Unit 5: EV Charging Facility Planning

Syllabus

EV Charging Facility Planning: Identification of EV demand, Impact of EV charging on power grid, Energy generation scheduling, different power sources, centralized charging schemes, Energy storage integration into micro-grid, Overview and applicability of AI for the EV ecosystem, design of V2G aggregator, case studies.

Identification of EV demand

1. To identify the demand of EV charging we consider EV technical specifications and traffic pattern.

2. The set of parameters can be separated into two subsets as follows

A .Constant Parameters:

1. EV penetration level:

1 .The number of simulated EV depends on the forecasted EV sales for each country.

2. Assuming that vehicle sales are proportional to population changes. The future sales trend for all countries is increasing.

3. In the realistic scenario, it is expected that EV sales will amount for 15% of total vehicle sales in 2030, while in the optimistic scenario this EV share is almost double..

4. In the very aggressive scenario, half of the vehicle sales in 2030 is assumed to be electric vehicles.

2. Charging station technologies:

I. This parameter determines the maximum power flow between the EV and the power grid which depends on the line power capacity of the charging infrastructure.
II. Three different charging modes have been adopted, namely, normal (Mode 1), fast (Mode 2), and de (Mode 3).
III. The selection of the charging mode for each specific EV is probabilistic and depends on its type.

3. Availability of charging:

Different scenarios can be simulated for the availability of charging:

i. Charging after last trip. (home charging).
ii. Charging when a (public or private) charging point is available.

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iii. Charging when the battery state of charge is lower than a desired level.

4 .Charging losses:

I. This parameter expresses the losses of AC/DC power conversion from the grid to the DC charging of the EV batteries and vice versa, due to the power electronic interfaces.

II. In the present simulations, these are considered equal to 10-15% of the total energy demand.

5. Charging strategy:

The assessment of the impacts of EV penetration in power systems should take into account the charging strategies, discussed as follows:

i. Dumb Charging: This is the unplanned "plug and play" connection of electric vehicles into the grid, typically after the last trip of the day or when a charging point is available.

ii. Multiple Tariff Charging: This is the normal market way to manage energy demand. Cheaper energy tariffs are implemented at specific hours to shift demand to off-peak hours.

iii. Smart charging: In this strategy, bidirectional power flow exists between the EV and the power grid. It is based on the fact that average daily EV mobility lasts only 2-4 hrs and the respective energy requirements are only a fraction of their battery capacity. The excess battery power can be utilized during peak hours as a source of energy, thus contributing to a more stable grid operation.

B. Probabilistic Parameters:

1. Classification of EV:

EV can be classified into two categories depending on the type of engine: the plug-in hybrid EV (PHEV) and the pure battery EV (BEV).

Each type of EV has specific battery capacity ranging between a minimum and a maximum values

Following ones are expected to dominate the vehicle market sales:

a. L7e: small city purpose vehicles.

b. M1: 4-seater passenger vehicles.

c. NI: carriage of goods with a maximum laden mass of less than 3,500 kg.

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d. N2: maximum laden mass of 3,500-12,000 kg for commercial purposes

2. Daily travel distance:

I. This parameter expresses the daily distance covered by an EV between two successive charging cycles.
II. The daily travel distances depend highly on the purpose of EV usage.
III. For example ,during weekdays ,vehicles are used mainly for working purpose ,thus the distance profile exhibits approximately the same pattern .During weekends ,vehicle mobility is reduced and the distance profile exhibits varying pattern.

Impact of EV charging on power grid

Recent concerns about environmental pollution accompanied by the advancements in battery technology have initiated the electrification of the transportation sector. The paradigm shift from conventional vehicles to EVs has many environmental and economic advantages. The increasing number of EVs is however accompanied by a rise in charging demand. Hence, the development of the charging infrastructure as well as efficient Inductive Power Transfer (IPT) has become necessary to meet the requirements of substantial operation of the EVs. However, with the universal resurgence of EVs the adverse impact of the EV charging loads on the operating parameters of the power system has been noticed. The establishment of charging stations imposes an additional burden on the power grid, as the high charging loads of fast EV charging stations will degrade the operating parameters of the distribution network. Massive penetration of EVs increases the load demand thereby degrading the operating parameters of the distribution network. The degradation of voltage profile, increase in peak load, harmonic distortions are some of the consequences of the uncoordinated charging of EVs.

