A Review of Voltage Stability Issues in Distribution System Influenced by High PV Penetration and Its Mitigation Techniques

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Abstract- The installation of the photovoltaic system across the world is dramatically increasing to meet the increase in electrical energy demand. But the higher penetration of PV will lead to severe impacts on the distribution system such as instability in power balancing, over-voltage, under-voltage, etc. Voltage fluctuations may cause recurrent disturbances in voltage-controlled devices connected to the feeder which will reduce their estimated lifetimes and necessitate more maintenance. Typically, voltage stability is achieved using conventional and emerging mitigation technologies. The inconsistent nature of the output with SPV power generation systems, which is brought on by changes in their input sources, such as solar intensity and extensive use of electric vehicles along with solar power plants has an adverse influence on the grid's reliability. It is necessary to understand and investigate the stability aspects of the distribution system and provide necessary control mechanisms. This paper provides two field studies for the purpose of understanding the voltage stability issues in the distribution system due to high penetration of SPV generation and EVs. A field study on variation in PV power generation was carried out at a 10 kWp solar power plant in Umayanalloor, Kollam, Kerala, and a study on the charging pattern of a TATA Nexon EV car having a 30-kWh power bank from the same 10 kWp PV plant at Umayanallor, Kollam. This paper attempts to provide a comprehensive survey of related literatures, giving emphasis on the high penetration of SPV generation and EVs in the distribution systems, their effects, and suitable mitigating techniques.

Keywords PV system, distribution system, OLTC, voltage regulation, active power curtailment, reactive power compensation, FACTs devices, and BES.

1. Introduction

The world's electric power systems have experienced total grid failure numerous times throughout history, according to the chronicles of history [1]. In today's microgrids and distribution networks, renewable energy generation is capable of operating at voltages of up to 33 kV. Such distributed and renewable sources produce electricity with a high degree of inconsistency and frequently cause unplanned systemic disruptions under a variety of weather conditions. The electricity demand all over the world is drastically increasing because of industrial development, increase in populace and urbanization, etc. Nowadays, all electrical energy demand is met through the usage of renewable energy sources. [1]. The Ministry of New and Renewable Energy reports that renewable energy installation capacity in India as of 28th February 2022 is 106374.63MW [2]. Figure 1 illustrates the scheme-wise cumulative progress of renewable energy installation as of February 2022 (Source: MNRE report) [2]. Also, the Power System Operation Corporation Limited (POSOCO) signed a MoU with IIT Roorkee, India, for an advanced power grid control all over India, under the Union Ministry of Power on March 16th, 2022 [3]. So, it is crucial to study and scrutinize the impact of large-scale solar PV integration into the distribution system.

Under varying weather conditions, such renewable and distributed sources have highly inconsistent power production and many spontaneous disturbances to the system's operation.

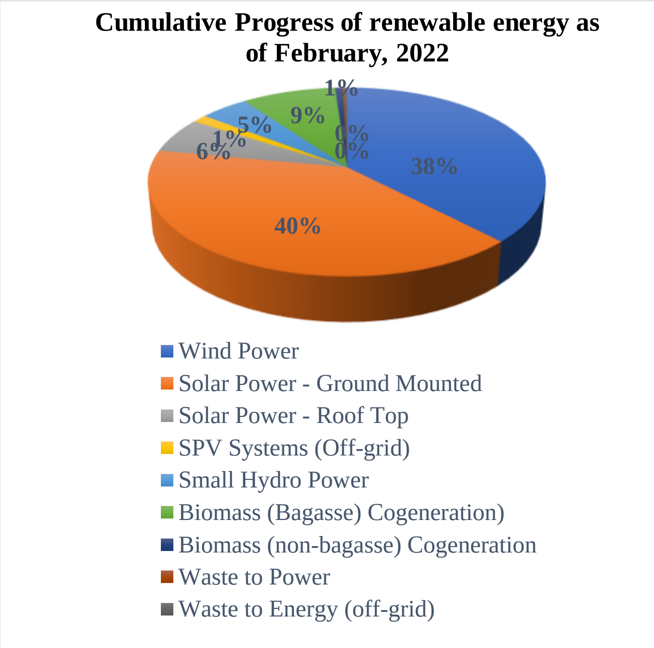

Fig. 1. Pie diagram for cumulative progress of renewable energy as of February, 2022.

