Energy Management in Hybrid Electric Vehicles

P. Anitha[1], R. Ramakrishna[2], M. Sai Kumar[3], P. Rohith[4]

[1,3,4]B.Tech Student, Department of EEE, GMR Institute of Technology, Rajam-532127, Andhra Pradesh, India

[2]Assistant Professor, Department of EEE, GMR Institute of Technology, Rajam-532127, Andhra Pradesh, India

Email: 22341A0292@gmrit.edu.in[1]

---***---

Abstract-Hybrid Electric Vehicles (HEVs) represent a significant advancement in automobile technology, combining internal combustion engines (ICEs) with electric motors to improve performance while reducing environmental impact. This study provides a complete review of HEVs, including their historical history, numerous varieties, and the advantages they offer over conventional cars. It emphasizes the importance of energy management techniques in improving fuel economy and lowering emissions, looking at various methodologies such as rule-based, optimization-based, and machine learning tactics. Furthermore, the study analyses the issues of energy management, how energy flows inside HEVs, and future developments, such as smart grid integration and improvements in autonomous driving technology. Finally, it highlights the present state of energy management in HEVs and proposes prospective areas for future study and development in this field.

Keywords: *Hybrid Electric Vehicles (HEVs), Energy Management, Fuel Efficiency, Emissions Reduction, Machine Learning*

I. Introduction:

Hybrid electrical vehicles (HEVs) combine an internal combustion engine (ICE) with an electric motor to power the car. Electric motors are Powered with batteries, whereas the internal combustion engine operates on conventional Energy sources such as diesel and petrol. This dual energy source allows HEVs to have higher fuel economy and fewer emissions than regular cars, especially in low-speed, stop-and-go situations. HEVs may operate in a variety of modes, including electric-only, ICE-only, or a hybrid of the two, depending on the driving conditions and energy requirements. HEVs are a significant step toward fully electric cars (EVs) since they combine electric and conventional power technologies. Efficient energy management between the ICE and the electric motor allows HEVs to considerably cut fuel consumption and emissions, promoting more environmentally friendly mobility. Furthermore, regenerative braking systems in HEVs gather and store energy, improving the vehicle's overall efficiency.

A. Importance of energy management in HEVs:

Energy management in Hybrid Electric Vehicles (HEVs) is critical for establishing the best balance of fuel use and electric power utilization, hence increasing total vehicle economy. HEVs may effortlessly transition between the internal combustion engine (ICE) and the electric motor in response to changing driving circumstances by using appropriate energy management systems. This capacity results in increased fuel efficiency, lower emissions, and superior vehicle performance. Proper energy distribution between the engine, motor, and battery allows the vehicle to operate efficiently in a variety of modes, including electric-only or hybrid. Furthermore, smart energy management reduces battery deterioration, which extends the life of crucial vehicle components [1]. Energy management in hybrid electric vehicles (HEVs) is critical for increasing fuel efficiency, battery life, and performance. It optimizes the mix of electric and gasoline power, lowers pollutants, and allows for features such as regenerative braking. Effective energy management makes HEVs more sustainable and cost-effective by assuring efficient energy consumption and smooth power changes, so facilitating the move to greener transportation.

Objective:

The Objective of the paper is to provide an overview of hybrid electric vehicles, to study the importance of energy management hybrid electric vehicles, to provide an overview of hybrid electric vehicles in HEVs such as Historical development and evolution of HEVs and type of HEVs such as series HEVs, parallel HEVs, series-parallel HEVs and role of HEVs in reducing emission and improving fuel efficiency. Types of energy management strategies such as rule based, optimization based, Machine learning approaches, energy recuperation during braking next one is challenges in energy management, types such as Balancing fuel efficiency and battery usage, reducing emissions while maintaining performance, Impact of driving condition on energy management. Future trends in energy management such as Integration with smart grids and renewable energy, Vehicle-to-grid technology.

