International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Experimental analysis of UPQC with Distributed Generation to enhance Power Quality

Dr Sathik Basha A[1], Vadivel M[2], Fathimanasreen R[3], Gobika S[4], Nandhini B[5]

Submitted: 15/03/2024 **Revised:** 18/04/2024 **Accepted:** 01/05/2024

Abstract:
Cleaner and more sustainable energy alternatives are needed as oil prices rise and environmental concerns grow. Transportation currently consumes a significant amount of energy and emits pollutants. This article examines hybrid vehicle development using a Power Split setup with an ICE and a battery. The efficiency of aHEV is evaluated using a battery with a greater amp-hour capacity. The adapter circuit is used in the advanced condition to lower the battery capacity. Various situations have been detected with various battery discharging and charging circuits.HEV are renowned for their capacity to match the capability of a normal car while significantly reducing fuel consumption and pollutants. The automotive industry is becoming increasingly interested in EVs and PHEVs. Thanks to developments in energy storage devices, power electronics adapters such as Direct current converters, DC to AC inverters, and battery power systems, electrical equipment, and efficient energy voltage control techniques. The commoditization of PHEVs and EVs in various applications e.g, heavy duty, light duty, and mediumduty vehicles is now possible.. This paper focuses on current breakthroughs in EV and PEV that cover new powertrain technologies and overhead to the SOTA.

Keywords: *PHEV, electric vehicles, machines, oil, DC, AC inverters, hybrid vehicles, SOTA.*

1. Introduction:

Electricity and gasoline are the two forms of energy storage units in a HEV. Electricity entails the use of a battery to generate power and the use of an electric motor as a speed control. Fuel entails the use of a tank and the use of an ICE to produce electrical energy, or the use of a fuel cell to transfer fuel to electrical energy. The electric motor will be the sole source of traction in this situation. The automobile will have both a motor and an engine in the first situation. We may differentiate between series, parallel, and mixed HEVs based on the drive train design.Micro or Mild hybrid , energy assist hybrid, complete hybrid, and Ph can all be classified based on the percentage of

1, Associate Professor & 2 Assistant Professor, 3, 4, 5, 6Final Year B.E. EEE
Department of Electrical and Electronics Engineering
Al-Ameen Engineering College (Autonomous)
Erode – 638 104, Tamilnadu, India.

traction power provided by the electric motor. Researchers can differentiate between combustion (ICE), fuel cell, pneumatic or hydraulic power, and human energy based on the type of the non-electric source of energy. The ICE is either a spark combustion (gasoline) or a CI/DI(diesel) engine in the 1st scenario. The power conversion unit can be fueled by hydrogen, gasoline, compressed natural gas, methanol, or other alternative energy sources in the first two cases.

Modern cities must place a strong emphasis on green energy. The explosive development of modern cities has resulted in increasing transportation use, which has resulted in increasing pollution and other critical environmental issues. Automobile emissions must be regulated, and proactive efforts must be implemented to reduce these pollutants. The locomotive company has produced hybrid cars, like the Toyota Prius, and Honda Insight that integrate diesel engines with electric motors to reduce the use of internal combustion [1]. By lowering gas emissions, this technology has a good impact on the environment.

Hybrid cars generate propulsion using two or more energy processors. An adequate on-board energy storage feeds each energy converter. A HEV is a vehicle with an internal combustion engine (ICE) and more motors. The motor transforms conventional gasoline from the tank into kinetic motion, whereas the electrical machine(s) converts electrical power from a backup system, like a cell, into mechanical energy [2]. Unlike a combustion engine, an electrical motor can invert the operation by functioning as a producer and converting mechanical power into electrical power.The potential for increased fuel economy motivates the addition of an electric channel to the conventional drive system. In today's society, we are confronted with the issue of diminishing car fuel resources. There is little uncertainty that carbon dioxide emissions from vehicle emission are a source of concern for the rising rate of global warming.

Hybridization of the automobile is one of the most positive answers to such issues. It means that HEVs can run on both internal combustion engines and electricity. Because the gasoline engine in a HEV may be tuned to run at maximum efficiency, it creates fewer emissions than a comparable-sized gasoline automobile. The importance of an electric power train is that it uses less energy and so improves total fuel efficiency. Vehicle hybridization can lower CO_2 emissions as well as fuel costs.

2. Literature Survey:

Several areas of the manufacture of electric vehicles, as well as the employment of technological advances and their sales, have made substantial progress in the recent decade. Likewise, research activities have expanded, resulting in a large increase in new positions and initiatives relating to electric automobiles. This unit introduces a concise list of the important subjects linked toelectrical automobiles that have been covered by published publications in the literature.

Richardson [10] investigates the EVs impact on the electric networkneeded capacity, productivity, and efficiency. He also considers the environmental and economic implications of electric automobiles.

Habib et al. [11] give an assessment of electric car charging technologies and their effects on electrical distribution infrastructure. Furthermore, the authors examine non-coordinated andcoordinated charging methods, smart charge planning, and delayed loading. Finally, they look into the financial advantages of V2G technology based on charging ways. Another topic that has been discussed in many works is the utilisation of renewable energy sources such as biomass, wind, and solar, and its integration into the electric car area.

Liu et al. [12]give a broad overview of renewable energy sources, and EVs. They concentrate on wind and solar power and present a collection of works divided into 3 groups: i) research into the interplay of electric vehicles and renewable energy sources for the purpose of lowering energy costs, (ii) research into enhancing energy efficiency, and (iii) suggestions aimed primarily at lowering emissions.

Hawkins et al. [13] examine previous research on the ecological consequences of HEVs andBEVs. They describe a study of 52 environmental assessments conducted across the life of the 2 types of vehicles for this purpose suc as HEVs and BEVs. The writers consider variables like electricity production, distribution, ,transmission, andgreenhouse gas emissions,as well as car manufacture, battery production, and battery life span in their research.