The recent development in the field of electric vehicles (EVs) and use of grid energy for EVs also add to the grid disturbances. As in power grid, the energy balance between the supply and consumption must always be maintained to avoid the chances of blackout. More electric power from renewable energy sources will be delivered by increasing the penetration of PV into power networks, but it could have a negative influence on distribution systems in the form of instability in power balancing, over-voltage, under-voltage, etc. [4]-[9]. The adverse effects of these impacts directly depend on the percentage of PV penetration and its installation geography. So, knowing the possible impact attributed to higher PV penetration systems on distribution systems can provide feasible solutions before the practical installation. The common standards for PV integration in LV distribution systems are IEEE 1547 and IEC 61727 [10]. These standards are employed to maintain grid-connected PV stability and power quality. Coordinated and efficient control strategies should be mandatorily implemented when the utilization of solar photovoltaic energy is massive in the distributed generation system to rectify integration and measurement-related issues. Numerous mitigating techniques for voltage fluctuations due to higher PV penetrations were suggested by researchers. Two categories can be used to group the voltage regulation strategies for better solar PV distribution system.

- Conventional mitigation techniques
- Emerging mitigation techniques

The conventional accessible mitigation technique uses reconductoring, an on-load tap changer, fixed or switched capacitors, and active power curtailment. In addition to these conventional methods, researchers have proposed several new ones, such as FACT devices, load-side management, and distributed energy storage systems, etc.

Higher PV systems penetration on distribution networks may significantly deteriorate power quality and will affect its normal operating conditions. Voltage fluctuation is amongst the most adverse effects of higher PV penetration. A comprehensive tool has been introduced to examine the all-day-long fluctuations in distribution network efficiency as a result of more PV penetration [11]-[13]. The tool is used to model distribution networks' asymmetry and unbalanced complexities. This study discovered by W. Bingsen and G. Venkataramanan [43] that is, the PV output during noontime may change the network characteristics like over-voltage, under-voltage, and reverse power flows. At midday, there is a possibility of over-voltage and reverse power flow at the phases with lighter loads. Reinaldo Tonkoski et al. [14] show that controlling this voltage fluctuation may result in the continued operation of capacitor banks, load tap changers, and line voltage regulators. The recurrent operation will reduce the lifetime of these types of equipment and increase the possibility of maintenance. Numerous studies were performed to discover the impacts of higher PV penetration. Farhad Shahnia, Ritwik Majumder, and Arindam Ghosh [15] summarize the theoretical outline of limitations in radial distribution systems due to higher PV penetration, considering voltage rises and conductor ampacity rating. The ampacity rating of a feeder is the maximum current that can be securely carried without exceeding its insulation and temperature limits. The loading of feeder sections can be adversely influenced by the location of the PV system [15]. Hence, the feeder sections must be situated among the PV and the substation and have adequate capacity to distribute surplus energy of the PV system during lightly loaded conditions.

One of the viable and constructive methods to manage the system voltage instability is by supporting the sudden change in energy requirement using energy storage systems. Battery energy storage systems are the most widely used energy storage because they are easy to implement. In contrast to batteries, super-capacitors offer rapid charging or discharging rates. Thus, hybrid energy storage systems (HESSs) of battery and super-capacitor can provide benefits of both devices. Anindya Bharatee, Pravat K. Ray, and Arnab Ghosh [16] designed an efficient energy management strategy for an on-grid PV system with hybrid storage having both super-capacitor and battery storage system. A rapid control for the DC-link voltage was provided by the hybrid combination of super-capacitor and battery storage system, which stabilizes the system and aids in the smoothing of PV power. It also grabs average and transient power fluctuations [16] - [17]. Haytham M. A. Ahmed, Hatem F. Sindi, and Maher A. Azzouz [18] proposed a model for enabling large PV penetration levels of renewable energy sources in distribution systems using mobile energy storage systems. This model minimized the total cost of distribution system [18] – [19].