II. Overview of Hybrid Electric Vehicles (HEVs):

Hybrid Electric Vehicles (HEVs) combine an internal combustion engine (ICE) with an electric motor, drawing energy from both a rechargeable battery and conventional fuels like gasoline. These cars may operate in a variety of modes, including electric-only, ICE-only, or a mix of the two, improving fuel efficiency and cutting emissions compared to traditional automobiles. HEVs act as a bridge between regular cars and completely electric vehicles, so contributing to a more sustainable future in transportation.

A. Historical development and evolution of HEVs:

Hybrid Electric automobiles (HEVs) originated in the late nineteenth century, coinciding with the advent of the first electric automobiles. HEVs rose to prominence in the late 1990s and early 2000s, with the introduction of cars like as the Toyota Prius. This automobile popularized hybrid technology by combining a combustion engine (ICE) with an electrical motor, leading to improved fuel efficiency and less pollution. Since then, advances in battery technology, energy management systems, and electric drivetrains have played critical roles in the development of HEVs, transforming them into a necessary component of today's automotive industry [2]. Recently, the emphasis has switched toward boosting HEV performance and efficiency through novel technologies. Researchers are looking at advanced energy management systems and improved powertrain designs to help optimize fuel usage and minimize pollutants.

B. Types of HEVs:

Hybrid Electric Vehicles (HEVs) exist in a variety of kinds, each employing a combination of an internal combustion engine (ICE) and an electric motor in unique ways:

i. Series HEVs:

A Series Hybrid Electric Vehicle (HEV) uses an electric motor as its primary source of propulsion, while the internal combustion engine (ICE) only serves as a generator for power production. In this configuration, the ICE does not directly power the wheels. Instead, it creates electricity to charge the battery, powers the electric drive. This enables the vehicle to run on electric power for extended periods of time, especially in low-speed or city travel, improving fuel efficiency and lowering pollutants. One of the primary advantages of Series HEVs is their ability to run the ICE at its most efficient performance level, resulting in increased total fuel efficiency. This concept is especially useful in stop-and-go driving, where the electric motor may operate independently [3].

However, Series HEVs may have worse efficiency at greater speeds because to many energy conversion processes, from fuel to electricity and finally to motion. Nonetheless, Series HEVs are seen as a crucial urban transportation alternative, playing an important part in the transition to fully electric cars (EVs). Fig.1 depicts the operation of a series hybrid electric vehicle (HEV). In this method, the engine produces energy through a generator, which drives the electric motor that moves the wheels. Excess energy is stored in a battery for later use. The technology improves fuel economy by effectively balancing power between the engine and the electric motor.

IC An electric motor serves as the only source of propulsion in a Series Hybrid Electric Vehicle (SHEV), a form of hybrid vehicle in which the internal combustion engine (ICE) exclusively generates energy. This architecture differs from other hybrid systems, including parallel hybrids. In a series hybrid, the engine only works to maintain or recharge the battery that powers the elect common because it does not interact with the wheels. If the battery charge drops while the car is moving, the internal combustion engine kicks in to produce electricity, which can either be utilized by the motor right away or stored in the battery. This ongoing power generation and supply.

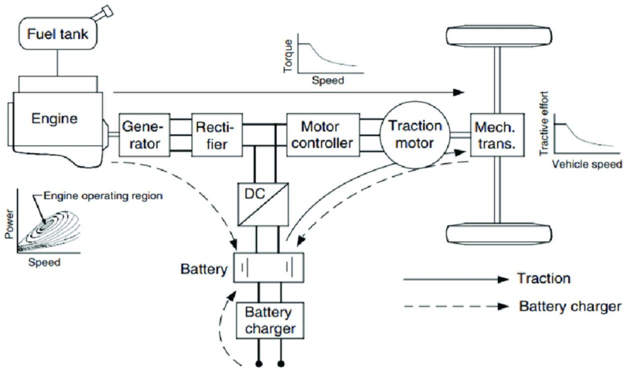

Fig.1 Configuration of a series hybrid electric drive train [3]

ii. Parallel HEVs:

A Parallel Hybrid Electric Vehicle (HEV) use both an internal combustion engine (ICE) and an electric motor to power the vehicle, either independently or concurrently. Unlike series hybrids, which solely generate electricity, parallel HEVs have both the ICE and the electric motor directly attached to the wheels. This allows for the switching or combination of power sources based on driving circumstances, which improves fuel efficiency and reduces emissions, particularly at higher speed [4].