Vasant et al. [14] evaluate daily PHEV consumption and conclude that the proper construction of daytime charging points, as well as effective charging regulation and administration of this network, may lead to a larger PHEV installation.

Shuai et al. [15] offer a broad overview of the growth ideology seen in electric vehicles, taking into accounts both bidirectional and unidirectional energy flows. To do so, they look at different EV charging stations as well as different bidirectional and unidirectional energy marketing strategies.

Tan et al. [16] Review the advantages and limitations of V2G charging in both bidirectional and unidirectional modes. They examine the disadvantages, such as battery degeneration and significant investment costs, in addition to the benefits. Finally, they compile a list of V2G optimization techniques by categorising them based on the technique used such as, GAs and PSO and the goals like operation costs, (co2 emission, profit, endorse for renewable energy generation, power loss and load curve,.

Hu et al. [17] give a review and categorization of approaches for smart charging of EV, focusing on fleet controllers in this situation. They discuss work on battery modelling, charging and transmission standards, and mobility patterns, in particular. Finally, they present a variety of control mechanisms for managing EV fleets and also a mathematical tools for modelling them.

Rahman et al. [18], provide a set of strategies that have been used to solve various difficulties relating to the charging network for BEVs and PHEVs . They also evaluate various charging methods in various situations, including as private garages, residential complexes, and shopping malls. Because the widespread use of electric vehicles will have negative consequences for the existing power infrastructure, some studies examine the various difficulties and chances that EV inclusion in the smart network can provide. It examines the implications of EV adoption from the standpoint of vehicle-to-grid systems, with a focus on mitigating the intermittent nature of renewable energy sources.

Das et al. [20] give an analysis of how future linked EVs and self-driving vehicles will effect EV indicting and network integration. Other essential EV charging challenges include battery management, battery condition, and battery lifespan projections, all of which are crucial elements in extending battery life. He goes through current advances in Big Data analytics and how they can be used to estimate battery health using data. They categorise them in terms of capabilities and cost-effectiveness, as well as highlight their benefits and drawbacks.

3. Proposed Methodology:

3.1. Need of Hybrid Electric Vehicle:

Because the supply of gasoline was finite and will eventually run out. With a projected one billion petroleum-fuelled automobiles on the road by the year 2027, gasoline will become cost prohibitive. The world needs solutions for the 450 million cars that are otherwise useless. So, by 2027, Private transportation will no more rely on petroleum, and gasoline will be depleted.

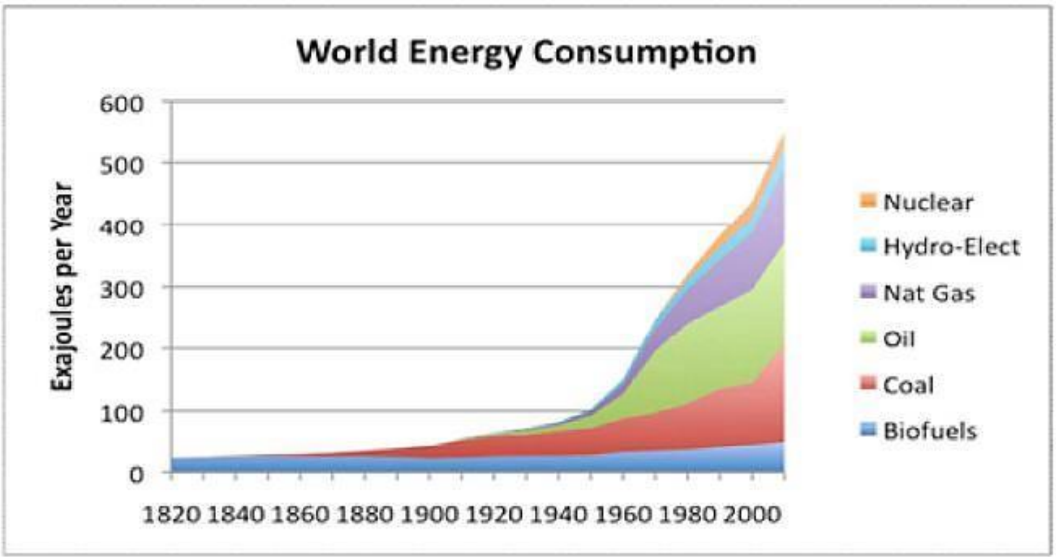

Figure 1 Shows the world energy consumption

Electric vehicles the size of a golf cart or scooter may create a market. Because hybrid technique is more applicable to heavier vehicles, hybrid trains and buses will be increasingly prevalent. One of the most significant advantages of a hybrid vehicle over a gasoline-powered vehicle is that it is cleaner to drive and has greater gas efficiency, making it more ecologically friendly. A hybrid car has two engines, which reduces fuel usage and saves energy. Figure 2 depicts the influence of an anticipated idea of deploying hydroelectric vehicles on energy usage.

