Vehicle-to-grid connected hybrid renewable system regularization using Reptile search algorithm using ITAE as objective function

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ABSTRACT

Vehicle-to-grid (V2G) is a technology that enables bi-directional charging of an electric vehicle's battery, allowing it to charge and store energy before redistributing it back to the power grid, facilitating the flow of energy from the car's battery. This research evaluates the efficacy of the Reptile Search Algorithm (RSA) in regulating vehicle-to-grid (V2G) systems connected to hybrid renewable energy sources, focusing on its ability to use frequency oscillations. Through a simulated 24-hour scenario, RSA demonstrated superior performance over the particle swarm optimisation (PSO) algorithm effectively reducing frequency deviations even though disturbances in the system can lead to power imbalance between generation and loads, resulting in frequency deviation. The results indicate that RSA not only provides more stable and efficient outcomes over time, as evidenced by the convergence plot, but also enhances system stability and power balance. This makes RSA a positive approach for the optimization of V2G systems within hybrid renewable energy frameworks.

Key words: Vehicle-to-grid (V2G), Reptile Search Algorithm (RSA), particle swarm optimisation (PSO), hybrid renewable energy, Frequency Oscillations.

1. Introduction

The global need for renewable energy has gained traction in plug-in electric vehicles (PEVs), as energy reserves have emerged as a critical problem across social, economic, industrial, and environmental dimensions. The worldwide market is now seeing a rise in the viability of electric cars (EVs) for personal transportation. Electric vehicles (EVs) provide substantial benefits for pollution-free, energy-efficient, and silent driving. The worldwide electric vehicle ownership rate is projected to attain 10% by the conclusion of 2030. The production and sales of electric cars (EVs) are projected to reach 20 million by the end of 2030 [1]. The rise of electric vehicle (EV) applications in the transportation industry is a feasible solution to several modern concerns, like energy security, environmental degradation, and limitations of fossil fuels. Batteries are often used for storing energy for the functioning on an electric vehicle (EV). Electric vehicle batteries may have a single charge range of 200 to 400 km or beyond. The average daily need of 60 km is considerably exceeded by the single-charge range of electric vehicles owned by most families. Certain external services may harness the significant surplus energy stored in EV batteries. Vehicle-to-home (V2H), vehicle-to-building (V2B), and vehicle- to-grid (V2G) are applications that use the surplus energy of plug-in electric cars (PEVs) for functions beyond vehicle operation [2].EVs with high-capacity batteries are currently experiencing an increase in popularity worldwide. The perception of electric cars as only a considerable strain on the electrical grid has been notably transformed by the expected rise in their prevalence. The principal rationale for the shift in this perspective is the charging and discharging capabilities of lithium-ion batteries in contemporary electric cars. Moreover, electric cars are acknowledged as storage devices that may provide supplementary advantages to the electric grid, such as frequency stabilisation, energy storage, enhanced inertia, inventory rotation, and improved peak shaving [3]. The energy storage capacity of electric vehicles (EVs) may be used in several applications, including the improvement of dependability and stability, such as voltage and frequency control [4].The prevailing scientific agreement is that human activities are responsible for environmental degradation. Addressing the problem prior to its potential irreversibility is a crucial responsibility for scholars and politicians. A significant segment of the population in underdeveloped countries [5] have not yet realised the advantages of universal electrical access. Moreover, the expected shift in the transportation industry from petroleum-based fuels to electrification would increase electric power demand in industrialised countries [6]. Renewable energy sources have the capacity to address this challenge. The limited adoption of renewable energy is partly attributable to its un favourable economics. Historically, renewable energy extraction apparatus was much costlier than conventional techniques. Nature offers an abundant and gratuitous source of energy. Advancements in manufacturing and mass production have effectively mitigated the issue of installation costs.Combining several renewable energy sources is a viable strategy to address fluctuating production. A renewable source may be combined with a conventional or several renewable sources. This integration might significantly save storage space. This is referred to as Hybrid Renewable Energy Systems (HRES). HRES may integrate renewable and conventional energy sources. It may or may not include an energy storage device. When HRES is connected to the grid, it may be shown as an infinitely large battery [7]. The HRES has been studied and optimised using several combinations of solar photovoltaic, solar thermal, wind turbines, biogas, gas production, geothermal energy, hydrogen fuel cells (which may substitutebatteries), diesel generators, and batteries [8]. Hybrid renewable energy plants may provide energy for heating, cooling, and multi-generation uses.The energy crisis caused by fossil fuel depletion has raised public awareness of environmental protection. Scientists have made significant progress in the last decade by integrating distributed renewable energy sources (RESs) into the electrical grid[9]. This includes a significant number of RESs and electric vehicle charging stations. Multi-objective techno- economic optimization was introduced to identify optimal charging and discharging times for electric cars[10]. Frequency control was initially used in residential micro grids to optimize end-user energy costs, battery degradation, grid interactions, and CO2 emissions. To improve reliability, optimize renewable energy sources, and lower costs, a suitable optimization approach based on techno-economic views is essential[11].