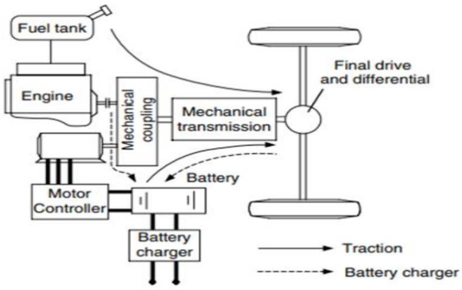

Fig.2 Configuration of parallel hybrid electric drive train [4]

Parallel HEVs provide versatility in a variety of driving scenarios, including interstate travel, where the ICE and electric motor may collaborate to improve performance and fuel economy. While balancing the power between the two systems might be difficult, improved energy management technologies aid in efficiency [4]. Parallel hybrids are popular because to their simplicity and efficacy, and they are seen as a critical step toward more sustainable transportation. Fig. 2 depicts the operation of a parallel hybrid electric vehicle (HEV). In this setup, the engine and electric motor are connected to the wheels via a mechanical gearbox. The motor controller adjusts the battery power sent to the motor, with any excess energy retained in the battery. This configuration allows the vehicle to run on the engine, the motor, or a mix of the two, increasing total performance and fuel economy.

iii. Series-Parallel HEVs:

A Series-Parallel Hybrid Electric Vehicle (HEV) combines both series and parallel hybrid systems, allowing the vehicle to operate with an internal combustion engine (ICE), an electric motor, or a mix of the two depending on the driving circumstances. In series mode, the ICE produces energy, however in parallel mode, both the ICE and the electric motor may directly power the wheels. This arrangement increases fuel efficiency and reduces emissions in a variety of driving circumstances, including city and highway travel, by enabling smoother transitions and better energy management [5].

One significant feature of Series-Parallel HEVs is their flexibility to maximize efficiency by using either electric or mechanical power depending on the scenario. The electric motor is usually favored at lower speeds, whilst the ICE offers more power during high-speed driving or acceleration. Fig.3 shows the structure of a series-parallel hybrid electric vehicle (HEV). In this configuration, the internal combustion (IC) engine is linked to a gen. The generator generates electricity, which is sent to the electric motor through a power [5] converter.

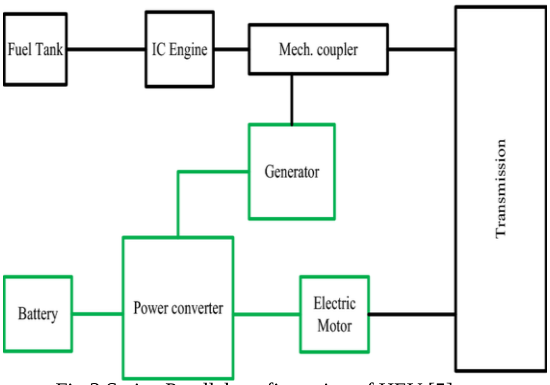

Fig.3 Series-Parallel configuration of HEV [5]

Additionally, the battery may power the electric motor using the same converter. According to the motoring method, the vehicle's gearbox can be driven directly by the electric motor or the engine, providing adaptability while increasing overall economy.

C. Role of HEVs in reducing emissions and improving fuel efficiency:

Hybrid Electric Vehicles (HEVs) make major contributions to pollution reduction by combining internal combustion engines (ICEs) with electric motors, reducing dependency on fossil fuels. This dual powertrain solution enables HEVs to switch between electric motors and gasoline engines, increasing energy efficiency and cutting greenhouse gas emissions. Research shows that HEVs significantly reduce CO_2 emissions, particularly in urban areas where regenerative braking and electric driving modes are most effective, reducing environmental impact compared to traditional vehicles powered solely by internal combustion engines [6].

HEVs also improve fuel efficiency by regulating engine load and recovering energy during braking, making them perfect for city driving. Advanced control algorithms further optimize the energy flow between the engine and motor, resulting in fuel savings of up to 35% over typical cars and providing a viable bridge to full electrification [6].