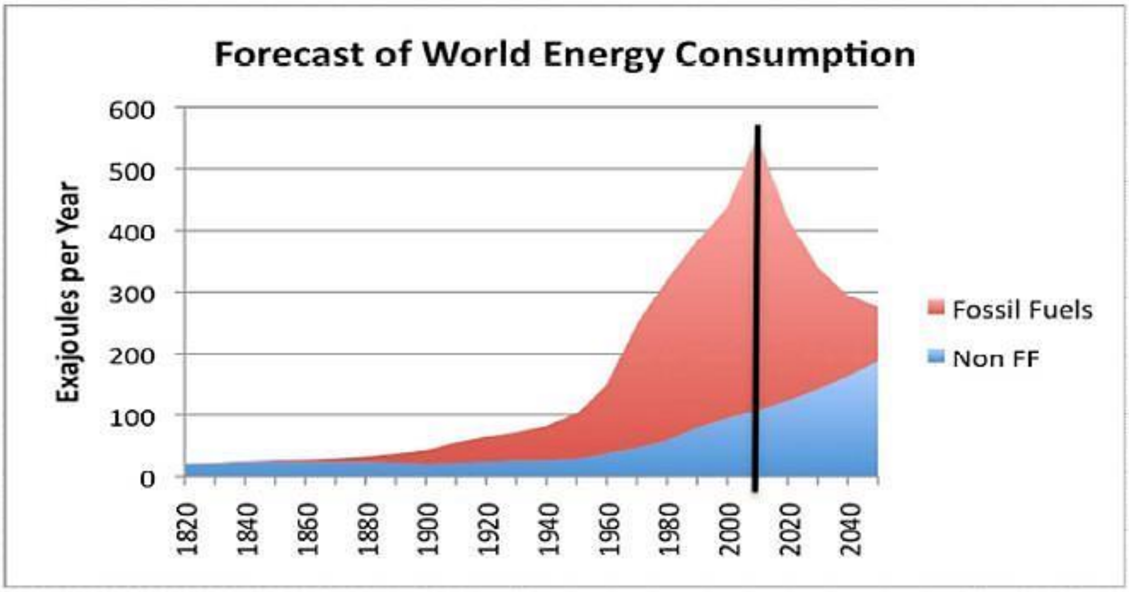

Fig. 2projected energy situation by using HEV

3.2. KINDS OF HEV

HEV drivetrains are responsible for the transmission of power in hybrid automobiles A hybrid vehicle is propelled by a variety of sources of energy. Because the electrical drive mechanism directly substitutes the mechanical gearbox rather than being an additional source of internal combustion, a gasoline powertrain does not meet the definition of hybrid. The 'trackless' trolleybus of the 1920s, which generally employed propulsion current carried by wire, is one of the oldest forms of hybrid road automobiles. An ICE was often installed on trolleybuses, either to directly operate the bus or to produce energy on its own. The truck was able to navigate around obstructions and damaged overhead power grids as a result of this.

All of the systems that are used to convert stored potential energy are included in the powertrain. Kinetic, nuclear, solar, and chemical energy can all be used for locomotion in powertrains. Hybrid powertrains are available in a variety of combinations. The initial is a parallel hybrid model, which has both an ICE and an electric engine that may move the automobile independently or together. As of 2015, this is the most popular hybrid system. If they're connected along one axis, the speeds along that axis must be the same, and the generated torques must total up.

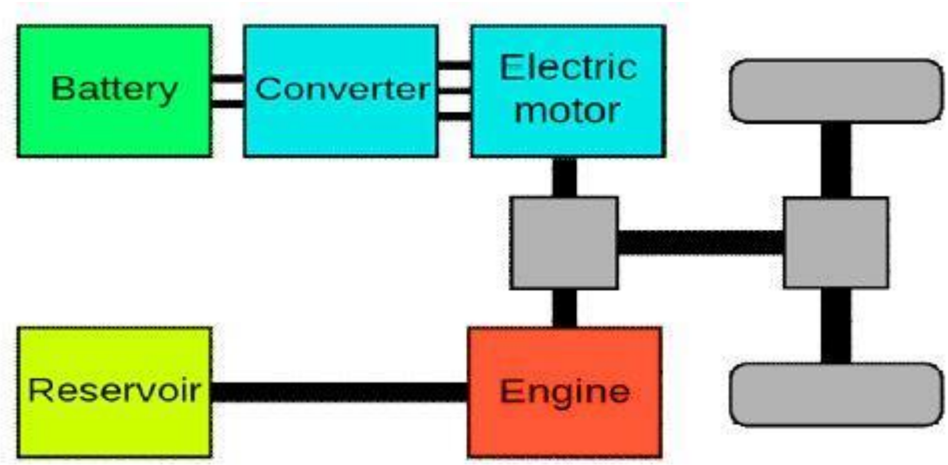

Figure 3 Parallel hybrid vehicle system

The second type is a series HEV, which is made up of a series of resources as illustrated in the diagram. The complete mechanical connection between the wheels and the ICE is effectively replaced and removed with an electric engine, some wire and valves, and electric drive engines, with the added benefit of removing the ICE's direct connection to the requirement.

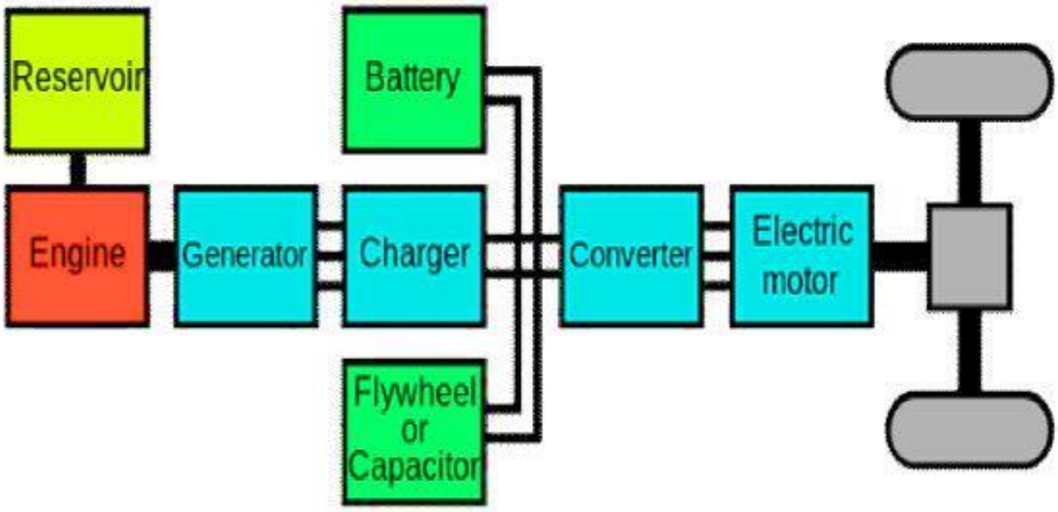

Fig. 4 HEV Series

The final type was a series parallel hybrid automobile with power-split features that enable either electrical or mechanical power pathways from the ICE to the tires. The key idea is to separate the power delivered by the main source from the energy consumed by the driver.