Chapter 2 contributed three-day field research (15 April 2022, 12 May 2022, and 17 May 2022) that was conducted at a 10 kWp solar power plant at Umayanalloor, Kollam, Kerala. With the survey details, the findings of this study demonstrate unequivocally that the primary drawback of SPV power production systems is the unpredictable nature of their output, which is caused by variations in their input sources, such as solar intensity. On April 21, 2022, a study on charging process of the TATA Nexon EV with 30 kWh power bank using the same 10 kWp SPV plant was also carried out in Umayanallor, Kollam. These studies show that high penetration of solar power plants and frequent usage electric vehicles charging has a negative impact on the grid's dependability. To keep the system stable in this sense, the grid's power stability must be controlled. Chapter 3 gives the study on various voltage stability issues and their mitigation techniques in detail.

2. Effects of High PV Penetration on Voltage In The Distribution System

Suppose the renewable energy generation is increased or decreased due to changing weather conditions which will cause fluctuations in solar PV output power. Such a field study has been conducted for three days in a 10kWp solar power plant in Umayanalloor, Kollam, Kerala. Table 1 gives the survey details and Fig.2 figures out the survey details for 15 April 2022, 12 May 2022, and 17 May 2022 showing the change in PV output power during variable weather conditions. G. D. Rai [20] described that under those circumstances, the conventional power plants linked with the power system have to compensate for these power fluctuations, since the storage of electricity in large quantities is limited. The major drawback of all these renewable power generation systems is the inconsistency in their output caused by the variation of their input sources such as solar intensity or wind velocity. Most of the reference papers identified that higher PV penetration impacts into LV distribution systems are over-voltage, under-voltage, and reverse power flow.

An experimental analysis was conducted by Mehdi Zeraati and al.[21] which is shown in figure 3(a) displays a radial distribution feeder with two buses. Bus-2 contains a PV panel, a battery energy storage system (BES), and a residential load. The feeder's equivalent circuit is depicted in Fig. 3(b). The load connected to the PCC (point of common coupling) and the PV's net power injection are both represented as current sources in the equivalent circuit.

Table 1. PV Power generation during variable weather conditions in a 10kWp power plant

Time(hrs)	Power generation (kW)		
	15-04-2022	12-05-2022	17-05-2022
7:00 AM	0.45	0.39	0.3
8:00 AM	2.2	1.62	0.6
9:00 AM	4.73	3	5.86
10:00 AM	6.31	5.43	0.36
11:00 AM	7.45	6.76	1.47
12:00 PM	7.51	7.28	4.73
1:00 PM	7.48	2.04	5.11
2:00 PM	7.01	5.77	6.01
3:00 PM	6	6.12	5.98
4:00 PM	4.25	3.28	0.45
5:00 PM	2.2	1.82	2.51
6:00 PM	0.3	0.4	0.47
6.40 PM	0	0	0
7:00 AM	0.45	0.39	0.3

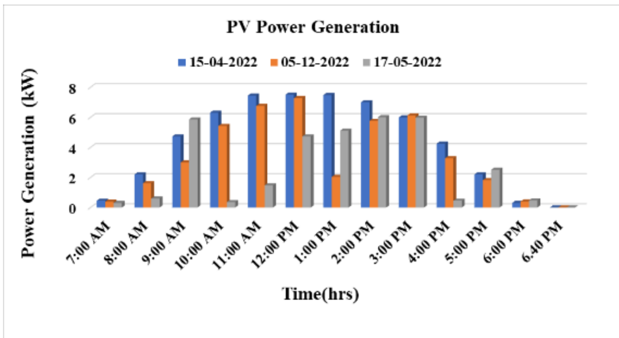

Fig. 2. Change in PV output power of 10kWp power plant during variable weather conditions.