III. Type of Energy Management Strategies:

A. Rule-based Strategies:

Rule-based energy management systems in Hybrid Electric Vehicles (HEVs) employ established rules to control how power is divided between the internal combustion engine (ICE) and electric motor. These guidelines are often dependent on variables like as driving speed, battery charge level, and torque needs. The method allows the vehicle to convert between electric-only, ICE-only, and hybrid modes based on predefined factors. Because of their simplicity and minimal computing needs, rule-based techniques are ideal for real-time energy management in HEVs [7]. However, while these tactics are useful in fundamental driving circumstances, they may not be as effective in dynamic situations requiring more complicated decision-making.

B. Optimization-based Strategies:

Optimization-based energy management systems in Hybrid Electric Vehicles (HEVs) aim to achieve the most efficient power distribution between the internal combustion engine (ICE) and the electric motor. These solutions use mathematical models and algorithms to save fuel, reduce pollutants, and enhance overall vehicle efficiency. Unlike rule-based systems, optimization methods respond to changing driving conditions in real time by continually monitoring variables such as speed, battery state of charge, and energy requirements. Model predictive control (MPC), dynamic programming, and Pontryagin's minimum principle are all common strategies used to guarantee that the vehicle runs as efficiently as possible [8].

C. Machine learning approaches:

Machine learning methods to energy management techniques for HEVs use data-driven algorithms to improve power distribution between the internal combustion engine (ICE) and the electric motor. These approaches use historical and real-time data to create models that can predict the most successful energy management measures under a variety of driving scenarios.

Neural networks, reinforcement learning, and decision trees allow the energy management system to adapt continually, resulting in improved performance and efficiency as compared to traditional rule-based or optimization procedures. These techniques, which learn from various driving conditions, can considerably improve fuel efficiency and reduce emissions [9]. One significant advantage of using machine learning in HEVs is its capacity to manage complicated and nonlinear data interactions, which traditional models may struggle to handle.

D. Energy recuperation during braking (regenerative braking):

Regenerative braking is an important part of energy management for Hybrid Electric Vehicles (HEVs), improving fuel economy and lowering energy loss. Conventional braking systems waste kinetic energy produced during deceleration as heat.

However, regenerative braking collects this energy by reversing the electric motor and operating as a generator. The produced electrical energy is stored in the vehicle's battery and may subsequently be utilized to power the electric motor during acceleration or in electric-only mode. This not only extends the driving range of HEVs, but also helps to minimize fuel consumption and emissions by recovering energy that would otherwise be squandered [10]. Fig. 4 shows how regenerative braking works in electric and hybrid automobiles. When the automobile accelerates, the battery transfers electricity to the motor, which turns the wheels.

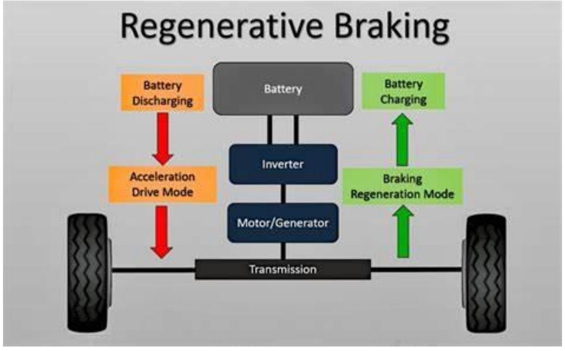

Fig.4 Energy flow of Regenerative Braking [10]

When the automobile slows down, the wheels create power, which returns to the battery and recharges it. This technology conserves energy by utilizing the vehicle's motion to recharge the battery while braking. Regenerative braking systems are especially useful in metropolitan areas, where traffic is constantly stopping and going, allowing for more frequent energy recovery. Recent research has focused on enhancing these systems to maximize energy capture while preserving optimal braking performance and safety.

IV. Challenges in Energy Management:

Energy management in HEVs involves issues such as maximizing fuel economy while also using batteries to guarantee that both power sources are used effectively. Another significant challenge is reducing emissions without sacrificing vehicle performance. Furthermore, energy management must adapt to changing driving situations, such as traffic or topography, while being highly efficient.