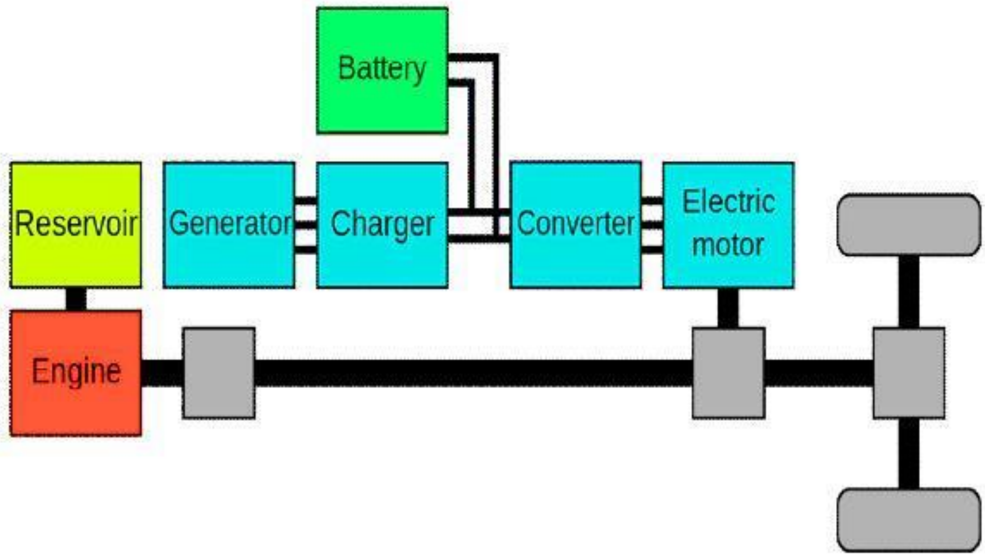

Fig. 5 HEV ParallelSeries

At lower RPMs, ICE power performance is modest, so traditional vehicles have to enhance size of engine to match market demands for acceptable starting speed. The larger engine produces more horsepower than is required for cruising. At low RPMs, electric motors can supplement ICE torque shortage by producing full power at static. A smaller, more efficient engine, and less flexible can be employed in a power-split fusion. ANN, Hybrid Networks, Fuzzy Logic,Artificial intelligence, and other technologies have been identified as key tools for improving the efficiency of power electronics-based systems in industrial applications.Presently, the most intriguing study topic in the practical control and accountability of electrical motors appears to be the integration of smart control and adaptiveness. A summary of the research conducted by researchers on ANFIS programming of electrical equipment was presented. It took a long time for the replies (speed) to reach the desired level.

4. Problem Formulation:

There are 2 components to the current scheduling and placement challenge. To begin, the LRI approach is used to determine the best position for the CS while keeping the power loss and voltage limits in mind. Second, the suggested TPSO method is used to schedule the tasks with the goal of minimising the TOC.

4.1.Method for Choosing an Appropriate Location for the CS

The model parameters of the optimization issue with inequality and equality constraints are the position of CS. The goal is to keep the transmission system's voltage deviation and power loss to a minimum. The objective function's mathematical model was as follows:

4.2. Power loss

The major purpose in controlling the distribution network with the addition of extra units is to choose the site that results in the least amount of power loss, that is defined as follows:

$$\min f_1 = P_{loss} \tag{1}$$

The power loss can be computed using the formula:

$$P_{loss} = \left(\sum_{h=1}^{24} \sum_{i=1}^{NB_Z} \sum_{j>1}^{NB_Z} Y_{ij} \left[V_{i,h}^2 + V_{j,h}^2 - 2V_{i,h} V_{j,h} \cos\left(\delta_{i,h} - \delta_{j,h}\right) \right] \right) \quad \forall z \in K \tag{2}$$

where h denotes the time horizon, Z NB the bus in zone Z, I the starting bus, and j the finishing bus; The power factor at bus I and j is I V and j V, respectively; the voltage direction at bus I and j is I and j, respectively.

As a vector K, the zones are depicted as follows

$$K = [1, \ldots z, \ldots, Z] \tag{3}$$

where z stands for the distribution system's zones. Z = 2 with zones 1 and 2 with business and residential movement patterns, respectively, was used in this research

4.3. Voltage deviation

The following equation can be used to compute the voltage deviation of the distribution system:

$$\min f_2 = V_{dev} \tag{4}$$

$$V_{dev} = \left(\sum_{i=1}^{NB_Z} | V_{i,base} - V_{i,new} | \right) \quad \forall Z \in K \tag{5}$$

where I stands for the load bus; The load bus voltage in the linear system is I base V; the new V of the bus after combining the CS unit into the system model . The bus in zone Z is designated by the letter Z NB.