Voltage stability of distribution network:

Voltage stability is the power system's capability to maintain acceptable voltages at all the system buses under normal operating conditions and when an external disturbance is applied. During voltage instability phenomena, the bus voltage of the declines progressively and uncontrollably. The system may become unstable because of sudden disturbances fault conditions, single or multiple contingencies, line overloading load increase. Voltage stability criterion is that voltage of all the system buses must be within acceptable limits. Voltage stability is a local phenomenon but in some cases, it may lead to severe voltage collapse.

Impact of EV charging station load on a voltage stability:

The potential impact of EV charging station loads on the voltage stability has been investigated by a number of researchers. It was observed that:

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1. The voltage profile of the node where multiple charging stations were placed degraded to some extent.
2. The high loads of EV charging stations caused degradation of the voltage profile of the weak buses of the system.
3. The transient voltage stability index degraded for high penetration of EVS.
4. Old networks designed decades ago are not equipped to withstand any large-scale integration of EVs.
5. Placement of charging station at the weakest bus caused severe degradation of the voltage stability.
6. Distributing the charging stations between a number of buses is advantageous than concentrating the charging stations at a single bus.

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Reliability of Distribution Network

The reliability of a distribution network refers to its ability to consistently deliver electricity to consumers without interruptions or failures. The impact of electric vehicle (EV) charging stations on the distribution network depends on various factors, including the number of charging stations, their location, charging infrastructure, and the charging patterns of EV owners. Here are some key points to consider:

1. **Load Increase:** EV charging stations introduce additional electrical load to the distribution network. The magnitude of this load increase depends on the number of EVs being charged and their charging rates. If there is a high concentration of EV charging stations in a specific area, it can significantly affect the local distribution infrastructure.
2. **Peak Demand:** Charging EVs typically occurs during peak demand periods, such as evenings when people return home from work. This concentrated charging load can strain the distribution network, especially if it is not adequately designed to handle the increased demand. Insufficient capacity could lead to voltage drops, overloads, and potential outages.
3. **Load Management:** Utilities and grid operators can implement load management strategies to mitigate the impact of EV charging stations on the distribution network. This may involve time-of-use pricing, demand response programs, or smart charging systems that optimize charging schedules based on grid conditions. By incentivizing off-peak charging and distributing the load more evenly, stress on the network can be reduced.
4. **Infrastructure Upgrades:** In some cases, distribution infrastructure upgrades may be necessary to accommodate the increased load from EV charging stations. This can involve upgrading transformers, power lines, and substation equipment to ensure the reliable delivery of electricity. These upgrades require planning and investment by utilities to maintain grid stability.
5. **Grid Integration:** Proper integration of EV charging infrastructure with the grid is crucial. Smart charging systems can communicate with the grid to balance the charging load, considering factors like renewable energy generation and overall demand. This integration helps minimize disruptions and optimize the use of available resources.

To ensure the reliability of the distribution network while accommodating the growing demand for EV charging, utilities, grid operators, and policymakers need to collaborate on planning, infrastructure investments, load management strategies, and grid modernization efforts.

Power Loss of Distribution Network

The power loss in a distribution network can occur due to various factors, including resistive losses in power lines, transformer losses, and losses in distribution equipment. The impact of EV charging station load on power loss in the distribution network can be summarized as follows:

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1. **Increased Load:** EV charging stations introduce additional electrical load to the distribution network. This increased load results in higher current flow through power lines and equipment, leading to higher resistive losses. As a result, power loss in the distribution network can increase when EV charging stations are added.
2. **Voltage Drops:** The additional load from EV charging stations can cause voltage drops in the distribution network. When large numbers of EVs are charged simultaneously, especially during peak demand periods, the voltage at the charging stations may decrease due to the combined effect of increased load and line losses. Voltage drops can impact the charging efficiency and performance of EVs.
3. **Infrastructure Overloading:** If the distribution infrastructure is not adequately sized to handle the increased load from EV charging stations, it may become overloaded. Overloaded equipment can lead to overheating, higher losses, and potential failures. This can further contribute to power losses in the distribution network.
4. **Power Factor Considerations:** The power factor of EV charging stations can also affect power losses in the distribution network. Power factor is a measure of how efficiently electrical power is utilized. If EV charging stations have a low power factor (indicating reactive power), it can result in increased currents, higher losses, and reduced efficiency in the distribution network.
5. **Grid Management Strategies:** Load management strategies and smart charging systems can help mitigate the impact of EV charging station load on power losses. By implementing techniques such as load balancing, time-of-use pricing, and demand response programs, utilities can optimize the charging load and reduce stress on the distribution network, thereby minimizing power losses.

To ensure minimal power losses in the distribution network while accommodating the increasing demand from EV charging stations, utilities need to conduct thorough load studies, evaluate infrastructure requirements, and consider factors such as power factor correction and grid management strategies. Proper planning, infrastructure upgrades, and smart grid solutions can help mitigate the impact on power losses and ensure efficient power delivery.

EV Energy generation scheduling

Joint Scheduling method

Joint Scheduling Method in JSM, the EV energy scheduling is considered to be performed by a central entity like a system operator that also plans for the dispatch of the generators. The central operator is assumed to receive data related to the generators and EV batteries. The operator could then schedule both the generators and the EV charging energy demand by minimizing the total cost of generation. In a scenario where advanced methods of communication and control are feasible, individual EV owners could directly interact with the market 24 by submitting the necessary EV data. In this scheduling method, the central operator is assumed to receive the following three sets of information:

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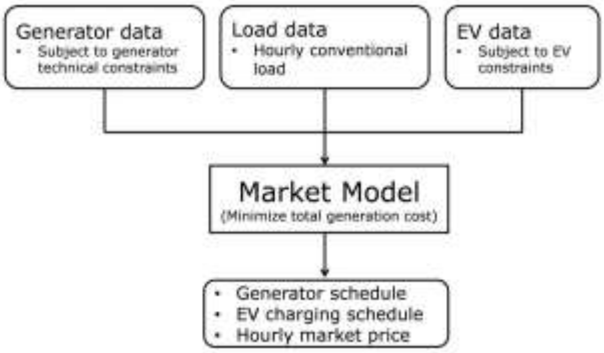
1. Generator costs along with its technical constraints

2. Daily EV driving energy requirements, driving pattern data and aggregated EV battery energy limits.

3. Hourly conventional load data, which represents the inflexible demand data.

Using these three sets of information, the market model jointly schedules the generators and EV charging demand to minimize the total generation cost within a unit commitment framework. Overview of JSM the generators are assumed to bid their true marginal cost of generating electricity and the market is settled with the minimum generation cost objective. Demand, except that of EVs, is considered to be perfectly forecasted a priori, and is fixed for each hour.



2. Aggregator Scheduling Method

In ASM, the EV aggregator is assumed to function similar to an electricity retailer in the market. The aggregator plans for DAM participation by independently scheduling EV energy based on its objective of minimizing the total cost of charging. For the scheduling, the EV aggregator is assumed to have the following three sets of information:

1. Daily EV driving energy requirements, driving pattern data and aggregated EV battery energy limits.

2. Hourly conventional load data, which represents the inflexible demand from all other loads other than EV demand.

3. Estimated supply function. Using the above sets of data, the aggregator schedules the charging energy of EVs such that the total cost of charging is minimized as shown in Figure.

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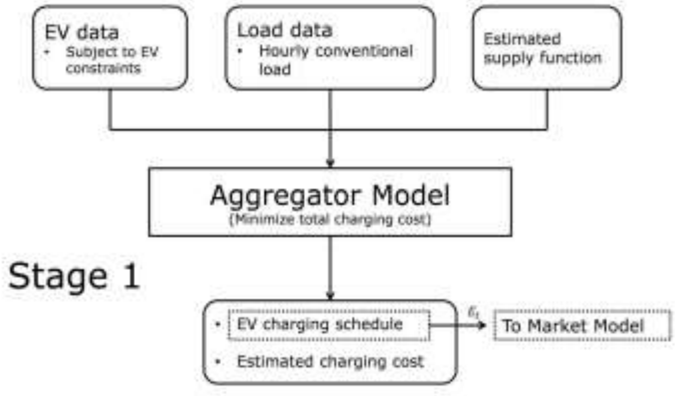