1.1 Overview of Hybrid Renewable Energy Systems (HRES)

The worldwide shift towards a stable and feasible hybrid renewable energy system is mostly driven by two factors: the fast exhaustion of traditional energy sources and the prospective techno-economic advantages of hybrid configurations. A considerable segment of rural regions in India is devoid of power availability [12]. Diesel generators (DG) are used to provide the requisite energy demand in distant areas. The elevated operational expenses of diesel generators stem from the volatility in fossil fuel prices and the upkeep of the generator. Thus, power production in off-grid regions is enabled by alternative energy sources, including solar and wind energy, along with their many hybrid combinations. In the present age of escalating energy problems, photovoltaic and wind renewable energy are recognised as the foremost unconventional power generating alternatives. These renewable energy sources are advantageous owing to their ecological sustainability, abundant availability, and site-specific characteristics. It has the capacity to diminish the whole life cycle costs and improve dependability. The Economic Times analysis estimates India's total renewable energy potential (as of 2022) to be 175 GW.Energy plays a pivotal role in global economic and social development. At now, fossil fuels constitute the predominant energy source in almost every nation worldwide, because to population growth, escalating energy consumption, and the exhaustion of natural resources.The evolution of climate change is significantly exemplified by the shift in generations of electrical energy to a new phase of advancement. The hydrocarbon-based economy modifies the efficient arrangement of energy sources. The principal energy sources globally arepetroleum products, including natural gas, coal, and oil. The natural stock of these resources was exhausted due to the twentieth century's reliance on non-renewable energy sources. Wind turbine generators (WTG), solar photovoltaic (SPV), and hydropower are the main renewable energy sources (RES) used. In many nations, renewable energy sources (RES) are considered a significant alternative. The integration of wind turbine generators, hydropower, and solar photovoltaic systems is feasible in hybrid renewable energy systems. In such scenarios, a backup unit consists of storage batteries and diesel generators to meet peak hour demand [13].

1.2 Introduction to Vehicle-to-grid (V2G) Technology

The transportation industry that uses internal combustion engines (ICEs) is worried about many issues, including the depletion of petroleum supplies, abrupt changes in climate, and a declining index of air quality that is correlated with rising costs. Making the transition to e-mobility is necessary for a sustainable future since EVs provide many more grid-supporting and environmentally friendly services than internal combustion engine cars. The direct connecting of electric vehicles (EVs) to renewable energy resources (RESs), such as solar photovoltaic (PV), has been made easier by the integrated energy storage facility. EVs may be quickly linked for emergency services, such as military applications, and can operate as Distributed Energy Resources (DERs) to power micro grids. Furthermore, by providing the required utility assistance, the usage of electric vehicles (EVs) would greatly improve the quality and effectiveness of the electrical sector[14].By 2030, EVs will raise global power consumption from 0.3% to 4%, according to the global EV-Outlook 2020 technology assessment, placing more strain on system operations. A power demand crisis might arise from the distribution network's increasing load, voltage oscillations, harmonic pollution, and energy losses as the number of EVs and uncontrolled charging rises [15]. Numerous elements need to be taken into account in order to minimise grid imbalance brought on by charging EV batteries. Vehicle-to-Grid (V2G) power transfer, which is bidirectional between EVs and the grid, may lessen the need for power system modifications to handle rising demand. In a V2G system, EVs are connected to the grid to charge and discharge power during off-peak and peak loading hours, respectively, which helps fill valleys and lower peak loads [16].The last ten years have seen a broad adoption of environmentally friendly, renewable energy sources, which has led to stricter enforcement of carbon taxes to reduce global warming [17]. The restriction prohibiting a rise in global temperature of less than 2 ◦C was put into effect bythe Paris Agreement in 2016. According to a research by the International Renewable Energy Agency (IRENA), there is a growing quantity of renewable energy coming from natural sources, especially solar power plants.

2 Literature Review

[18] The study presented an optimized bidirectional Vehicle-to-Grid (V2G) operation using a fleet of electric vehicles (EVs). The system uses real-time data to schedule charging and discharging, reducing ownership charges. Factors such as starting battery state, plug-in time, regulatory pricing, intended departure time, battery deterioration cost, and vehicle charging needs are considered. The system works on two case studies and a conventional IEEE 33-node distribution network. Extensive simulations show that the system can lower charging costs while providing voltage and frequency assistance, demonstrating its potential for a more sustainable and efficient charging system.

[19] technology known as Vehicle-to-Grid (V2G) allows electric vehicle (EV) batteries to function as distributed resources, facilitating a two-way flow of power from the AC grid to the EV batteries. The grid and the electric vehicle's battery are linked in this way by use of bidirectional power electronic converters. In order to rectify power factor and match voltages, the majority of V2G application research use two separate power conversion stages: one that converts AC to DC and the other that does the opposite. V2G and G2V active power transfers may, however, also be facilitated by a single AC-DC conversion step.

[20] critically examined the introduction of electric vehicles, focussing on its ancillary functions within the vehicle-to-grid (V2G) system and the possible effects they may have on the power grid. Additionally, it weighs the pros and cons of integrating the V2G technology into the electricity grid. This

paper's overarching goal is to categorise, according to the methods they suggest for future research, the four primary ways in which the V2G system affects the electrical grid. [22] showcased an innovative approach to managing vehicle-grid interaction, enabling the grid to receive power balancing services quickly and simultaneously during peaks. It proposes a multitime scale architecture for optimizing vehicle-to-grid scheduling and providing real-time control. The system uses a mathematical optimization problem to represent the grid's peak-shaving need in a centralized V2G state coordinator. The system uses signals to communicate vehicle states to the grid, and a vehicle-to-grid power controller controls the amount of electricity used to charge a car in real time.