4.4. Proposed Loss Reduction Index (LRI)

The load bus with the least amount of power loss is the best place to put the CS. Equation 6 defines the proposed method for determining the LRI owing to the input of a unit into a load bus.

$$LRI_i = \left(\frac{P^i_{loss} - P^b_{loss}}{P^{inc}_{i,Z}} \right) \quad \forall z \in K \tag{6}$$

4.5. **Development of the TOC Minimization**

The time range for a day is T = [1,...,h,....H], and it consists of 19 equal 1 hour time frames. A vector N = [1,....,v,....V] can be used to denote the PHEVs. The discharging, charging, and idling states of PHEVs can all be managed. A vector S represents the scheduling method of the vth PHEV as follows:

$$S_v = \left[S^1_v, \ldots, S^{h_{in},v}_v, \ldots, S^h_v, \ldots, S^{h_{out},v}_v, \ldots, S^H_v \right] \quad \forall v \in N \tag{7}$$

Where hv S = 1 denotes charging, hv S = -1 denotes charging at time slot ‘h,' and hv S = 0 denotes neither. The device's initial SOC is chosen at random from 20 percent to 80 percent. This research also considers a hybrid algorithm of PHEV departure and arrival. The discharging and charging strategies are represented by the vectors C and D, which are specified in (8) and (11), respectively. The goal is to reduce the TOC by minimising the discharging and charging costs, as stated in equations 8 to 11.

$$C_v = \left[C^{1,v}_v, \ldots, C^{h_{in},v}_v, \ldots, C^h_v, \ldots, C^{h_{out},v}_v, \ldots, C^{H,v}_v \right] \quad \forall v \in N \tag{8}$$

$$C^h_v = \begin{cases} 1 & if\ S^h_v = 1 \\ 0 & otherwise \end{cases} \quad \forall v \in N \tag{9}$$

$$D_v = \left[D^{1,v}_v, \ldots, D^{h_{in},v}_v, \ldots, D^h_v, \ldots, D^{h_{ounr},v}_v, \ldots, D^{H,v}_v \right] \quad \forall v \in N \tag{10}$$

$$D_v^h = \begin{cases} 1 & if\ S_v^t = -1 \\ 0 & otherwise \end{cases} \quad \forall v \in N \qquad (11)$$

5. Results and discussion:

The location of a PHEV charging station within the current distribution system should be carefully considered. Planning operations and planning for future growth opportunities all necessitate a thorough load flow analysis of the system. The goal of load flow analysis is to determine system parameters such as active and reactive power, current, voltage, power factor at various points in the electric systems under different operating situations. The power loss in the model is measured using load flow simulation. The LRI is used to locate the best position after evaluating the power loss in every bus.By taking into account the system's attributes, this study aids in selecting the best location for a charging point. This approach is used with the IEEE 69-bus and IEEE 33-bus standard systems.

5.1.IEEE 33-Bus System (Case 1)

A 15.78 kV substation supplies the IEEE 33-bus radial delivery system, which has 30 load buses with a maximum weight of 2987 kW and 1950 kVAr. The slack bus is known as Bus 1. There are two zones in the testing system, each having a distinct travel route, to analyse the mobility patterns of business and residential PHEV owners. Figure 6 shows a one-line design of the IEEE 33-bus network.

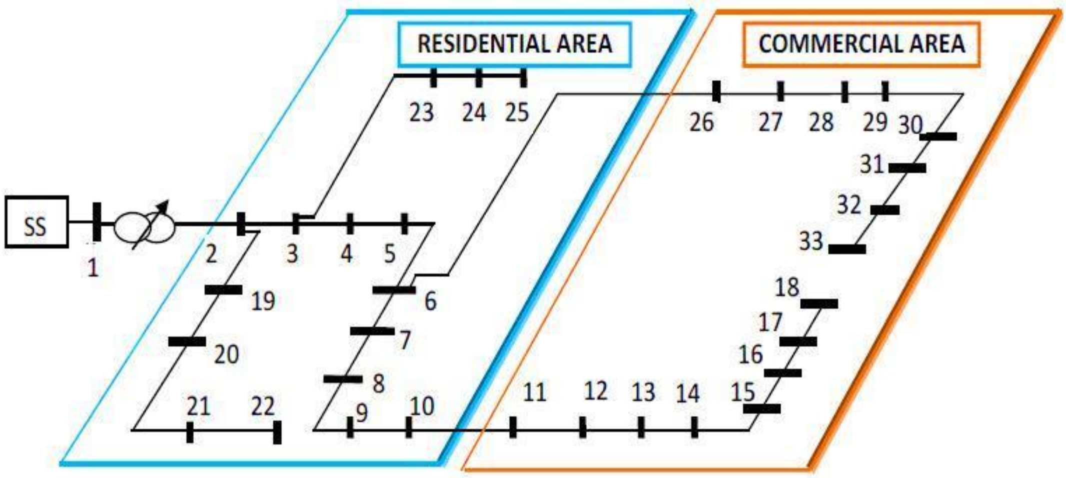

Figure 6.IEEE 33-bus distribution model with two zones

The LRI is generated using formula for every load bus. The highest value of LRI indicates a good location for a PHEV charging point. Table 1 shows the LRI values for several load buses, along with their rankings, with a capability of 299 kW.

Tab. 1 Position of each bus according to LRI

Bus No.	LRI	Grade	Bus No.	LRI	Grade
3	0.3456	2	20	0.1111	9
4	0.1234	4	21	0.2134	12
5	0.2345	6	23	0.5678	15
6	0.3214	8	24	0.3214	18
7	0.3256	10	26	0.8765	21
8	0.2098	12	28	0.1234	24
9	0.2876	14	29	0.1098	27
10	0.7289	16	30	0.0987	30
12	0.1236	18	32	0.1567	33
13	0.5123	20	34	0.7652	36
15	0.9723	22	36	07324	39
16	0.1235	24	37	0.1456	42
17	0.4567	26	38	0.7623	48
19	0.2834	28	39	0.5622	32

