An Optimized Smart Grid Solution for Charging and Discharging Services in Cloud Computing using Genetic Algorithm with ANN

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Abstract — *Smart Grid (SG) scheduling is a most important research apprehensive in grid computing, a skill that enables resource virtualization, on require provisioning and resource allotment between organizations. In the SG, there is no need to be concerned about the whereabouts from where the vehicles energy you are using comes from, yet when you plug your vehicles into the SG system it acquires the energy, which the profession needs to acquire it done. SG scheduling is the strength of character of the optimal use of such a magnificent system. On the way to minimize the energy consumption and plug-in time, an optimization technique based SG solution performed for charging and discharging services in cloud computing environment using the concept of Artificial Neural Network (ANN), which focuses on the efficiency of scheduling in SG environment by utilizing Artificial Intelligence (AI) algorithms to address the smart usage of grid resources and to ensure an overall good balance in the system with healthy reduction in plug-in time and motivate the users to get a comfortable level of quality of service. On the additional side, the appearance of Electric Vehicles (EVs) promises to capitulate numerous benefits to both energy and transportation industry divisions.*

In this research try to solve the problem of plug-in EVs at public supply stations (EV-PSS) using the Genetic Algorithm (GA) with ANN architecture for SG as an optimization technique which helps to optimized the vehicles properties using fitness function and also it is a novel approach to solve these type of issues based on cloud computing. For real supply energy scenario, an extensive simulation performed and compared it with other relevant datasets (recent datasets) to propel the need to provide intelligent systems in SG based cloud-computing environment. The observations based on GA with ANN, the various result parameters improved as compare to previous datasets such as approx. 0.3% in Plug-in Time, approx. 0.7% in charging & discharging Time, approx. 0.5% in Energy Demand. Further, Simulation results demonstrate the effectiveness of the improved results when considering real EVs charging-discharging loads at peak-hours periods.

Keywords — *Smart Grid, Electric Vehicles, Artificial Intelligence, Energy management, Genetic Algorithm, Artificial Neural Network (ANN), Cloud Computing.*

I. INTRODUCTION

Smart Grid (SG) is an advanced and modernized electrical grid with more improvements to the traditional power grid. The term was first introduced by Andres E. Carvallo at an International Data Corporation (IDC) conference in the year of 2007 at Chicago. In his paper, SG is described as a combination of energy, communication, and software with hardware, along with the controlling systems with data distribution, storage, and utilization as described by Carvallo and Cooper (2015).

It has the capability to get more efficiency, security, reliability and easy maintenance. The automation of grid activities and fast reliable wireless two-way communication through smart meters and distribution lines used to achieve this in the smart grid. Energy consumption requirements are huge in the current development under many circumstances to survive in this human world. The energy requirements and usage can cause global environmental changes and shows effect on the usage. However, there is an advantage of using renewable energy sources like wind, tidal, hydro. SG is a better solution to generate, transport and distributions aspects under efficient power management. The basic architecture of the smart grid infrastructure contains Home Area Networks (HAN) and Neighbourhood Area Networks (NAN), data centers, and automation systems. The smart grid communication system offers sustainable operations to clients or customers and smart grid utilities. The system provides a reliable and efficient distribution system with clean natural renewable energy sources like wind, hydro along with two-way wireless communication systems integration.

Electric vehicles (EVs) are one of the encouraging solutions to improve energy efficiency and reduce the carbon emissions in the transportation sector using the concept of SG scheduling in cloud environment.

Today, both academic and industry world are focusing on the challenges of EVs, in terms of energy consumption and integration with the power grid networks based on the cloud computing. The large penetration of electric vehicles raises significant issues for electric utilities.

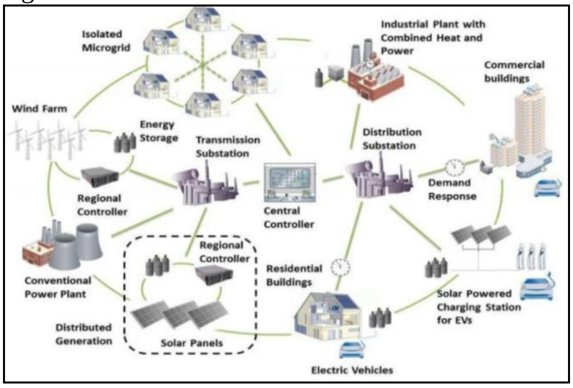


Figure 1: Smart Grid System

The Figure 1 shows the modernization process and vision of grid. The future of SG system come with advanced communication architectures integrated to electrical infrastructure.