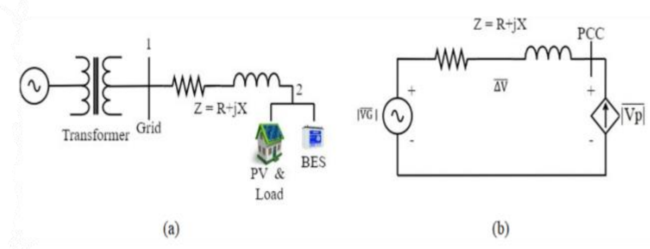

Fig. 3. (a) Radial distribution feeder; (b) The equivalent circuit

The voltage at PCC, $\overline{Vp} = \overline{|Vp|}\angle 0^0$

$\bar{Z}$ is the impedance of feeder between PCC and distribution transformer ($\bar{Z}$ = R + jX)

$\overline{VG}$ is the bus one voltage

Voltage deviation in the feeder due to injection of current ($\overline{In}$) at bus-n can be represented as,

$$\overline{\Delta V}=\bar{Z}.\overline{Ip}=(R+jX).\overline{Ip} \quad (1)$$

$\overline{Ip}$ is find out by complex power ($\overline{Sp}$) in bus-p, $\overline{Sp} = P_p - j\, Q_p$

$$\therefore \overline{Ip}=\left(\frac{\overline{Sp}}{\overline{Vp}}\right)^*=\left(\frac{Pp}{\overline{Vp}} - j\frac{Qp}{\overline{Vp}}\right) \quad (2)$$

Substitute equation (2) in (1)

$$\overline{\Delta V}=(R+jX).\left(\frac{Pp}{\overline{Vp}} - j\frac{Qp}{\overline{Vp}}\right)=\left(\frac{R.Pp+X.Qp}{|Vp|}\right)+\left(\frac{X.Pp-R.Qp}{|Vp|}\right) \quad (3)$$

From equation (3) $\overline{\Delta V}$ has two components,

$$\Delta Vd = \left(\frac{R.Pp+X.Qp}{|Vp|}\right) \quad \text{and} \quad \Delta Vq = \left(\frac{X.Pp-R.Qp}{|Vp|}\right)$$

$$\therefore |\overline{VG}|=\sqrt{(|\overline{Vp}| - \Delta Vd)^2 + (Vq)^2} \quad (4)$$

Vq is very small as compared to $(|\overline{Vp}| - \Delta Vd)$

$$\therefore |\overline{VG}| = \overline{|Vp|} - \Delta Vd$$

$$\Rightarrow \overline{|Vp|} = |\overline{VG}| + \Delta Vd \quad (5)$$

ΔVd can be approximated by substituting $\overline{|Vp|}$ by $|\overline{VG}|$

$$\therefore \Delta Vd \approx \left(\frac{R.Pp+X.Qp}{|\overline{VG}|}\right) \quad (6)$$

$$\text{Finally, } \overline{|Vp|} = |\overline{VG}| + \left(\frac{R.Pp+X.Qp}{|\overline{VG}|}\right) \quad (7)$$

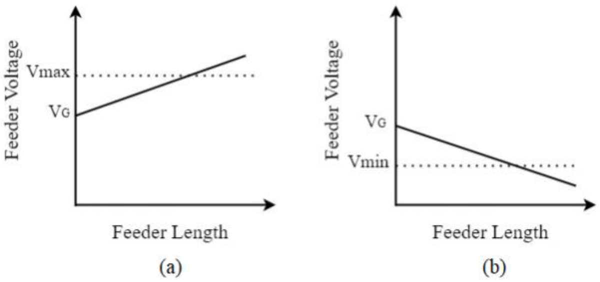

Fig. 4. (a) Voltage rise; and (b) Voltage drop

This equation discloses that instability in power generation and consumption are the cause of over-voltage and under-voltage [21]. The under-voltage is determined by active and reactive power flows as well as the R/X ratio, according to equation (3). When the active power injected (Pp) by the solar PV is positive (i.e., power generated by the solar PV is greater than the load consumption), as illustrated in Fig. 4(a), the voltage at the feeder will rise. In contrast, when load consumption exceeds PV power generation (i.e.Pp is negative) [21], as seen in Fig. 4(b), the feeder voltage would fall.