[23] Renewable energy sources like wind and solar power have gained popularity due to their environmental advantages and cleanliness. In 2017, they accounted for 41.4% of the total renewable energy capacity, with over 80% being hybrid systems that operate independently of the grid. To improve performance, further optimization studies are needed. This study analysed modern approaches for sizing, assessment indicators, and hybrid renewable energy system categorization. Decision-makers should investigate hybrid solutions like pumped hydro storage and hydropower, considering environmental and social factors. Hybrid techniques were found to be the most promising sizing strategy, alongside conventional and artificial intelligence approaches.

[24] studied the difficulties of optimising V2G systems, which provide two-way energy transfers between electric cars and the underlying grid. The paper explains how AI-driven algorithms, machine learning, metaheuristic extensions, and agile optimisation ideas may fill in the gaps left by previous efforts in this area and solve these problems. In order to make V2G optimisation more responsive and flexible, the article also presents agile optimisation principles. Finally, the study highlights the promise of AI-driven algorithms and methodologies by examining the difficulties and possible future possibilities of incorporating them into V2G systems.

[25] Issues including the oil crisis, increasing petroleum costs, fossil fuel depletion, and greenhouse gas emissions are driving the need to switch from internal combustion engines to electric cars, according to the analysis. The "Vehicle to Grid" technique uses EVs as load and energy storage, but disorganized charging affects the power grid. This report discusses recent findings on V2G systems, power transfer procedures, challenges faced by businesses, and the technological status of V2G, V2H, and V2V. Optimization algorithms aid in optimal energy management in a coordinated V2G system.

[26] presented an optimum Vehicle-to-Grid scheduling system aimed at minimizing grid load variation. The system prioritizes charging and discharging power based on the battery's current charge level. The algorithm uses priority charging, peak load shaving, and valley filling modes. Charging can occur in any mode, while discharging is limited to peak load shaving. The study was conducted in a commercial-residential neighbourhood with 1300 electric vehicles. The algorithm prioritizes low-state-of-charge electric cars while minimizing grid load variation. The initial maximum variance between peak and off-peak loads was reduced to 1.5 MW.

[27] Renewable energy is gaining popularity due to pollution and rising energy costs. However, the implementation of hydrogen-renewable energy systems (HRES) is challenging due to its complexity and high net present cost. This research examines the current state of HRES optimization using software-based tools, hybrid algorithms, artificial intelligence, and classical methodologies. AI-based approaches have limitations, but combining multiple algorithms improves speed, reliability, and effectiveness. As research on HRES optimization increases, focus should shift to sources like hydro, geothermal, biomass, and biofuel.

[28] The paper presents a wide-area optimal damping control method using the time-weighted absolute error (ITAE) to reduce low-frequency oscillations in interconnected power grids. The method involves modal analysis of the open-loop system, derive the wide-area optimal closed- loop control, formulate an objective function using ITAE, and use the bird swarm algorithm for coordination control. Simulation results show the control strategy has a highly accurate dynamic response and effectively suppresses inter-area oscillations.

2.1 Reptile Search Algorithm in Optimization

[30] The Reptile Search method (RSA) is a meta-heuristics optimization method based on crocodiles' encircling, hunting, and social behaviours. It has gained attention in academics due to its efficient convergence rate and superior effectiveness. This research aims to provide an updated survey on RSA, its traditional variations, and applications across various disciplines. It uses mathematical benchmark functions to analyse RSA and compare it to its peer NIOAs, ensuring a comprehensive understanding of its effectiveness and application in various domains.

[31]

[32] determined HRSA, a hybrid optimization approach that merges the Reptile Search Algorithm (RSA) with the Remora Optimisation Algorithm (ROA). The aim is to find superior solutions while avoiding the drawbacks of previous methodologies. The HRSA approach outperforms the original and comparable methods on twenty-three benchmark test functions and eight data clustering challenges, and outperforms all comparative methods in solving clustering problems, demonstrating its remarkable efficacy in solving various clustering problems.

[33] introduced IRSA, a reptile search method that combines Levy flight with a sine-cosine algorithm. This method avoids local minima trapping and improves search agents' exploitation capabilities. After applying the method to 23 test functions, it showed quick convergence, minimal time complexity, and effective global search. The method was compared with metaheuristic verification methods and the RSA algorithm. The model was trained on a radial basis function neural network and a multi-layer perceptron neural network, showing better classification and prediction skills in real-world categorisation challenges.

[30] A recently developed meta-heuristics optimisation technique, Reptile Search (RSA) takes its cues from the social behaviours, hunting mechanisms, and encircling mechanisms of crocodiles. Ever since its introduction in 2022 by Abualigah et al., RSA has garnered a lot of interest from academia and has seen heavy application in solving various optimisation problems across many fields. The reason for this is because it outperforms other popular optimisation approaches in terms of efficacy, efficiency, and execution time. This study provides an in-depth review of both classic and improved forms of RSA, as well as an examination of its uses in various fields. To properly analyse RSA, mathematical benchmark functions are used to conduct a complete comparison of RSA to its peer NIOAs.The study [33] The reinforcement reptile search algorithm (RLRSA) is an optimization solution that faces issues in balancing exploration and exploitation. To address this, a new learning approach combining reinforcement learning with the Q-learning model

is proposed. Random opposite-based learning (ROBL) is used to improve solutions and diversify populations. RLRSA performed better than conventional RSA methods, especially in unimodal, multimodal, and fixed multimodal tasks. It was also used to solve cost-effective vessel design difficulties. Experiments showed that RLRSA outperformed RSA and other optimization techniques.