1. ***Communications:*** To communicate the devices with the latest communication technologies make every part of the smart grid to talk and respond.
2. ***Sensing Technologies:*** There is big requirement to obtain the faster response and it is required to create remote sensing and demand management. All these activities can be monitored using the sensing technologies.
3. ***Components:*** To manage generation, storage and distribution and other diagnostic management.
4. ***Control Methods:*** Obtaining the analysis of the components and generating precise solutions to the events.
5. ***Decision Management:*** Amplifies the human decisions and creates automatic decision making wherever necessary with an advanced knowledge base and decision making in the smart grid systems.

Traditional power grid architecture is given in the Figure 2 with three stages called power generation phase, transmission phase and distribution phase. The distribution phase is connected to residential users, commercial users and Industrial users. In the normal traditional grid system, the direction of flow is only in one way. As shown in Figure 2 the power generation unit transmitting power in one-way direction using power transmission lines and that is consumed by residential users or Industrial users or Commercial users. Few important examples to motivate the use of smart grid are as follows. The smart grid helps by integrating the renewable energy sources like wind, solar, tidal, wave, bio fuel, etc. It provides a great opportunity to use electrical vehicles in place of the traditional fuel vehicles. It reduces the emission of carbon dioxide from the factories, vehicles and other business and industrial areas. It facilitates the user to communicate in a two-way as power producers and consumers. Each user has the opportunity to produce the power at home or capable to create micro grids.

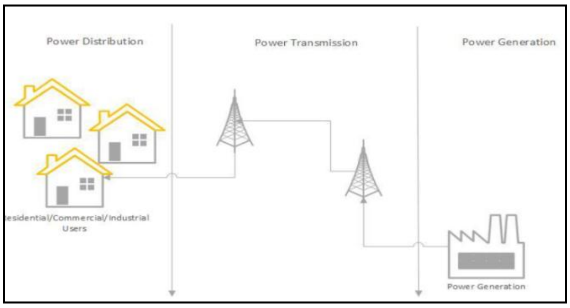


Figure 2: Traditional Power Grid

Traditional grid vs. Smart grid: The basic differences between traditional grid and smart grid are very crucial to know before going to the original concepts of the research. In the traditional grid system, only one-way communication is possible and in the smart grid system two way communications is possible between the two ends of the network. The power generation is completely centralized in the traditional smart grid system and distributed in the smart grid system due to active participation from the users. The user may utilize the power or sell the own produced power to the markets. Creation of two-way business is possible between markets and end-users vice versa. The complete smart grid system is fully automatic with sensors integration and can avoid huge block outs from the smart grid system. The main difference is relying on the communication among the customers, devices, suppliers and various applications. The major difference comes with the fossil fuel consumption and it is more in the traditional grid and almost nil in the smart grid system. However, there is no user participation in the traditional grid and each user has lot of choices and options to manage or participate in the system of smart grid.

Recovery management is very efficient in the smart grid system and traditional system needs a human involvement at maximum extent.

Table 1: Traditional Grid vs. Smart Grid

Type	Traditional Grid System	Smart Grid System
Communication	One-Way	Two-Way
Power Generation	Centralized	Distributed
Sensors	Small quantity	Fully Sensor Integrated
Monitoring	Manual	Automatic
Recovery	Human based	Fully Automatic
User Options	Very few options	More user options
Control	Limited Control	Pervasive Control
Responsive	Prevents further damage	Automatic detection and responsive to problems

Smart Grid Communication Architecture: In Sensor networks are already using the technologies of smart grid. Smart grid communication classified into five major areas.