Depending on the ranking established for a certain load level, this sends a signal to the parking lot owner, primarily the aggregator, to raise or reduce the effectiveness of PHEV charger outlets. The IEEE 33-bus transmission system's ideal position for charging points in commercial and residential areas can be determined using LRI. As a result of the charging station being located at various locations, the aggregator can get a sense of the system parameters. Following the installation of the charging point in both places, it is required to plan the PHEVs at the unit while taking into account the technological challenges.For the purpose of determining the best billing scenario, a deterministic approach is used. The driving trends are based on actual departure and arrival characteristics of vehicles in business and residential sectors. Table 2 summarises the deterministic model's driving trend data

Table 2 Deterministic model

Area	Arrival time of PHEVs	Preferred Departure time	Initial SOC	Desired final SOC
Residential	08:00-24:00	10 hours from the time of arrival	Generated Randomly Between 30% to 80%	100 %
Commercial	01:00-17:00			

The battery's volume is estimated to be around 20 kWh. All vehicles are expected to have a SOC of between 40% and 75% at the start. A fixed recharging power of 3.8 kW was used for this analysis since it is likely to be available in both home and business electrical outlets. The testing process investigates both controlled and uncontrolled charging situations, with the controlled charging case requiring the hourly current rate trace on a specific day to be as shown in Fig. 7.

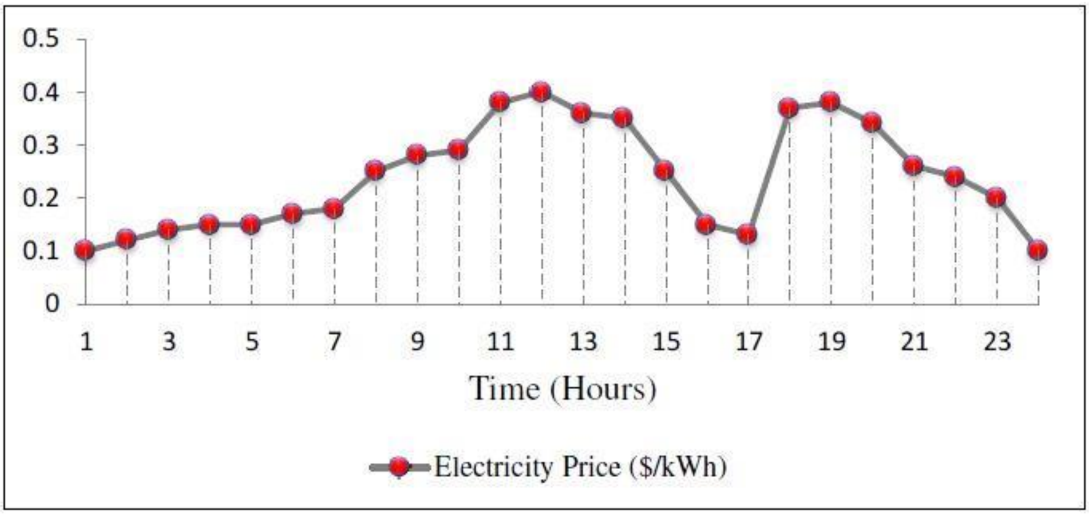

Figure 7 Electricity price ($/kwh)

Only until the entire cost of the two transmission system was decreased will the parking internet user profit. To make this a successful concept, adjusting the charging and discharging of automobiles to account for the cost of electricity appears to be the best choice.The following are the scenarios:

1. 1. Case #1: Charging PHEVs as soon as they arrive
2. .Case 2: Plug-and-forget .

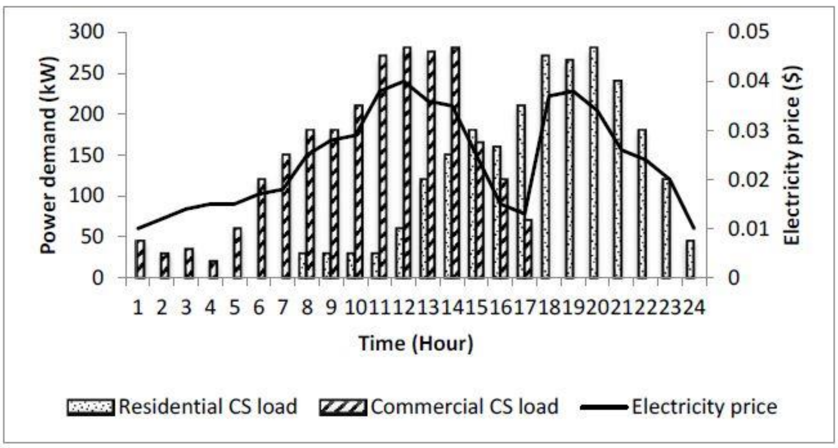

Figure 8(case1) system's energy consumption

Figure 8 depicts the results of charging the PHEVs as soon as they arrive. The CS's peak is determined by the quantity of vehicles arriving at the same time. Automobiles are more likely to arrive in residential areas between 11:00 and 23:00, while in business areas, vehicle arrivals steadily increase from 10:00 to 16:00. As a result, the CS's load demand is determined to be high at those hours. Also assumed from the number is that the PHEV begins charging immediately upon arrival, regardless of the hourly electricity price.The cost of charging is the expected amount that the PHEV user will pay to charge their car, i.e. for G2V power transfer, and the unloading cost is the amount that the PHEV user will get for enabling their car to engage in V2G power transmission. Table 3 shows the TOC results obtained utilizing case1.

Table 3 Total operational cost in case1

Case 2		
	Discharging cost($/day)	charging cost ($/day)
Commercial	-	69.34
Residential	-	74.76
TOC	140.78	

Each PHEV linked to the charger plug receives the appropriate charge without any control in this situation 2. This scenario seeks to reach the target end SOC without taking into account the PHEV users TOC or electricity costs. The users simply connect their automobiles in and ignore the discharging - charging strategies. Figure 9 depicts the charging - discharging power.