[34] Wireless sensor networks (WSNs) are crucial for capturing physical environment data, and their growth has been accelerated by the Internet of Things (IoT). However, network coverage build up can negatively impact WSN efficiency. This paper proposes the Reptile Search Algorithm (RSA) for WSN coverage optimization, which mines the population's hidden positional information. The enhanced RSA is compared with conventional optimization techniques and ordinary RSA, and experimental findings show increased efficiency across various scenarios, suggesting its potential for improving WSN coverage optimization.

3. Problem of the statement

The rising demand for electric vehicles (EVs) and the quick integration of renewable energy sources into the power grid pose a serious threat to grid efficiency, energy management, and stability. Electric cars may function as providers and consumers of energy in vehicle-to-grid (V2G) networks, which present a viable way to improve grid resilience. Nonetheless, controlling the sporadic character of renewable energy, enhancing EV-grid interaction, and guaranteeing smooth coordination between diverse energy sources continue to be crucial obstacles. Efficient control solutions that minimize oscillations and departures from desirable performance metrics, while also optimizing power flow, are necessary to handle these problems and stabilize the system.In this context, a unique method to improve system regularization and control is revealed: The Reptile Search Algorithm (RSA) coupled with the Integral of Time-weighted Absolute Error (ITAE) as the objective function. Inspired by reptile hunting methods, the RSA's metaheuristic optimization skills hold promise for enhancing the precision and efficacy of V2G systems in managing variable renewable energy outputs and dynamic energy needs. The proposed model aims to improve system performance by implementing ITAE, which penalizes system deviations, thereby enabling the V2G architecture to integrate hybrid renewable energy sources more reliably and sustainably into the grid.

3.1 Research Objective

Optimization of Hybrid Renewable Energy System:

To optimise the power production of a hybrid renewable energy system (solar, wind, etc.) connected to a vehicle-to-grid (V2G) infrastructure using the Reptile Search Algorithm (RSA).

Minimization of Integrated Time Absolute Error (ITAE):

To reduce the ITAE throughout the grid-to-electric vehicle energy transfer process, maintaining the V2G system's efficiency and stability.

Regularization of Power Fluctuations:

To create a technique that uses the RSA to preserve grid stability and regularizes power fluctuations in a hybrid renewable energy system linked to the V2G network.

Maximizing Energy Efficiency:

To improve parameter optimization utilizing the Reptile Search Algorithm in V2G-connected hybrid systems in order to increase energy storage and usage efficiency.

Analysis of RSA Performance:

The purpose of this study is to evaluate the Reptile Search Algorithm in relation to other optimisation methods for V2G system regularisation in an effort to provide better ITAE-based outcomes.

Improvement in System Responsiveness:

To use the Reptile Search Algorithm with ITAE as the goal function to fine-tune the control methods and increase the vehicle-to-grid system's responsiveness.

3.2 Research Gap

The existing literature on Vehicle-to-Grid (V2G) technologies and hybrid renewable energy systems underscores notable progress while exposing several research deficiencies. Although several research investigates V2G operations, bidirectional power flow, and optimum scheduling for managing grid load fluctuations, there is a paucity of integration of sophisticated metaheuristic algorithms, especially in dynamic real-time contexts characterised by system disruptions. Much research emphasises static optimisation, neglecting the intricacies of real- time power balance amid variable renewable energy production and consumption. Hybrid renewable energy systems also exhibit inadequate investigation of AI-driven optimisation methods, particularly the Reptile Search Algorithm (RSA), in the context of multi-energy networks. Moreover, while AI and machine learning techniques have shown promise for V2G optimisation, agile and adaptable optimisation methods are yet inadequately investigated in the realms of power transfer management, cost-efficient energy management, and frequency oscillation. There is a need for applied research that incorporates complex algorithms such as RSA into practical energy systems, addressing their dynamic and non-linear characteristics while taking into account environmental and economic considerations.

4. Methodology

This research proposes a comprehensive simulation and optimization process using the Reptile Search Algorithm(RSA) to enhance the performance of a vehicle-to-Grid connected hybrid renewable energy system. This system is simulated using MATLAB 2021A, including photovoltaic (PV) solar energy, wind power, a diesel generator, and electric automobiles. The Reptile Search Algorithm (RSA) is used to optimise the control parameters of the system, using the Integral of Time-weighted Absolute Error (ITAE) as the objective function to minimise power imbalances and frequency deviations. RSA, inspired by the hunting behaviour of crocodiles, employs an iterative encircling and hunting mechanism to efficiently explore and utilise the search space. The system's 24-hour performance is modelled under several disturbance situations, including asynchronous machine initiation, partial solar shading, and wind farm outages, which impact load demand and electricity output. The RSA's capacity to maintain system stability is evaluated against Particle Swarm Optimisation (PSO) using total power production, residential and industrial load, and V2G system characteristics. The detailed explanation of the model is given below.