- Advanced Components
- Sensing and measurement
- Advanced Interfaces and Support
- Standards and Groups
- Integrated Communications

Electrical Vehicles (EVs): Electric Vehicles (EVs) are a clean alternative to traditional vehicles. The revolution from traditional gasoline-powered vehicles to EVs has been a gradual process for some – and an exciting leap for others. With increasing innovation and environmental awareness, EVs have never been safer, sleeker, or more exciting to drive. Boasting features like immediate torque, silent ride, and premium performance, EVs also have lower fuel and maintenance costs. And consumers ultimately garner social pride and responsibility from creating a better, healthier planet. For all of these reasons and more, EVs have caught the attention of car-lovers and commuters alike. Electric vehicles are one of the encouraging solutions to improve energy efficiency and reduce the carbon emissions in the transportation sector.
The contributions of this research work are summarized as follows:

1) We resolve the existing problem of EVs charging and discharging and present an efficient scheduling approach based on the concept of Artificial Neural Network (ANN) as an Artificial Intelligence (AI) technique based on the cloud computing transportation environment.
2) We design a novel architecture of communication between SG and cloud platforms based on the Genetic Algorithm (GA) as an optimization approach, and define the interaction between EVs, EVs at public supply stations (EV-PSS), SG based scheduling and cloud platforms providers. The objective is to manage EVs and EV-PSS information using ANN to minimize the energy load.
3) We focused on priority assignment concept using GA which defines the strategy to attribute the optimal priority for EV using demand-supply. The objective of this research is to maintain the grid stability particularly for the duration of peak hours.

The remains research paper is organized as follows. Section II discusses the survey of related work. In section III, the difficulty of charging-discharging of EVs is originated. Section IV introduces a development architecture and well-organized AI approach based on cloud computing. The simulation results and discussions are presented in Section V. Lastly, the conclusion and future of this research paper is described in Section VI.

II. BACKGROUND SURVEY

In this section, we present the survey of existing work based on a smart grid solution for charging and discharging services in cloud computing scheduling using genetic algorithm and artificial neural network. Chekierd and Lyes Khoukhi [1] suggested an efficient smart grid approach for EVs charging and discharging services at public supply stations (EV-PSS), based on cloud computing scheduling. The approach ensures the communication between smart grid and cloud platforms, and manages the smart grid entities and operations. In order to optimize the waiting time to plug-in at EVPSS, they introduced priority assignment algorithms. The simulation results proved that the grid stability is improved but they do not work well for with increase in time for a day. To minimize this problem, need a modification based on the optimization algorithm. Javaid, Sakeena, et al. [2] Presented an orchestration of the Fog-2-Cloud based frame work has been presented for intelligently managing the resources in the residential buildings. Assignment of the resources has been done through the fog layer. The fog layer has reduced the latency and enhanced the reliability of the cloud computing services. Chekierd and Lyes

Khoukhi [3] suggested a D2P model for EVs charging and discharging scheduling and building energy management in SG, which considers real-time and energy demand constraints. The model is based on a decentralized Cloud-SDN communication architecture. As proved in simulations and comparisons of this work with four other works, using real electric load can be useful for SG applications. But, in this work AI based Cloud-SDN architecture can also improve the grid stability, especially in peak hours. Zijian Cao et al. [4] suggested a novel cost-oriented model is to optimally allocate the cloud computing resources for demand side management considering the load profile of computing applications and the characteristics of cloud computing instances. A MPL algorithm is developed to solve the complex optimization problem of the model. Baris Yuce et al. [7] suggested a model ANN based district grid energy demand forecasting. According to the results, the high level energy consumption was determined about 4% average percentage error. The result of work done is also highly related to electricity consumption pattern. As the regular user has a repetitive pattern which allow the intelligent system such as ANN to learn patter quicker with higher prediction rate. However, this prediction profile may change with load and need to minimize the load.

III. EV's Charging and Discharging problem

In these recent years, national power industries of various countries from Asia, Europe and others are showing a lot of interest in the change of current power grid system to new era of advanced intelligent communication system and wide range of research is going on at various sub levels of smart grid communication system to solve the electrical vehicles charging and discharging problem based on the cloud computing. The smart grid structure follows the hierarchical format; many operations need to be performed to achieve the smooth flow from power generation unit to the user consumption along with control rooms for processing the necessary actions to user data management. There are few challenges that affect the smart grid including demand management, dynamic pricing and load balancing. Demand management is major issue with smart grids, under some circumstances, the power demand increases to more than the expected range. Recent developments suggest various solutions to solve those problems but outcomes are not acceptable.