A. Balancing fuel efficiency and battery usage:

Finding a balance between fuel economy and battery utilization is a significant difficulty in the energy management of Hybrid Electric Vehicles (HEVs). These cars use both internal combustion engines (ICEs) and electric motors, complicating the optimization of energy use from each. Effective energy management systems must guarantee that the ICE operates at its peak efficiency while optimizing battery consumption, especially during low-speed running and regenerative braking.

Furthermore, this balancing process is complicated by the need to maintain battery health, since repeated charging and discharging cycles can accelerate battery deterioration and reduce long-term efficiency [10]. Effectively regulating the battery's state of charge (SoC) is critical for high-performance HEVs. A low SoC limits electric power utilization, increasing reliance on the internal combustion engine (ICE) and fuel consumption. However, a large SoC reduces energy recovery via regenerative braking. To address these issues, research has concentrated on improved energy management algorithms, such as predictive control and machine learning approaches, to maintain an efficient balance of fuel and battery consumption while ensuring vehicle performance is not jeopardized [11].

B. Reducing emissions while maintaining performance:

Reducing emissions while maintaining good performance in Hybrid Electric Vehicles (HEVs) is a major problem for energy management. To reduce emissions, both the internal combustion engine (ICE) and the electric motor must be efficient, which can often clash with performance needs. Aggressive driving, for example, can increase fuel consumption and emissions, emphasizing the importance of modern energy management systems that prioritize eco-friendliness while maintaining power and responsiveness. According to research, optimal control techniques can efficiently balance these opposing aims; nevertheless, managing energy distribution between the ICE and electric motor while limiting emissions needs a thorough understanding of driver behavior and vehicle dynamics [12]. The use of different energy sources hampers emissions reduction in HEVs. Factors such as steep inclines and heavy traffic can increase reliance on internal combustion engines (ICEs), resulting in increased emissions.

C. Impact of driving conditions on energy management:

Driving circumstances have a substantial impact on energy management in Hybrid Electric Vehicles (HEVs), which presents a number of issues. Road slopes, traffic congestion, and weather all have an impact on how efficiently the vehicle's internal combustion engine (ICE) and electric motor operate. Driving up inclines, for example, increases the ICE's power requirement, resulting in greater fuel consumption and emissions. Similarly, stop-and-go traffic necessitates frequent switching between electric and gasoline power, making energy distribution difficult to optimize and resulting in inefficiencies in overall energy management techniques [13]. These algorithms must find a

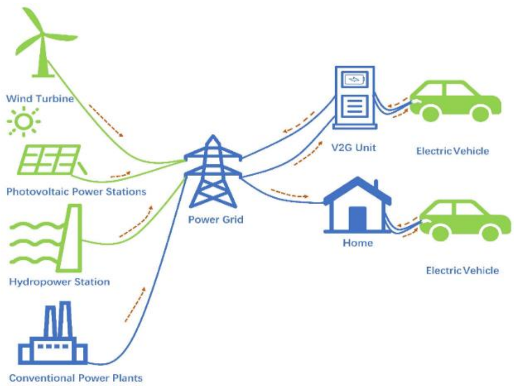

Fig. 5 Service of Vehicle to Grid(V2G) [15].

compromise between performance and efficiency, adjusting the functioning of the internal combustion engine (ICE) and electric motor based on the current driving circumstances.

V. Future Trends in Energy Management:

Future energy management will prioritize smart grids in order to successfully integrate renewable sources such as solar and wind. Electric cars (EVs) will help balance energy demand by storing and transmitting electricity to the grid using vehicle-to-grid (V2G) technology. Autonomous driving will improve energy efficiency by reducing traffic and charging mostly during off-peak hours. Overall, these tendencies help to create more efficient and sustainable energy systems.