System Modeling

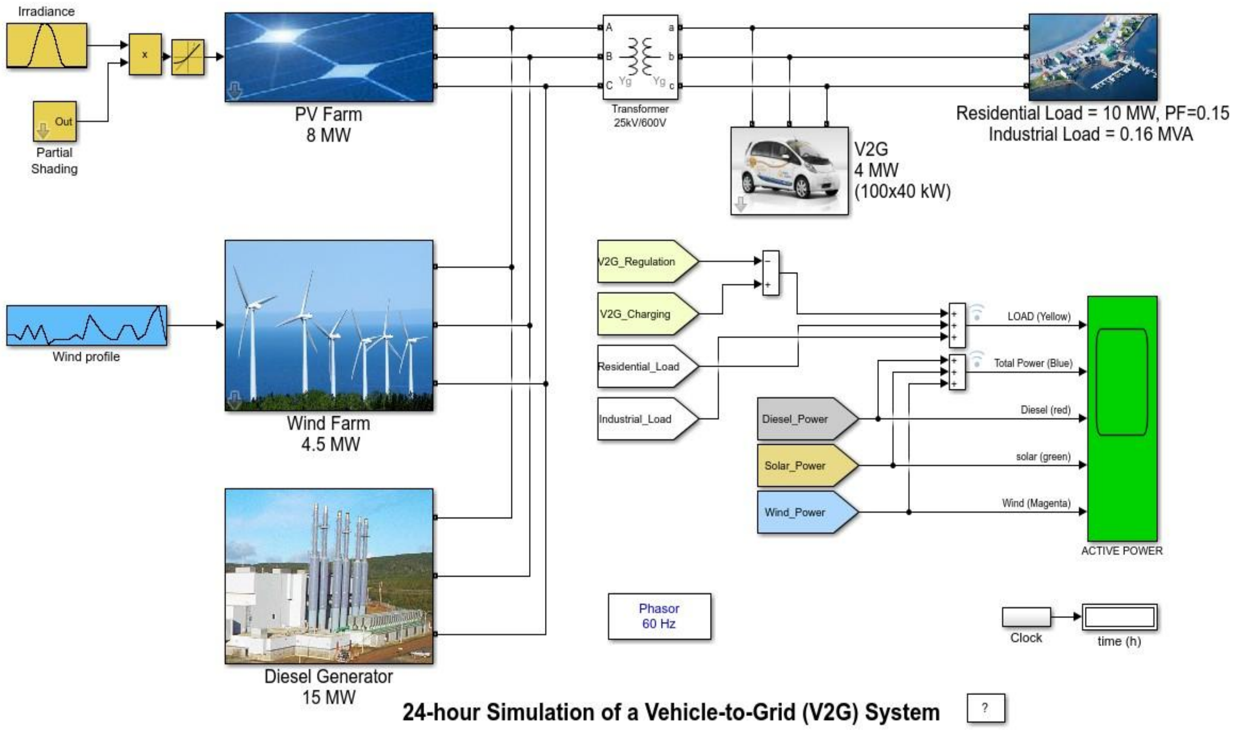

Figure 2 24-hour Simulation of a Vehicle-to-Grid (V2G) System

The system concept incorporates many energy sources, including solar (PV farm), wind (wind farm), and diesel (generator), along with a Vehicle-to-Grid (V2G) system, to provide uninterrupted power to both residential and industrial electricity demand. In order to improve power flow, the model employs a Reptile Search Algorithm and sets the Integral of Time- weighted Absolute Error (ITAE) as the goal function. In order to maintain system stability and efficiency, the components of the system interact dynamically, balancing power production, storage, and load demand while altering control settings.

PV Farm (Solar Power Generation)

The photovoltaic farm produces electricity by using solar panels to convert solar radiation into electrical energy. The output power is influenced by the irradiance and partial shade situations. The generated energy is sent to the electrical grid via the transformer to power the linked loads, which include residential and industrial sectors. Operates as a primary source of renewable energy during daylight hours, especially efficient when solar radiation is abundant. The output of the system fluctuates according to the current environmental circumstances, which in turn impact the power provided to the loads.

Wind Farm

In order to capture energy from the wind, the wind farm employs wind turbines. The power production is dictated by the wind profile, which varies according to meteorological circumstances. The transformer then feeds this energy into the main power system. Offers sustainable energy that is complementary to the solar farm. Wind power typically makes a greater contribution during gusty conditions, particularly during night-time or weather disturbances when solar power is unavailable.

Diesel Generator

If the amount of power produced by renewable sources is insufficient, the diesel generator may be used as a backup or additional power source. This non-renewable resource is often used in situations when wind and solar electricity are unable to meet the current demand. Maintains system stability by ensuring continuous power supply even when renewable sources are down. It is, however, minimized in an optimized system due to the fact that its utilization elevates emissions and operational expenses.

Vehicle (Vehicle-to-Grid) System

The V2G technology allows electric vehicles (EVs) to function as mobile energy storage devices. EVs may either draw electricity from the grid while charging or return power to the grid when discharging. act as a flexible energy storage option, collecting extra energy during times of low demand and discharging it at periods of high demand or when renewable power is insufficient, thereby balancing the energy system.