To solve the electrical vehicles charging and discharging problem, the scheduling algorithm will be designed with concept of optimization and artificial intelligence techniques in cloud computing environment. In this following methodology, genetic algorithm along with the artificial neural network is used to resolve the above mentioned problems. The performance of the smart grid is mainly depending on how it is handling these operations during the peak demands. These issues are resolved by integrating the effective smart grid system with the optimization technique, and designed the artificial intelligence technique based system architecture, also measured system performance in order to encounter the challenges in the smart grid communication networks.

IV. Structure of Solution Methodology

There are certain steps that are required to be followed in order to create a simulator for simulation of smart grid solution for charging and discharging services in cloud computing scheduling using genetic algorithm and artificial neural network. These steps are defined as follows:

***STEP 1*:** To design a simulator framework on the basis of certain width and height of the network for the cloud and smart grid communication.

***STEP 2*:** Initialize the N number of electrical vehicles within the simulator.

***STEP 3*:** Define local station controller (LSC) for each group of vehicles and one central station controller (CSC) for the interaction between them.

***STEP 4*:** Set the communication range for each vehicles, LSC and CSC.

***STEP 5*:** Develop a code for calendar scheduling model to manage the demands of all electrical vehicles.

***STEP 6*:** Analyze the performance of simulator on the basic of performance parameters and if network required the optimization then the scheduling in improved using the Genetic Algorithm.

***STEP 7*:** Set the objective function of the Genetic Algorithm according to the requirement.

***STEP 8*:** On the basis of the hybridization of the ANN along with the Genetic algorithm we optimized the scheduling problem of electrical vehicles using cloud computing environment and find out the best and optimal communicating route for the data transmission. So that, the charging and discharging problem will have been removed from the simulator.

***STEP 9*:** At last we calculate the performance parameters and compare with the existing work.

Algorithm of Simulator Design

Define height = 1000
Define width = 1000
Define N number of vehicles for the simulation of network
For i = 1 to N
Plot_node(i)=coordinate (X, Y)
Define node name = N(i)
Tx = random (N)
Rx = random (N)
If Tx == Rx
Tx = random (N)
Rx = random (N)
Else
Tx = Tx
Rx = Rx
End
Define Tx as transmitter
Define Rx as receiver
End

Coverage Range Algorithm for Communication

$$DefineCoverage\_Set = \frac{20*Network-Width}{100}$$

For i = 1 to N
Cov_set(i) = Coverage_set(N)
Cov_list(N, i) = Cov_set(i)
End
For i = 1 to N
Route (1) = Tx
Route (2) = LSC of Tx
Route (i) = LSC(Cov_se(N))
If Cov_set(Tx) == empty
Next_Vehicle = random
End
If Cov_set(Tx) == CSC
Next_Vehicle = CSC
End
Repeat while Rx is not found
Route (last) = Rx
End

Genetic algorithm with ANN

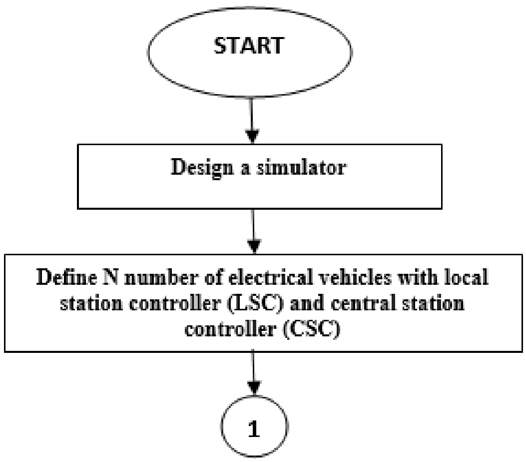
Initialize GA in simulator
Define population size, selection function, mutation function, crossover function etc (Default).
Data = Network Properties
F_s = Selected value from the Data
F_t = Threshold value from the Data (Average of Data)