Different power sources for electric vehicle Charging

Following are the different power sources for electric vehicle charging

A. Conventional source

1. The utility supply is the conventional source of electrical energy.

2. The supply from utility can be directly applied to charge depending on the type of charger.

3. In the case of AC charging, the EVs an on board charger that coverts AC supply to DC supply.

4. Due to less efficiency and slow charging of on-board chargers, y off-board chargers are preferred. 5. The EV is a nonlinear load; there are many adverse effects on the Grids.

6. The EV charging has huge power requirements in a short span of time hence it affects normal grid operations.

7. Charging EV in peak demand even contributes to higher pollution as more coal has to be burnt to meet the increasing demand

Renewable energy sources (RES)

1. As the utility supply cannot meet the increasing enter alternative sources have to be harnessed for charging EVs

2. Among various RES, most popular are the solar and wind.

3. RES should replace conventional sources of energy, such transture may reduce the environmental degradation.

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I. Solar Energy

1. Solar energy can be harnessed to generate electricity by using the PV Cell.
2. The PV cell uses the photovoltaic effect in which electromagrate radiation from the sun falls on the PN junction to produce an electric Potential which leads to flow a current.
3. Depending on the requirement of power and voltage of load, the PV panels are connected in series or parallel connection.
4. More panels are connected in series and parallel to increase voltage current output, respectively, this combination of panels in series and parallel connection increases overall power delivered.

II. Wind energy

1. For EV charging stations after solar energy, the next dominant source is wind.

2. As the nacelle of the wind system with small to medium size blades can be mounted on the top of parking lots.

3. By this kind of placement, the cost is reduced significantly.

4. It is known that the wind flows at variable speeds during a day. Thus, it requires a battery bank for smooth operation.

5. The complete set-up to harness wind energy is also referred as wind turbine generator (WTG).

6. The efficiency of the system is mainly dependent upon the construction of blades and turbine.

(III) Fuel cell:

1. Usually, the EV uses batteries to power its motors, but in FEV power is given by the fuel cells.

2. The battery is an electrochemical unit which converts chemical energy into electrical energy.

3. Similar to the working of the battery, fuel cell also converts the chemical energy-of hydrogen combining with oxygen to produce water-to generate electrons in the external circuit.

4. There are five types of fuel cells, viz. proton exchange membrane fuel cell (PEMFC), solid oxide fuel cell (SOFC), alkaline fuel cell (AFC), phosphoric acid fuel cell (PAFC) and molten carbon fuel cell (MCFC).

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5. The PEMFC is used for transportation purpose as it has high power density, and low weight and volume.

6. Fuel cells have advantages such as high efficiency, lower emissions and being quiet in operation.

7. The major problem in a fuel cell for transportation purpose is the requirement of pure hydrogen.

8. Usually, the hydrogen available is not pure, and it is hard to store and distribute.

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Centralized charging schemes for electric vehicles

Centralized charging schemes for electric vehicles (EVs) refer to systems where charging infrastructure is concentrated in specific locations or managed by a central entity. These schemes aim to provide efficient and organized charging solutions for EV owners. Here are a few examples of centralized charging schemes:

1. Public Charging Stations: Public charging stations are a common form of centralized charging infrastructure. These stations are strategically placed in public areas such as parking lots, shopping centres, or along highways. They provide charging services to EV owners who may not have access to private charging options.

2. Fast Charging Networks: Fast charging networks, often operated by third-party companies, establish a network of charging stations along major travel routes or in urban areas. These networks typically offer high-power chargers that can rapidly charge an EV's battery, reducing charging time significantly.

3. Workplace Charging Programs: Many companies and organizations install charging stations at their workplaces to encourage their employees to drive EVs. This centralized approach allows multiple EV owners to charge their vehicles while at work, utilizing the charging infrastructure efficiently.