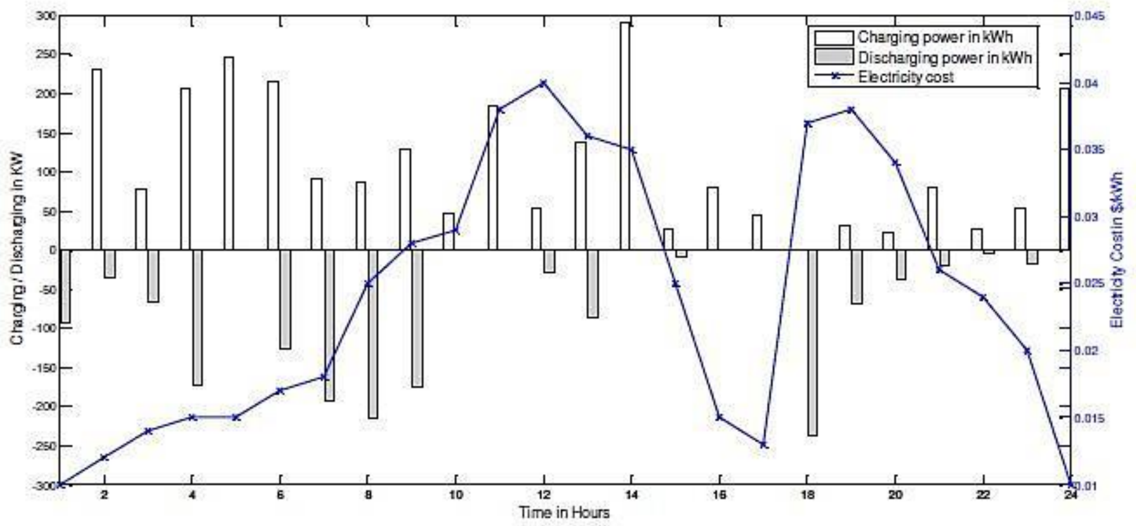

Figure 9 Charging and discharging power in case2

The discharge cost is included in the case2. However, discharging and charging of PHEVs, regardless of electricity costs, is an unregulated situation that results in a large TOC. Furthermore, not all vehicles using this case achieve the desired end SOC of 100 percent. The estimated maximum force and cost findings are presented in Table 4 below.

Table 4 Total operational cost in case2

Case 2			
	Peakload (kW)	Dischargingcost($/day)	charging cost($/day)
Commercial	213.67	50.23	40.32
Residential	245.78	90.87	49.09
TOC	90.98		
Power loss	250.87		

6. **Conclusion:**

HEVs combine the benefits of both internal combustion engines and electric motors, and can be customised to achieve a variety of goals, including improved fuel efficiency, enhanced power, and extra-auxiliary energy for electrical gadgets and power tools. Generated power via chain wheels and freewheels is both inexpensive and dependable. As a result, it enables each message node to determine whether or not to duplicate the path node message by optimising its broadcast effort to ensure an appropriate amount of message latency. Utilizing a channel selection technique maximises spectrum use while lowering main system interference.Transportation currently consumes a significant amount of energy and emits pollutants. This article examines hybrid vehicle development using a Power Split setup with an ICE and a battery. The efficiency of a hybrid electric car is evaluated using a battery with a greater amp-hour capacity. The adapter circuit is used in the advanced condition to lower the battery capacity. Various situations have been detected with various battery discharging and charging circuits.HEV are renowned for their capacity to match the capability of a normal car while significantly reducing fuel consumption and pollutants. The automotive industry is becoming increasingly interested in EVs and PHEVs.

References:

[1] C.C. Chan, The State of the Art of Electric and Hybrid Vehicles, *proceedings of the IEEE*, vol. 90, No. 2, February 2002.

[2] V. A. Shah, Jivanadhar A. Joshi, Ranjan Maheshwari and Ranjit Roy, Review of ultracapacitor Technology and its Applications, *15thNational*

[3] A. Emadi, K. Rajashekara, S. Williamson, and S. Lukic, Topological Overview of hybrid Electric and Fuel Cell Vehicular Power systemArchitectures and Configurations, *Vehicular Technology, IEEE Transactions on*, vol. 54, 2005, pp. 763-770.