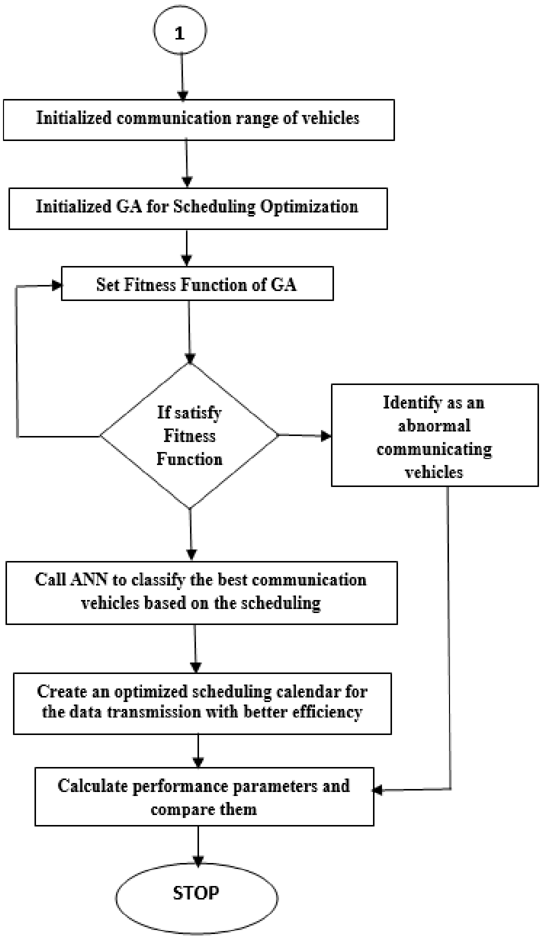
$$Fitness\_function = |fs.................. fs \geq ft|$$
$$= |ft...............Otherwies|$$

No. of variables = 1
For i = 1 to Node within route
Affected_Node (i) = GA(Fitness_function, Initialize GA, No. of variables)
End
Save the affected node list in the arrayof Affected_Vehicles
For i = 1 to N
Initialize ANN with parameters
– Epochs (E)
– Neurons (N)
– Performance parameters: MSE, Gradient, Mutation and Validation Points
– Training Techniques: Levenberg Marquardt (Trainlm)
– Data Division: Random
For each set of T
Group = Categories of Training Data
End
Initialized the ANN using Training data and Group
Net = Newff (T, G, N)
Set the training parameters according to the requirements and train the system
Net = Train (Training Data, Group, Neurons)
Classify the affected vehicles
End
If properties of unauthorized vehicle == true
Vehicle not consider in the route
Else
Create an optimized route
End
Calculate QOS parameters
End

In this work, a smart grid solution for charging and discharging services in cloud computing scheduling using genetic algorithm and artificial neural network is designed. The objectives of this research work has been identified as follows

1) To study the previous smart grid solution for charging and discharging services in cloud computing scheduling with different techniques.
2) To solve the electrical vehicle charging and discharging issue, genetic algorithm with a novel objective function will have been developed as an optimization algorithm.





3) To develop an artificial neural network based architecture of communication between smart grid and cloud as an artificial intelligence technique.
4) To evaluate performance parameters of EV charging and discharging like energy consumption, time to plug-in, charging discharging energy etc. and compare with existing work.
Using the above mentioned algorithm and methodology step we design a flow chart of work done is drafted to achieve these objectives.

V. Simulation Results & Discussion

The simulation environment of the work done is shown in the table and the simulation results are described in the below section.

Table 2: Network Requirements

Number of vehicles	50-100
Area	1000-1000 meters
Simulation Tool	MATLAB
Authentication Parameter	Energy Load
Evaluation Parameter	Network Life Time Time to Plug-in Simulation Time Energy Demand Charging & Discharging Energy Energy Load

To simulate this methodology and calculating performance metrics we need simulator and we design a simulator which is show on the below figure.