4. Utility-Managed Charging Programs: Some utility companies implement centralized charging programs where they offer special tariffs or incentives for EV owners who charge their vehicles during off-peak hours. These programs help manage electricity demand and ensure efficient utilization of the grid.

5. Managed Charging Services: Centralized charging schemes can also involve the use of smart charging platforms or mobile applications that allow EV owners to schedule their charging sessions. These systems can optimize charging times to balance demand and grid load, ensuring a more efficient use of available charging resources.

Benefits of Centralized Charging Schemes:

Improved accessibility: Centralized charging infrastructure increases the availability of charging options for EV owners, especially for those who do not have access to private charging facilities.

Enhanced efficiency: By strategically locating charging stations or implementing smart charging management systems, centralized schemes can optimize the use of charging resources, reducing wait times and minimizing energy waste.

Scalability and standardization: Centralized schemes can facilitate the deployment of standardized charging infrastructure, making it easier for EV owners to find and use compatible charging stations across different locations.

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Collaboration and partnerships: Centralized charging schemes often involve collaborations between various stakeholders, including government entities, utility companies, and private organizations, promoting the development of EV infrastructure and fostering sustainable transportation initiatives.

It's worth noting that decentralized charging options, such as home charging stations or private charging networks, also play a crucial role in supporting the widespread adoption of electric vehicles. A combination of centralized and decentralized charging solutions can offer the most comprehensive and convenient charging experience for EV owners.

Energy storage integration into micro-grid

A micro grid is a localized energy system that can operate independently or in conjunction with the main grid. Micro grids typically consist of distributed energy resources (DERs), such as renewable energy sources, generators, and loads. Benefits: Micro grids offer increased reliability, energy independence, and the potential for renewable energy integration.

However, the existing infrastructure cannot handle such a power transfer. To introduce V2G, three difficulties must be resolved right away:

(1) the use of a unidirectional charger,

(2) the need for improved communication modules, and

(3) sufficient power capacity to provide energy buffers.

However, the quantity of charging and discharging cycles reduces battery life. Intelligent charging solutions with superior battery and charger management hardware are sought to minimize these issues. This additional electricity could benefit grids by improving power quality and load control. Smart home models that use EVs micro grids to power homes reduce the strain on the grids during peak times. Additional because they reduce carbon emissions and improve social welfare, EV adoption would be encouraged by using those with distributed renewable resources. The block diagram the WTG-PV-fuel cell hybrid system is shown in Fig.