[4] M. Ehsani, Y. Gao, S. Gay, and A. Emadi, *Modern Electric,Hybrid Electric, and Fuel Cell Vehicles*: *Fundamentals, Theory and Design*, FL CRC Press, 2004.
[5] Wang, H. Zheng, Route and spectrum selection in dynamic spectrum networks, in Proc. IEEE CCNC 2006, pp. 625-629, Feb. 2006.
[6] R. Chen et al., Toward Secure Distributed Spectrum Sensing in Cognitive Radio Networks, IEEE Commun. Mag., vol. 46, pp. 50 55, Apr. 2008.
[7] H. Khalife, N. Malouch, S. Fdida, Multihop cognitive radio networks: to route or not to route, IEEE Network, vol. 23, no. 4, pp. 20-25, 2009.
[8] Y.-C. Liang et al., Sensing-Throughput Trade-off for Cognitive Radio Networks, IEEE Trans. Wireless Commun., vol. 7, pp. 1326 37 ,April 2008.
[9] P. K. Visscher, How Self-Organization Evolves, Nature, vol. 421, pp. 799 800 Feb.2003.
10. Richardson, D.B. Electric vehicles and the electric grid: A review of modeling approaches, Impacts, and renewable energy integration. Renew. Sustain. Energy Rev. **2013**, 19, 247–254.
11. Habib, S.; Kamran, M.; Rashid, U. Impact analysis of vehicle-to-grid technology and charging strategies of electric vehicles on distribution networks—A review. J. Power Sources **2015**, 277, 205–214.
12. Liu, L.; Kong, F.; Liu, X.; Peng, Y.; Wang, Q. A review on electric vehicles interacting with renewable energy in smart grid. Renew. Sustain. Energy Rev. **2015**, 51, 648–661.
13. Hawkins, T.R.; Gausen, O.M.; Strømman, A.H. Environmental impacts of hybrid and electric vehicles—A review. Int. J. Life Cycle Assess. **2012**, 17, 997–1014.
14. Vasant, P.; Marmolejo, J.A.; Litvinchev, I.; Aguilar, R.R. Nature-inspired meta-heuristics approaches for charging plug-in hybrid electric vehicle. Wirel. Netw. **2019**, 26, 4753–4766.
15. Shuai, W.; Maillé, P.; Pelov, A. Charging electric vehicles in the smart city: A survey of economy-driven approaches. IEEE Trans. Intell. Transp. Syst. **2016**, 17, 2089–2106.
16. Tan, K.M.; Ramachandaramurthy, V.K.; Yong, J.Y. Integration of electric vehicles in smart grid: A review on vehicle to grid technologies and optimization techniques. Renew. Sustain. Energy Rev. **2016**, 53, 720–732.
17. Hu, J.; Morais, H.; Sousa, T.; Lind, M. Electric vehicle fleet management in smart grids: A review of services, optimization and control aspects. Renew. Sustain. Energy Rev. **2016**, 56, 1207–1226.
18. Rahman, I.; Vasant, P.M.; Singh, B.S.M.; Abdullah-Al-Wadud, M.; Adnan, N. Review of recent trends in optimization techniques for plug-in hybrid, and electric vehicle charging infrastructures. Renew. Sustain. Energy Rev. **2016**, 58, 1039–1047.
19. Mahmud, K.; Town, G.E.; Morsalin, S.; Hossain, M. Integration of electric vehicles and management in the internet of energy. Renew. Sustain. Energy Rev. **2018**, 82, 4179–4203.
20. Das, H.; Rahman, M.; Li, S.; Tan, C. Electric vehicles standards, charging infrastructure, and impact on grid integration: A technological review. Renew. Sustain. Energy Rev. **2020**, 120, 109618.
21. Li, Y.; Liu, K.; Foley, A.M.; Zülke, A.; Berecibar, M.; Nanini-Maury, E.; Van

Mierlo, J.; Hoster, H.E. Data-driven health estimation and lifetime prediction of lithium-ion batteries: A review. Renew. Sustain. Energy Rev. **2019**, 113, 109254.
22. Liu, K.; Li, Y.; Hu, X.; Lucu, M.; Widanage, W.D. Gaussian Process Regression With Automatic Relevance Determination Kernel for Calendar Aging Prediction of Lithium-Ion Batteries. IEEE Trans. Ind. Inform. **2020**, 16, 3767–3777.
23. Hu, X.; Zhang, K.; Liu, K.; Lin, X.; Dey, S.; Onori, S. Advanced Fault Diagnosis for Lithium-Ion Battery Systems: A Review of Fault Mechanisms, Fault Features, and Diagnosis Procedures. IEEE Ind. Electron. Mag. **2020**, 14, 65–91.
24. insideEVs. Nissan Reveals LEAF e-Plus: 62 kWh Battery, 226-Mile Range. 2019. Available online: https://insideevs.com/nissan-reveals-leaf-e-plus-ces/ (accessed on 17 February 2021).
25. Mitsubishi Motors. Mitsubishi Outlander PHEV 2018. 2019. Available online: https://www.mitsubishicars.com/outlander-phev/2018/specifications (accessed on 17 February 2021).
26. Plötz, P.; Moll, C.; Bieker, G.; Mock, P.; Li, Y. Real-World Usage of Plug-In Hybrid Electric Vehicles: Fuel Consumption, Electric Driving, and CO2 Emissions; Technical Report; International Council on Clean Transportation Europe (ICCT): Washington, DC, USA, 2020.
27. The Car Guide. 2014 Toyota Prius PHV: To Plug in or Not to Plug in? 2014. Available online: https://www.guideautoweb.com/en/articles/21152/2014-toyota-prius-phv-to-plug-in or-not-to-plug-in/ (accessed on 21 February 2021).
28. Hyundai. All-New Hyundai NEXO—Technical Specifications. 2019. https://www.hyundai.news/eu/press-kits/all-new-hyundai-nexo-technical-specifications/(accessed on 21 February 2021).
29. insideEVs. 2019 BMW i3, i3 REx, i3s & i3s REx: Full Specs. 2019. Available online: https://insideevs.com/2019-bmw-i3-rex-i3srex-full-spec/(accessed on 21 February 2021).
30. EVvolumes.com. The Electric Vehicle World Sales Database. 2019. Available online: http://www.ev-volumes.com/ (accessed on 19 February 2021).
31. Framework Convention on Climate Change. Adoption of the Paris Agreement; Technical Report FCCC/CP/2015/L.9/Rev.1; United Nations: New York, NY, USA, 2015. Available online: http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf (accessed on 20 February 2021).
32.Sakthivel R., Sundareswari K., Mathiyalagan K., Arunkumar A., Anthoni S.M." Robust reliable H∞ control for discrete-time systems with actuator delays" *Asian Journal of Control* (2015).
33.Balusamy R., Kumaravel P., Renganathan N.G "Dielectric and electrical properties of lead zirconate titanate" *Der Pharma Chemica* (2015).
34.Jayapandian N., Rahman A.M.J.M.Z., Poornima U., Padmavathy P." Efficient online solar energy monitoring and electricity sharing in home using cloud system" *IC-GET 2015 - Proceedings of 2015 Online International Conference on Green Engineering and Technologies* (2016).