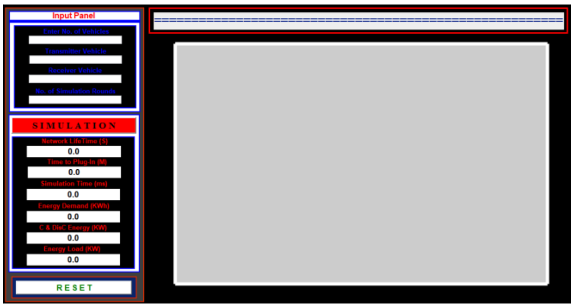


Figure 5: Simulator

The above figure represents the simulator with height and width (1000×1000). In the figure, there are two sections first is “Input Panel” and second is the “Simulator part”. In the “Input Panel” we provide the required input data to simulate the designed network and in “Simulator part” we check the performance parameters of work done. Figure 5 represents the deployment of EVs, within the network. In the below figure, we enter total 50 numbers of vehicles with five iterations. We select a vehicle as a transmitter(Tx) and as a receiver (Rx) and the 5 number vehicle is act as a Tx vehicle and 50 is act as a Rx vehicle. After that, define a communication range to each vehicles using above mentioned algorithm. When communication range is defined then create a route from Tx vehicles to Rx vehicle regarding energy request. This section introduces new interaction architecture based on the cloud computing technology with concept of hybridization of GA and ANN, in order to relieve the SG capacity and storage limits. This approach contributes to ensure an optimal scheduling of EVs demands. The cloud computing, with its massive data storage and computing capacity, and its distribution aspect, can help the SG to manage EVs requests while satisfying power and timing constraints.

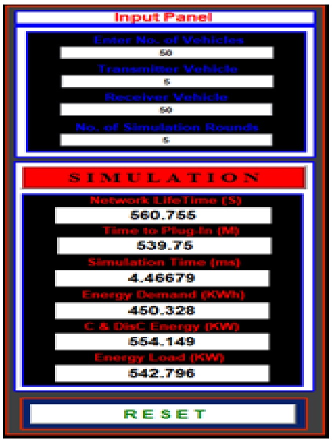


Figure 5.1: Simulator with Input Data

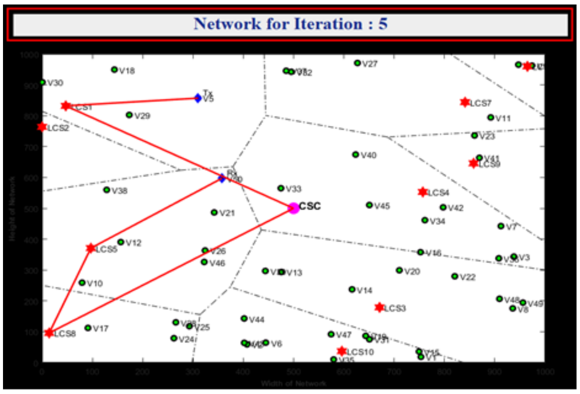


Figure 5.2: Simulator with Input Data

Here GA with ANN is used as a classifier to classify the unauthorized vehicles during the simulation. The QoS parameters of work done is given in the below section.

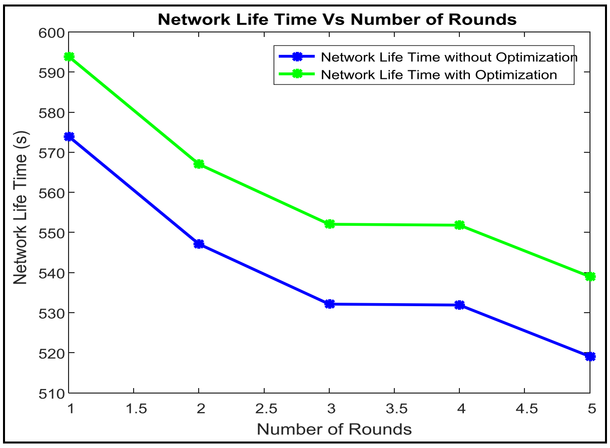


Figure 6: Network Life Time

The above figure represents the network life time of opined methodology with GA and ANN as an AI technique. Whereas the green line indicates the network life time values obtained for the network with optimization i.e. GA and ANN used to improve the performance of network. The process is repeated five times in order to obtained accurate results. From the figure, it is clear the network life time of work done is improved by using the concept of AI.