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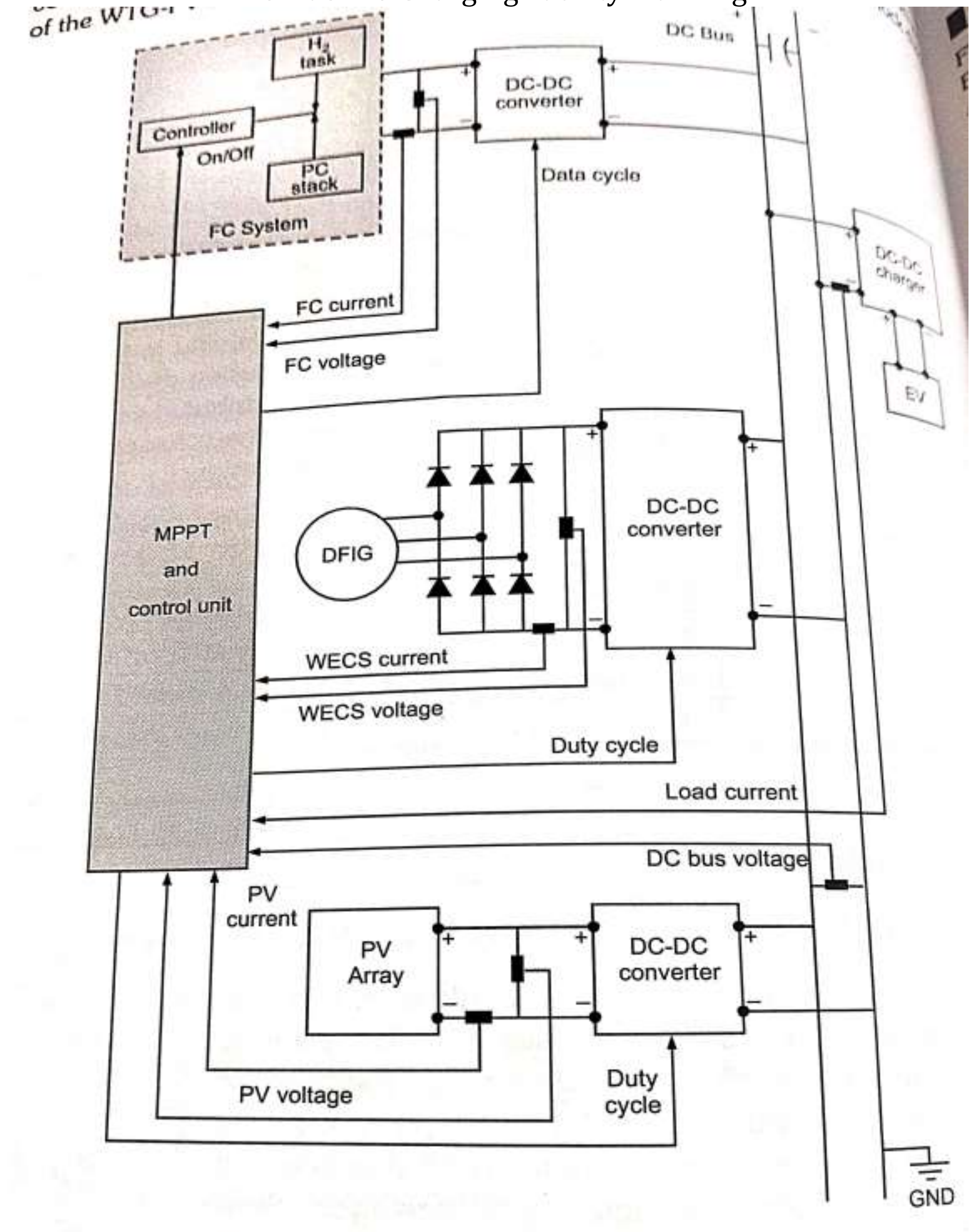

Fig. 5.8 Block diagram of WTG-PV-fuel cell hybrid system

MICROGRID SYSTEM WITH AN ELECTRIC VEHICLE

Flywheel energy storage systems have not yet been introduced to the EV energy market because EV technology is still under development. A revolutionary technology that can be investigated for energy utilization and EV technology is shown in Fig. The software for hybrid optimization of multiple energy resources grid can be used to reproduce and enhance it since it uses a range of distributed energy resources, such as solar panels, flywheel storage, clean

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diesel generators, and plug-in hybrid electric vehicles. Each part of the micro grid is connected via a local network communication system that uses wired and wireless technologies. Fig. depicts the composition of the micro grids for electric vehicle charging stations.