Transformer

This transformer adjusts the voltage levels to ensure that energy is transmitted efficiently. It converts the lower voltage produced by solar panels, wind turbines and diesel generators into a greater transmission voltage appropriate for grid integration. Ensures safe and efficient energy transmission from generating units to users (residential, industrial) and the V2G system.

Reptile search Algorithm(RSA)

The RSA is an optimization algorithm that optimizes the system's control parameters for the V2G regulation and charging blocks. Its objective is to optimize the interaction between energy sources and demands in order to minimize the error in the system's response. In real time, the regulator parameters are automatically adjusted to ensure that the system operates efficiently by balancing the power supply and demand and minimizing deviations (errors).

ITAE as an Objective Function

The objective function employed to evaluate the system's performance is ITAE. It reduces the integral of the time-weighted absolute error between the actual and intended power output. The ITAE is responsible for the reduction of systemic errors, such as imbalances in energy supply and demand, over time, with a particular emphasis on errors that persist for extended periods. This facilitates the attainment of a more stable and fluid system performance.

5. Results

The simulation goes on for a total of 24 hours. Solar intensity peaks at midday according to a normal distribution. Throughout the day, the wind fluctuates significantly, experiencing numerous peaks and valleys. Residential electricity usage mimics the usual trend seen in a standard home's power consumption. Consumption levels are minimal during the day, reach their highest point in the evening, and then gradually decline throughout the night. During the day, the grid frequency will be impacted by three different events:

- ✓ The kick-off of the asynchronous machine early at the third hour
- ✓ A partial shading at noon affecting the production of solar power
- ✓ A wind farm trip at 22h when the wind exceeds the maximum wind power allowed.

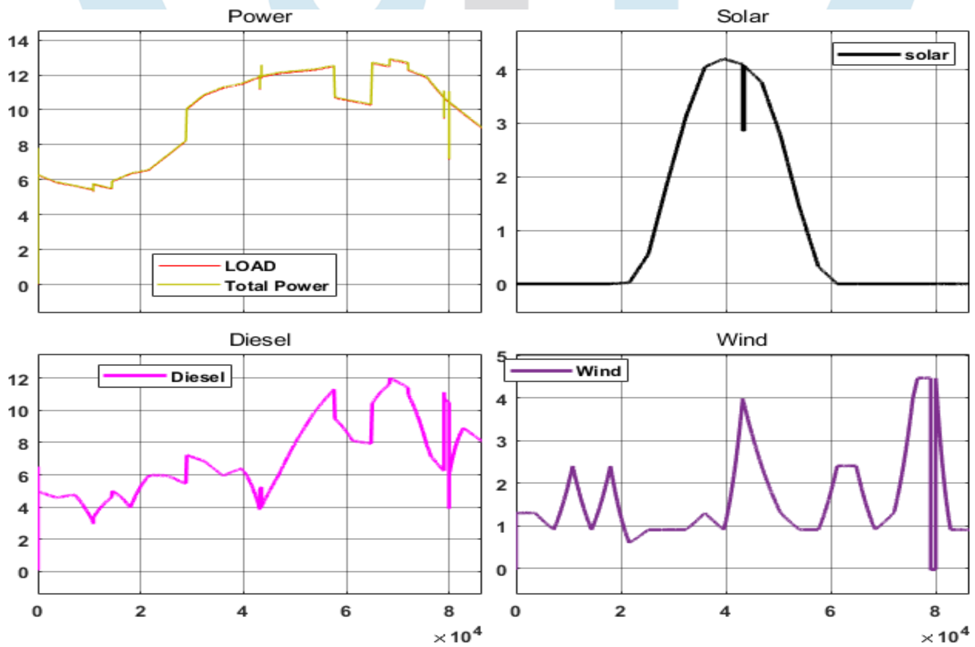

Figure 3 Total power, Diesel, Wind, Solar Generation profiles in KW.

The above figure depicts the profiles of load, total power, diesel, wind, solar generation profiles in KW.

The generation units such as PV, wind and diesel are supplying powers to the residential load in order to satisfy all the demands if there are any disturbance occurs in the system lead to power imbalance between generation and loads which consecutively leads in the frequency deviation.

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Car profiles:

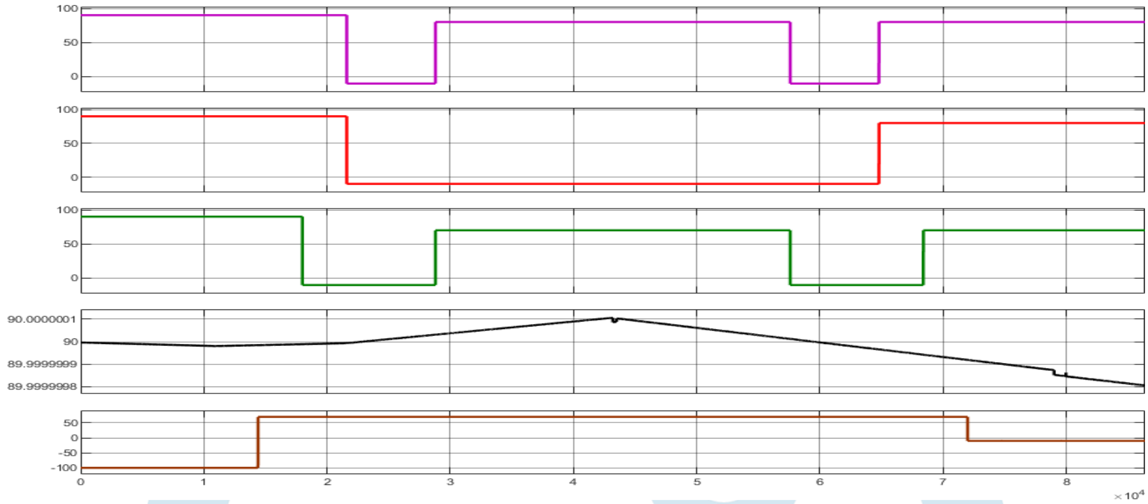

Figure 4 Car profiles

The considered car profiles of V2G system is shown in the above figure.