A. Integration with smart grids and renewable energy:

The integration of electric vehicles (EVs) with smart grids and renewable energy sources is pushing developments in energy management systems (EMS), allowing them to better handle complicated, real-time power flows and maintain grid stability. Emerging EMS trends highlight the use of bidirectional charging capabilities that enable vehicle-to-grid (V2G) connections, allowing EVs to give energy back to the grid as needed. This bidirectional energy flow reduces peak load demands and stabilizes the grid, which is especially useful during changes in renewable energy generation from variable sources such as wind and solar [14]. Furthermore, new algorithms focusing on predicted energy demand and supply are being created to improve charging schedules, reduce operating costs, and improve the overall dependability of smart grid services.

B. Vehicle-to-grid (V2G) technologies:

Vehicle-to-Grid (V2G) solutions are being developed to improve grid resilience and flexibility by utilizing electric cars (EVs) as mobile energy sources. Recent improvements in V2G have emphasized the development of bidirectional charging systems and efficient energy transfer protocols, which allow EVs to send power back into the grid during peak demand periods. This demand response function is expected to play an important role in improving grid stability and mitigating variations from renewable energy sources such as wind and solar. Current research focuses on enhancing energy transfer efficiency and reducing battery wear in EVs through bidirectional charging [15]. Furthermore, V2G improvements are addressing crucial concerns such as EV compatibility and smooth connection with the grid.

VI. Conclusion:

In conclusion, energy management systems in hybrid electric vehicles (HEVs) have made tremendous progress in balancing efficiency, performance, and environmental objectives. The core tactics are focused on optimizing power distribution between the internal combustion engine and electric motor, applying regenerative braking to harvest and store energy, and properly regulating the battery's charge status. Advanced control algorithms play an important role in guaranteeing effective energy allocation by responding to different driving circumstances and lowering fuel consumption. Furthermore, adaptive systems that use real-time data can make dynamic modifications to energy flow, improving overall vehicle performance and cutting emissions. Looking ahead, energy management in HEVs will encounter problems in boosting efficiency, integrating renewable energy sources, and meeting increasingly sophisticated driving requirements. Incorporating machine learning and artificial intelligence into energy management systems allows for predictive optimization based on driving behavio2rs, traffic situations, and even weather changes. Nonetheless, concerns including battery deterioration, proper thermal management, and the necessity for common communication protocols across vehicle models remain crucial areas for improvement. Overcoming these obstacles will be critical in propelling HEV technology ahead and contributing to the larger trend toward cleaner, more efficient transportation.

REFERENCES

1. S. Uddin, A. Basu, and M. M. Islam, "Energy Management in Hybrid Electric Vehicles: A Comprehensive Review," IEEE Transactions on Transportation Electrification, vol. 6, no. 3, pp. 1031-1045, 2020.
2. K. K. Gupta and P. Tiwari, "A Comprehensive Review on Hybrid Electric Vehicle Technology and Its Applications," IEEE Access, vol. 8, pp. 134199-134219, 2020.
3. X. Lin, H. Zhang, and J. Zhang, "Performance Evaluation and Energy Management of Series Hybrid Electric Vehicles," IEEE Transactions on Vehicular Technology, vol. 69, no. 8, pp. 8465-8474, 2020.
4. S. M. Mousavi, A. Bouscayrol, and M. H. Benbouzid, "Energy Management of Parallel Hybrid Electric Vehicles: A Review," IEEE Transactions on Vehicular Technology, vol. 68, no. 4, pp. 3381-3392, 2019.
5. J. Zhang, T. Hu, and W. Ma, "Energy Management and Control Strategy for Series-Parallel Hybrid Electric Vehicles: A Review," IEEE Transactions on Vehicular Technology, vol. 69, no. 10, pp. 10347-10358, 2020.
6. X. Wang, Y. Zhang, "Hybrid Electric Vehicles and Emission Reduction: A Review of Recent Advances," IEEE Access, vol. 7, pp. 22358-22368, 2020.
7. M. Zhang, Y. Zhao, and F. Gao, "Rule-Based Energy Management Strategy for Hybrid Electric Vehicles: A Review," IEEE Access, vol. 8, pp. 109340-109352, 2020.
8. Z. Yang, H. Peng, and S. Li, "Optimization-Based Energy Management Strategy for Hybrid Electric Vehicles Using Model Predictive Control," IEEE Transactions on Vehicular Technology, vol. 69, no. 7, pp. 7347-7357, 2020.
9. L. Chen, Y. Zhang, and Q. Chen, "Data-Driven Machine Learning Approaches for Energy Management in Hybrid Electric Vehicles," IEEE Transactions on Transportation Electrification, vol. 7, no. 3, pp. 1553-1564, 2021.
10. IEEE Xplore, "Optimization Strategies for Regenerative Braking in Hybrid and Electric Vehicles," 2021.
11. M. Chen, Y. Zhang, "Optimizing Battery Usage and Fuel Efficiency in HEVs: A Model-Based Approach," IEEE Transactions on Vehicular Technology, vol. 69, no. 7, pp. 7556-7566, 2020.
12. R. K. Singh, S. R. Dey, "Performance Optimization in Hybrid Electric Vehicles for Emission Reduction," IEEE Transactions on Vehicular Technology, vol. 70, no. 5, pp. 4142-4153, 2021.
13. A. H. N. Rasheed, M. Alavi, "Effects of Driving Conditions on Energy Management in Hybrid Electric Vehicles," IEEE Transactions on Intelligent