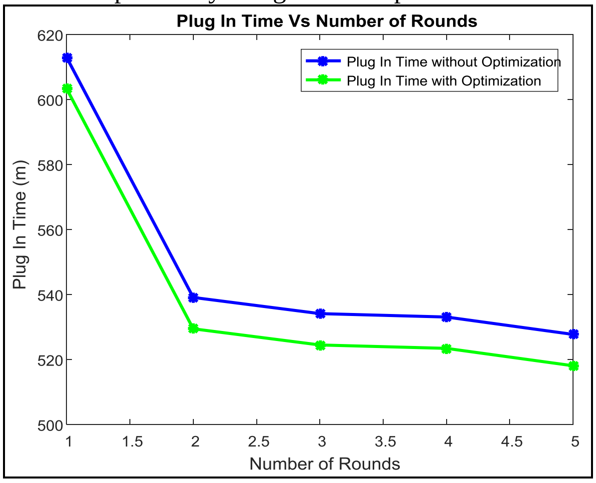


Figure 7: Plug-In Time

Plug-In time is the average time a network takes to charge the vehicles to reach the destination. In the above figure, green line shows the Plug-In time occurred in case of optimization used and blue line is indicating Plug-In time without optimization used. Therefore, it is clear from the graph that the Plug-In time obtained for network with optimization when GA and ANN techniques are applied is less than the value obtained for without optimization which means that in without optimization energy loss is more and take more time to reach at the destination.

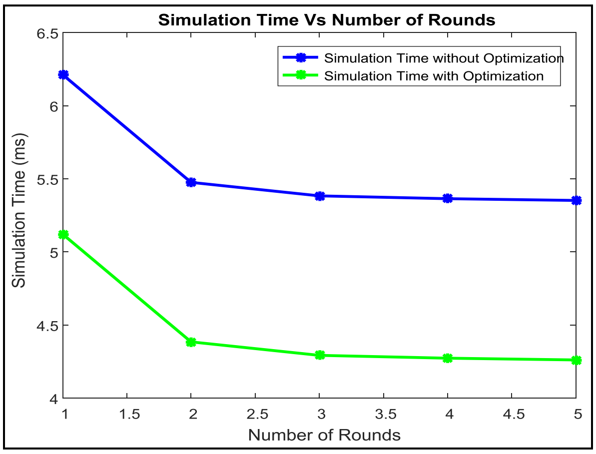


Figure 8: Simulation Time

Simulation time is the average time a network takes by vehicles to reach the destination. This includes all possible time caused by buffering during route discovery, queuing at the interface queue. This metric is calculated by subtracting time at which first information was transmitted by Tx from time at which first information arrived to destination using cloud computing environment. In the above figure, blue line shows the simulation time occurred in case of without optimization and green line is indicating simulation time with optimization. Therefore, it is clear from the graph that the simulation time value obtained for network with optimization when GA and ANN techniques are applied is less than the value obtained for without optimization.

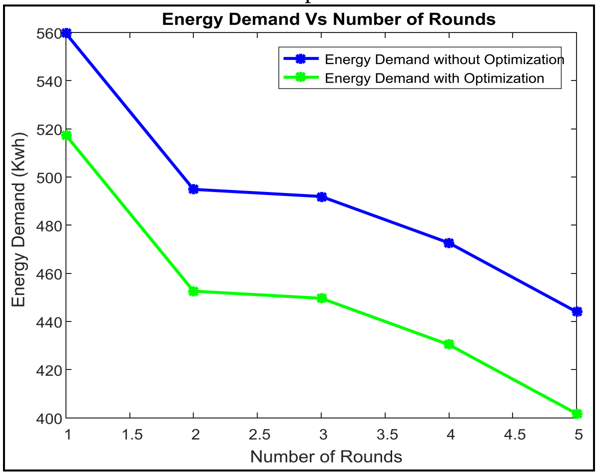


Figure 9: Energy Demand

Energy used by vehicles, LSC and CSC to transmit information bits correctly and received at the Rx vehicle. The total energy demand of network is the summation of energy demand by all intermediates vehicles. From the above figure, it is clear that the green line is for the energy demand when GA and ANN are applied to the network whereas blue line indicates the performance when GA and ANN are not applied. Thus, it is concluded that when GA and ANN are applied to the network, energy demand is less as compared to the energy demand obtained for the network without GA and ANN. Therefore, the results obtained for the network using optimization are better than without optimization.