Industrial load

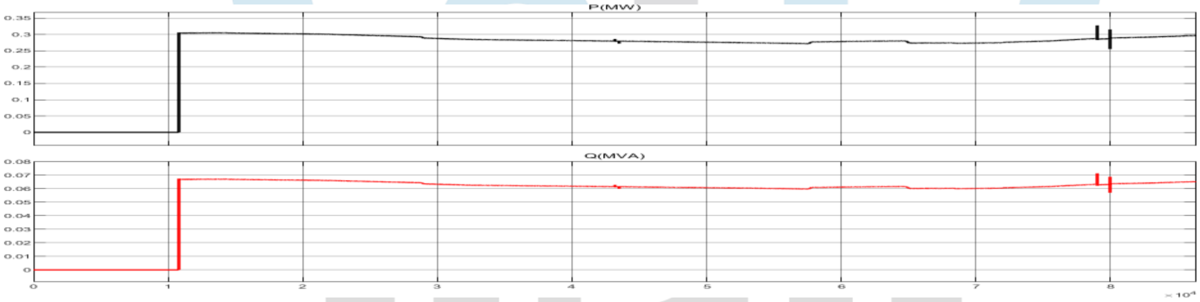

Figure 5 Industrial load

The active and reactive power industrial loads are shown above.

Residential load:

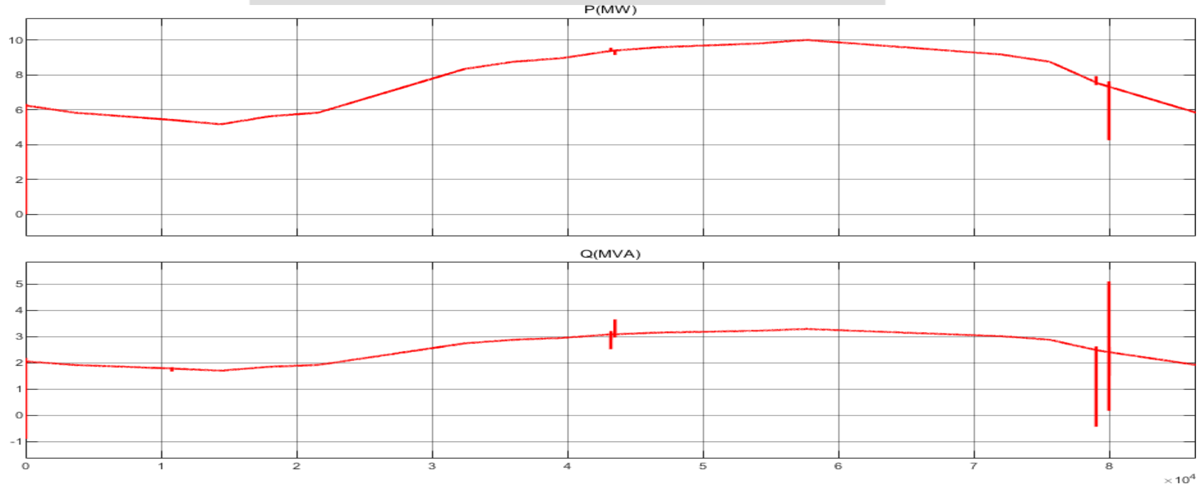

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Figure 6 Residential load

The active and reactive power residential loads are shown above.

Disturbance 1:

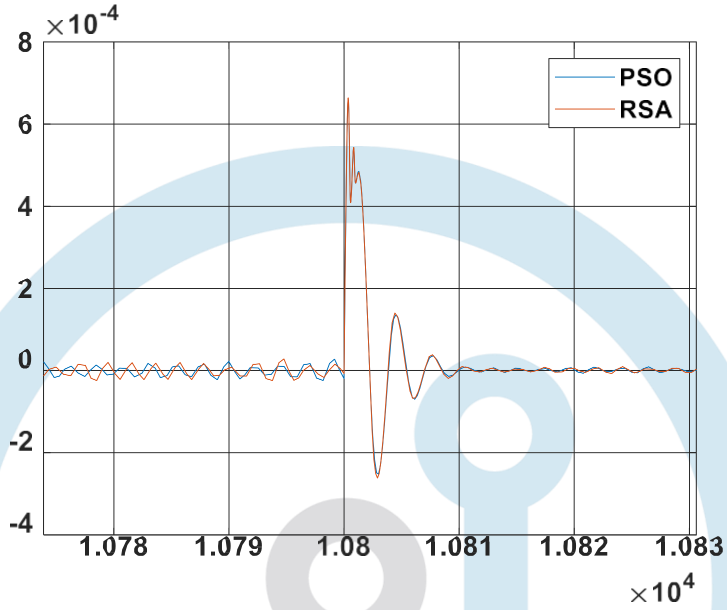

Figure 7 Disturbance 1

The figure illustrates that the RSA can effectively dump frequency oscillation in comparison to the PSO.