Transportation Systems, vol. 23, no. 2, pp. 993-1002, 2022.
14. S. S. Raj, S. Suresh, and R. Kalaiarasi, "Bidirectional V2G technology for EVs in smart grids: An overview," IEEE Transactions on Smart Grid, vol. 12, no. 3, pp. 1015-1023, 2019.
15. Y. Zhang, X. Yang, and C. Li, "Impact of V2G technologies on grid stability and EV battery degradation," IEEE Transactions on Smart Grid, vol. 14, no. 2, pp. 1345-1355, 2021.
16. Dinesh, L., Sesham, H., & Manoj, V. (2012, December). Simulation of D-Statcom with hysteresis current controller for harmonic reduction. In 2012 International Conference on Emerging Trends in Electrical Engineering and Energy Management (ICETEEEM) (pp. 104-108). IEEE
17. Manoj, V. (2016). Sensorless Control of Induction Motor Based on Model Reference Adaptive System (MRAS). International Journal For Research In Electronics & Electrical Engineering, 2(5), 01-06.
18. V. B. Venkateswaran and V. Manoj, "State estimation of power system containing FACTS Controller and PMU," 2015 IEEE 9th International Conference on Intelligent Systems and Control (ISCO), 2015, pp. 1-6, doi: 10.1109/ISCO.2015.7282281
19. Manohar, K., Durga, B., Manoj, V., & Chaitanya, D. K. (2011). Design Of Fuzzy Logic Controller In DC Link To Reduce Switching Losses In VSC Using MATLAB-SIMULINK. Journal Of Research in Recent Trends.
20. Manoj, V., Manohar, K., & Prasad, B. D. (2012). Reduction of switching losses in VSC using DC link fuzzy logic controller Innovative Systems Design and Engineering ISSN, 2222-1727
21. Dinesh, L., Harish, S., & Manoj, V. (2015). Simulation of UPQC-IG with adaptive neuro fuzzy controller (ANFIS) for power quality improvement. Int J Electr Eng, 10, 249-268
22. Manoj, V., Swathi, A., & Rao, V. T. (2021). A PROMETHEE based multi criteria decision making analysis for selection of optimum site location for wind energy project. In IOP Conference Series: Materials Science and Engineering (Vol. 1033, No. 1, p. 012035). IOP Publishing.
23. V. Manoj, P. Rathnala, S. R. Sura, S. N. Sai, and M. V. Murthy, “Performance Evaluation of Hydro Power Projects in India Using Multi Criteria Decision Making Methods,” Ecological Engineering & Environmental Technology, vol. 23, no. 5, pp. 205–217, Sep. 2022, doi: 10.12912/27197050/152130.
24. V. Manoj, V. Sravani, and A. Swathi, “A Multi Criteria Decision Making Approach for the Selection of Optimum Location for Wind Power Project in India,” EAI Endorsed Transactions on Energy Web, p. 165996, Jul. 2018, doi: 10.4108/eai.1-7-2020.165996.
25. Kiran, V. R., Manoj, V., & Kumar, P. P. (2013). Genetic Algorithm approach to find excitation capacitances for 3-phase smseig operating single phase loads. Caribbean Journal of Sciences and Technology (CJST), 1(1), 105-115.
26. Manoj, V., Manohar, K., & Prasad, B. D. (2012). Reduction of Switching Losses in VSC Using DC Link Fuzzy Logic Controller. Innovative Systems Design and Engineering ISSN, 2222-1727.
27. Manoj, V., Krishna, K. S. M., & Kiran, M. S. Photovoltaic system based grid interfacing inverter functioning as a conventional inverter and active power filter.