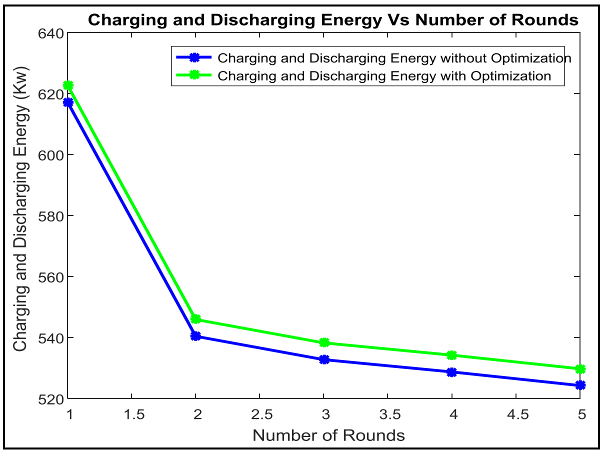


Figure 10: Charging & Discharging Energy

Figure 10 show the comparison of charging & discharging energy used by vehicles. It is clear that the green line is for the charging & discharging energy when GA and ANN are applied to the network and it is better than blue line which indicates the performance when GA and ANN are not applied.

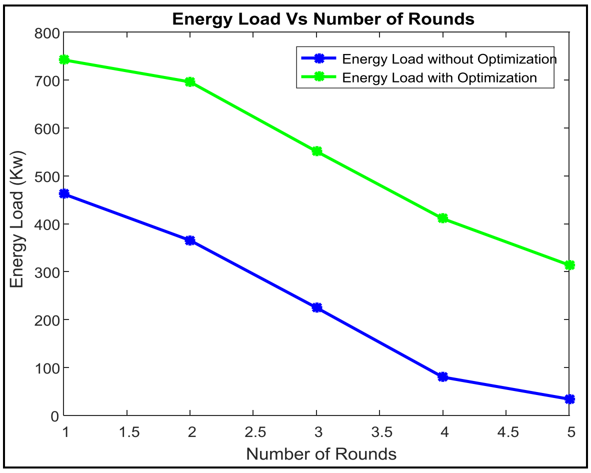


Figure 11: Energy Load

Figure 11 show the comparison of energy load used on the vehicles. It is clear that the green line is for the energy load when GA and ANN are applied to the network and it is better than blue line which indicates the performance when GA and ANN are not applied.

VI. CONCLUSION& FUTURE SCOPE

In modern era technologies are improved day to day and need to improve the vehicle charging system using the concept of smart charging. Smart charging can assist EVs to act as flexible loads and distributed storage resources that can benefit the energy system. This paper focuses on the efficiency of scheduling in SG environment by utilizing Artificial Intelligence (AI) algorithms to address the smart usage of grid resources and to ensure an overall good balance in the system with healthy reduction in plug-in time and motivate the users to get a comfortable level of quality of service. On the additional side, the appearance of Electric Vehicles (EVs) promises to capitulate numerous benefits to both energy and transportation industry divisions, but it is also probably affect the SG consistency, by consuming massive energy. On the way to minimize the energy consumption and plug-in time, we introduce through different factors an optimized technique based SG solution for charging and discharging services in cloud computing environment using the concept of Artificial Neural Network (ANN). In this research try to solve the problem of plug-in EVs at public supply stations (EV-PSS) using the Genetic Algorithm (GA) as an optimization technique which helps to optimized the vehicles properties using fitness function. Form the observation in result section, it is clear that the performance of the work done is improved and if load is more, then network can easily solve the charging-discharging problem. In future, to increase the efficiency of this methodology we can use combination of any two optimization algorithm such as genetic algorithm along with artificial bee colony algorithm based on the hybrid optimization techniques.

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