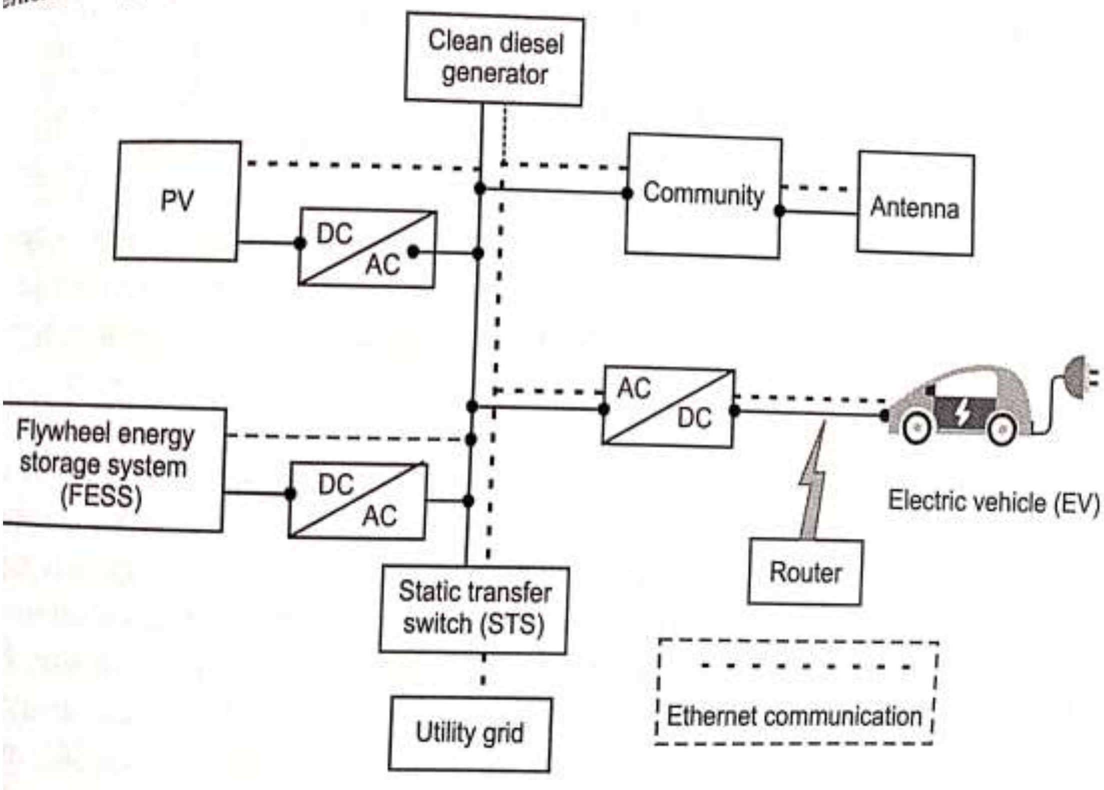

Fig. 5.9 Diagram of microgrid with different distributed energy resources

(a) When using EVs and micro grids, the PV and flywheel provide the community load during charging.

(b) The clean diesel generator will be able to feed the load whenever the PV system is unable to do so.

(c) The EVs can help in supplying to the community load if the PV is unable to do so and the diesel generator is empty, but the EVs are charged.

(d) The system will be stopped, and priority loads will be supplied if the PV, diesel generator, EVs, and flywheel cannot meet the demand.

(e) Micro grids will manage active power, reactive power, voltage, and frequency fluctuations. These variations depend on the type of controllers used, such a standard droop control and modified droop control.

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(f) All metrics will be monitored by the utility grid during grid supply, partly because the PV, diesel generator, and EVs will be unable to meet demand at that time. The utility grid will intervene depending on the controller type, typically PQ controller virtual synchronous machines, or the synchronverter approach.

Overview and applicability of AI for the EV ecosystem

EV costs are predicted to be higher than those of traditional combustion engine vehicles over the next five years. This accomplishment should be largely credited to artificial intelligence (AI). Al has the potential to accelerate the development of batteries, which will be helpful for electric vehicles. According to global market predictions, Al in the automotive market will expand at a compounded annual growth rate of more than 35% between 2020 and 2026. Many EV players are experimenting with self-driving EVs in order to collect data, analyse data, and repair electric vehicles. Al is extensively used in production, assembly lines, and other EV-related processes. Electric vehicle manufacturers can now process enormous amounts of sensor data more quickly by introducing Al and machine learning.

Battery performance must be considered at every step of a vehicle's life. One of most significant EV developments is the extension of battery life because the better makes up about 25% of an EV's entire cost. A vehicle's electric battery can now recharged at a petrol station, and artificial intelligence may also advance other fact of battery technology. The global battery market is growing significantly in size. No EV can be fully charged in less than an hour, not even the Tesla S 100D (355 miles OR 750 km), Hyundai Kona (198 miles or 320 km), or MG ZS EV (214 miles or 345 m). For instance, while Indian EV industry players would require more than 3 hours, it will take 75 minutes to fully charge at a Tesla supercharging station.

By examining battery consumption and recharge data, artificial intelligence is creating mathematical model to improve fast-charging capabilities without reducing the life of the vehicles and extending the battery life. These improvements (including driving range and charging time) are made possible by better battery performance and life cycle management. It can also help to precipitate battery field research by quickening the search for better materials and testing.

