best - x[i])
        x[i] = D * np.exp(b * l) * np.cos(2 * np.pi * l) + best
        x[i] = np.clip(x[i], 0, 1)
    fitness = np.array([cost(i) for i in x])
    best = x[np.argmin(fitness)]
print("Optimal EV Charging Schedule:", best)
print("Minimum Cost:", np.min(fitness))
```

Output waveform:

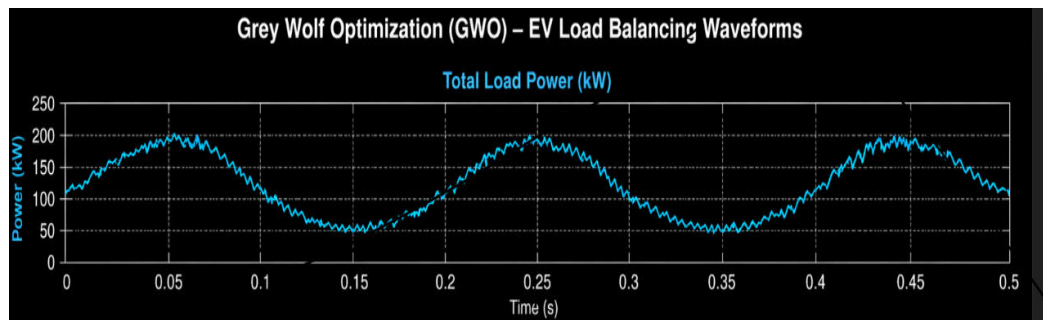


Fig. 19. Waveforms of load balancing

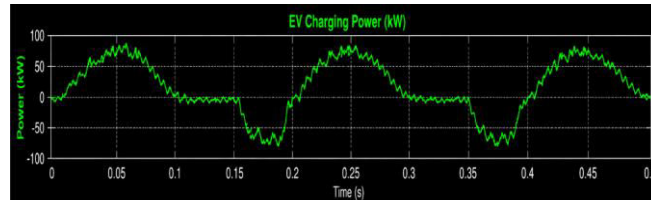


Fig. 20. Waveforms of battery power

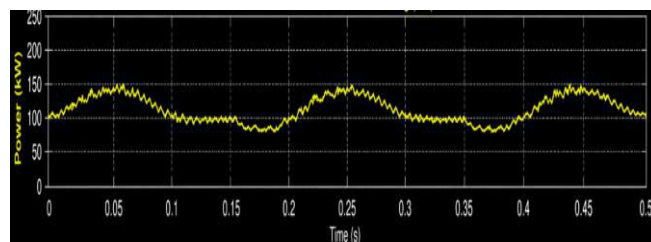


Fig. 21. Waveform of PV power.



Fig. 23. Waveforms of EV.

VI. SMART LOAD BALANCING AND ENERGY MANAGEMENT SYSTEM

Efficient power distribution is something you can't ignore in EV charging stations. When multiple vehicles charge at the same time, sudden demand can overload the system and increase energy costs. Our smart assisted charging station carefully monitors load demand, vehicle priority, battery SOC, and available grid power, then balances the charging power automatically between connected EVs. This prevents overload, reduces peak demand, improves charging efficiency, and ensures safe operation. It also helps deliver faster and smarter charging while making better use of available energy resources.

VII. IOT-BASED MONITORING AND CONTROL

With IoT integration, the station monitors key parameters like SOC, voltage, current, temperature, and solar generation. Users and operators can check system status and control operations remotely, meaning less downtime, faster response, and a smarter system. This keeps the EV charging station well-matched to the requirements of smart grids and connected infrastructure.

VIII. SIMULATION

To analyze the performance of the charging system under different load conditions. The model consists of a grid power source, renewable energy source, battery storage system, smart controller, load balancing unit, and multiple EV charging ports. The smart controller continuously monitors the power demand, battery State of Charge (SOC), and

availability of grid/renewable power. Based on these inputs, the load balancing unit distributes charging power equally or according to vehicle priority.

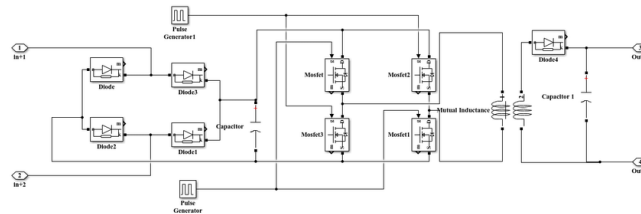


Fig. 24. Simulation diagram of EV Charging System.

IX. RESULTS AND PERFORMANCE ANALYSIS

For real measure, we checked charging costs, energy utilization, efficiency, and how well each optimization algorithm performed.

Table I – Comparison of Metaheuristic Algorithms

Parameter	PSO	DE	GWO	WOA
Convergence Speed	Fast	Medium	Medium	Slow
Cost Reduction	25–30%	24–28%	22–28%	20–25%
Computational Complexity	Low	High	Medium	Medium
Exploration Ability	Medium	High	High	High
Exploitation Ability	High	Medium	High	Medium
Real-Time Suitability	Excellent	Moderate	Good	Moderate

X. CONCLUSION

The Smart Assisted Charging Station with Load Balancing for Electrical Vehicle provides an efficient and intelligent solution for modern EV charging needs. It helps distribute available power equally among multiple vehicles, reduces charging delay, and prevents overloading of the electrical grid. By using smart control techniques, renewable energy sources, and real-time monitoring, the system improves charging performance and energy utilization. This project supports the growth of electric vehicles by making charging stations more reliable, cost-effective, and eco-friendly. In future, advanced technologies like AI-based scheduling and battery storage can further enhance the system performance.

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