Disturbance 2:

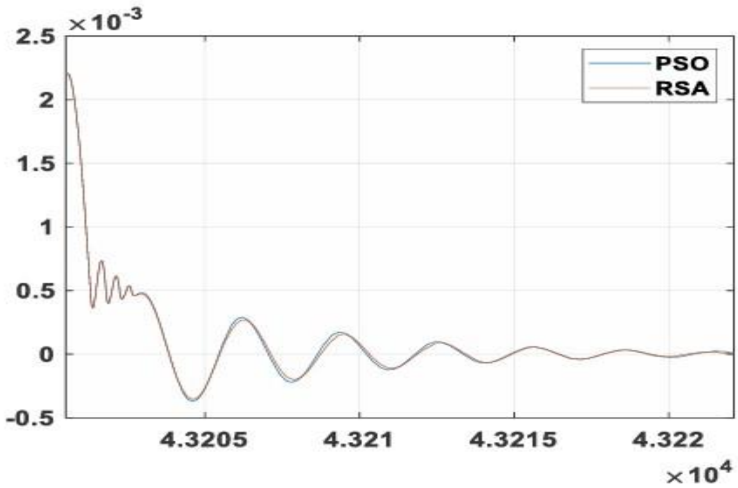

Figure 8 Disturbance 2

The figure illustrates that the RSA can effectively dump frequency oscillation in comparison to the PSO.

Disturbance 3

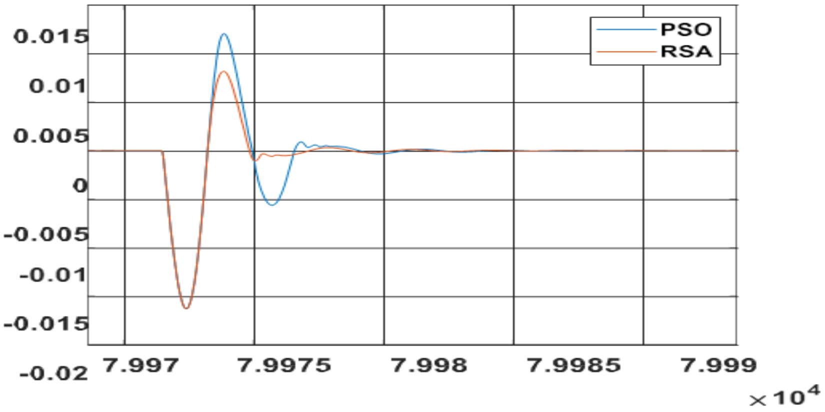

Figure 9 Disturbance 3

The figure illustrates that the RSA can effectively dump frequency oscillation in comparison to the PSO.

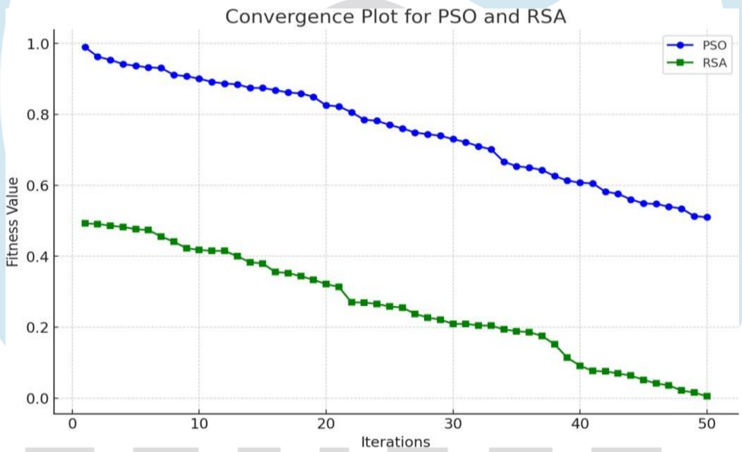

Figure 10 Convergent plots for PSO and RSA

The convergence plot comparing PSO with RSA are shown in the above figure. The RSA values (in green) are better than the PSO values (in blue) since they regularly exhibit lower measurements. This illustrates better performance RSA over iterations in this simulated scenario.

6. Conclusion

The conclusion of the RSA demonstrates the better performance in frequency oscillations compared to PSO in 24 hours' scenario. The profiles of load, total power, diesel, wind, and solar generation profiles in KW. The generation units, such as PV, wind, and diesel, supply power to the residential load to meet all demands. Any disturbances in the system can lead to power imbalance between generation and loads, resulting in frequency deviation. The car profiles of the V2G system, active and reactive power industrial loads, and residential loads. The RSA can effectively dump frequency oscillation compared to the PSO, and the convergence plot comparing PSO with RSA shows that the RSA values are better than the PSO values, as they consistently exhibit lower measurements, indicating better performance RSA over iterations in the simulated scenario. These results confirm that RSA offers more stable and efficient results over time, making it a more reliable approach for regulating vehicle-to- grid (V2G) systems connected to hybrid renewable energy sources, ensuring better system stability and power balance.

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