Future of Artificial Intelligence in the EV Industry

Many Al-based applications, including autonomous driving, monitoring of user behaviour, and intelligent navigation systems, significantly impact the EV industry. It can be utilized for safety purposes like monitoring driving patterns, scheduling equipment maintenance, and locking up vehicles. Numerous businesses are utilizing artificial inttelligence in automobiles. Some people use this technology to increase the battery life of their electric vehicles, while others use it to replace the current transportation networks with self-driving services. However, the market will keep pushing for overall efficiency of EVs Among other things, these include maximizing the charge, extending the charging time, extending the battery's life, maximizing the use of batteries in all devices, including lights, raising the top speed and acceleration, as well as improving safety and security. Al can offer the intelligence that EVS require to use resources intelligently. Al has a bigger role to play in the automotive industry as a whole beyond only EVs. It wouldn't be inaccurate to suggest that, in the future, vehicles will likely use Al more than smartphones.

DESIGN OF V2G AGGREGATOR

By logically grouping the PHEVs, an aggregator should be able to offer the frequency regulation service to the grid operator at the necessary scale. In this situation, the vehicle is unable to discharge on its own; instead, the grid operator must demand regulation. The system's architecture is condensed, as depicted in Fig. It is obvious that the aggregator serves as a conduit between the grid operator and the vehicles. Based on the condition of the vehicle, the aggregator will enter into a contract with each PHEV for the use of its battery. The PHEV will inform the aggregator of its present state of charge (SOC), anticipated departure time, battery size, charging rate, and other details. It is a requirement for PHEV owners to take part in this activity that their vehicles are adequately charged at the time of plug- out. Direct payment, credit points, or battery upkeep are some additional incentives. The driver must acknowledge that the battery might not be sufficiently charged at the time of plug-out if he violates the terms of the agreement by leaving before the pre-arranged departure time. However, the percentage of unexpected departures will never change because the aggregator will have contracts with hundreds to thousands of vehicles. According to studies, early departure has a minimal impact on the regulation process under certain circumstances. Then, the aggregator will enter into a new agreement with the grid operator outlining how much regulation capacity it can offer the electrical system. Alternatively, the aggregator might inform the grid operator of the power requirement for recharging automobiles. Remember that the regulated contract size shouldn't exceed a PHEV fleet's overall capacity. Once these agreements are made, the aggregator can be viewed as a committed energy user and service provider for the grid operator, greatly simplifying the grid operator's control role.

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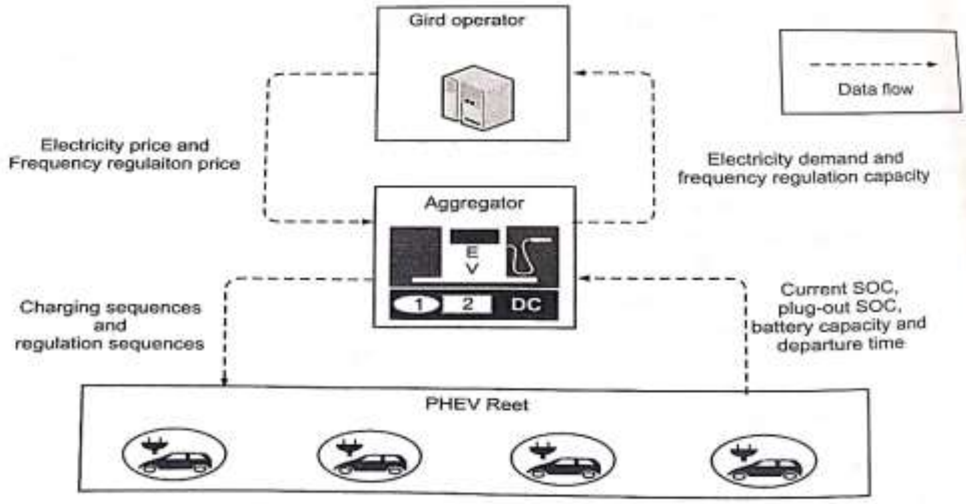

Fig. 5.10 System architecture for the design of V2G aggregator

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