28. Vasupalli Manoj, Dr. Prabodh Khampariya and Dr. Ramana Pilla (2022), Performance Evaluation of Fuzzy One Cycle Control Based Custom Power Device for Harmonic Mitigation. IJEER 10(3), 765-771. DOI: 10.37391/IJEER.100358.
29. Manoj, V., Khampariya, P., & Pilla, R. (2022). A review on techniques for improving power quality: research gaps and emerging trends. Bulletin of Electrical Engineering and Informatics, 11(6), 3099-3107.
30. V. Manoj, R. Pilla, and V. N. Pudi, “Sustainability Performance Evaluation of Solar Panels Using Multi Criteria Decision Making Techniques,” Journal of Physics: Conference Series, vol. 2570, no. 1, p. 012014, Aug. 2023, doi: 10.1088/1742-6596/2570/1/012014.
31. V. Manoj, R. Pilla, and S. R. Sura, “A Comprehensive Analysis of Power Converter Topologies and Control Methods for Extremely Fast Charging of Electric Vehicles,” Journal of Physics: Conference Series, vol. 2570, no. 1, p. 012017, Aug. 2023, doi: 10.1088/1742-6596/2570/1/012017.
32. Rajesh Babu Damala, Ashish Ranjan Dash, Rajesh Kumar Patnaik “Change Detection Filter Technique (CDFT) algorithm with Decision Tree Based Fault Analysis of VSC Based HVDC Transmission Link Fed by an Offshore Wind Farm interfacing with Utility” published by the journal “World Journal of Engineering”, ISSN 1708-5284, April 2022.
33. Rajesh Babu Damala, Rajesh Kumar Patnaik, Ashish Ranjan Dash, “A Simple Decision Tree-Based Disturbance Monitoring System for VSC-based HVDC Transmission Link Integrating a DFIG Wind Farm” accepted by the journal “Protection and Control of Modern Power systems”, June 7th 2022, ISSN: 2367-0983.
34. Damala.Rajesh Babu, B.P.Mishra, R.K.Patnaik, “ High Voltage DC Transmission Systems for Offshore Wind Farms with Different Topologies”, International Journal of Innovative Technology and Exploring Engineering (IJITEE) , ISSN:2278-3075,Volume-8,Issue-11,pp.2354-2363, September 2019.
35. Damala.Rajesh Babu, M.T.Naik,A.Jayalaxmi , “A Prototype model of augmented solar tracking system for electric vehicles”, International Journal of Control Theory and applications, Vol. No.10, Issue No.16, pp 23-31, . (ISSN No.:0974-5572), 2017.
36. Damala.Rajesh Babu, Rambabu.M “Time Lapse Based Single Axis MPP Tracking System for Solar Tree by Using Arduino Duemalinove Board”, published in "International Journal of Engineering & Technology (IJET) (ISSN 2227-524X)", Vol. No.7, Issue No.4.25, pp 271-277, November, 2018.
37. M.Rambabu, Damala RajeshBabu, T.Netaji, “Hybrid Power Generation in Remote Locations Based on Renewable Energy Sources” published in International Journal of Applied Engineering Research with ISSN 0973-4562, Volume 13, Number 8, pp. 56-59, 2018.

38. Ravikumar.Jalli, Damala Rajesh Babu, NSS Ramakrishna, "A Prototype Model of Induction Based and Solar Powered Hybrid Electric Vehicle to Achieve Zero Charging", Journal of Advanced Research in Dynamical & Control Systems, ISSN: 1943023X, Volume-11,Issue-05,pp.299-305, 2019.