Reverse power flow on a distribution system may happen during higher PV system generation with lightly loaded conditions. In response to these, voltage regulators and the protection system will both experience serious issues. Sometimes the voltage regulators are unidirectional and not intended to carry out reverse power flow and if the voltage regulator is a bidirectional one, then it is necessary to modify the regulator control which carries the reverse power flow [21]. An increase in solar PV penetration will also increase the amount of fault current in power system especially during faulty conditions. According to std IEEE 1547, for hundred percent of PV penetration will contribute 7% of fault current. So, it is essential to check whether the protection device connected to the power system should not exceed its interrupting rate. Accurate fault detection and immediate isolation are a very necessary things to protect the electrical equipment in the power system. Nowadays, the majority of distribution systems use over current relays to locate faults, and the fault is isolated using circuit breakers [4].

3. Mitigation Techniques

Renewable energy generation in microgrids and distribution networks nowadays operates up to a voltage level of 33kV. Under varying weather conditions, such renewable and distributed sources have highly inconsistent power production and many spontaneous disturbances to the system's operation. Voltage fluctuation is one of the most detrimental effects of increasing PV penetration. Figure 5 shows the classification scheme of mitigation techniques for voltage impacts due to higher PV penetration on the distribution system. The mitigation techniques can be mainly classified into two, which are conventional and emerging mitigation techniques.

3.1. Conventional Techniques

The conventional mitigation techniques for higher penetrations of PV are reconductoring, on-load tap changer,

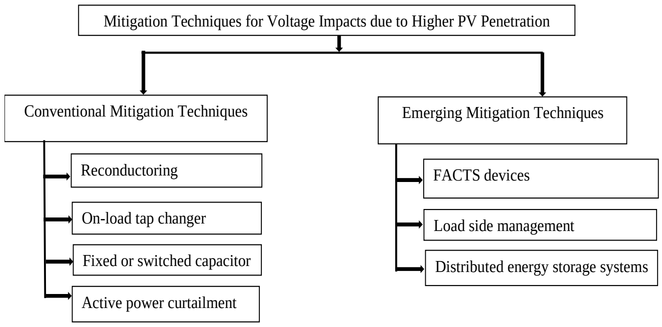

Fig. 5. Classification scheme of mitigation techniques for voltage impacts due to higher PV penetration

fixed or switched capacitors, and active power curtailment. Apart from these conventional techniques, some new emerging mitigation techniques comprise VAR control of PV inverter, distributed energy storage systems, coordinated control between utility equipment and PV inverter, dynamic voltage restorer, distributed static compensator, and unified power flow controller [22]-[24].

3.1.1 Reconductoring

If the feeder's cross-sectional area is bigger, its impedances become very low. This will cause a reduction in the voltage drop along the feeder. The effectiveness of this method can be verified by a stochastic investigation of the network with two different LV feeders having different cross-sectional areas. Results show that voltage unbalance was improved for the feeder having a greater cross-sectional area [26]-[27]. So, reconductoring is an efficient technique for compensation of voltage unbalance. But higher cost is the main disadvantage of this technique.

3.1.2 On-Load Tap Changer (OLTC)

On-load tap changer (OLTC) is one of the efficient conventional techniques to reduce voltage unbalance in LV distribution system [22]-[25], [27]-[28]. Transformers can regulate the secondary winding voltage by adjusting their tap position. The taping of OLTC can be done in two ways, mechanical tap changing (MTC) and electronic tap changing (ETC). Electronic tap changing is better than MTC, because MTC requires more uptime to adjust system voltages and has higher maintenance and service costs. By replacing the MTC mechanism with a power electronic switch, ETC can achieve faster response and reduced maintenance costs. But the major disadvantages of this technique are frequent tap changing of OLTC may cause arc generation, so it needs information and communication technology (ICT); therefore, they have a higher cost. Recent research shows that on-load tap changer (OLTC) control was more efficient than reactive power control. The coordinated control strategy for higher PV penetration scenarios was more beneficial [29], [31], [36]. The authors Xiaohu Liu, Andreas Aichhorn, Liming Liu, and Hui Li [36] proposed a technique that synchronizes various stratagems to improve performance and system efficiency. This paper summarized that to reduce the effects of overvoltage (SVR) in LV distribution networks brought on by a higher penetration rate of PV systems, a distributed energy storage system (ESS) comprising a conventional voltage regulator, an on-load tap-changer transformer (OLTC), and a step voltage regulator can be used. When PV penetration is high, the main goals of this coordinated control are to lower the tap-changer transformer's working load, the distribution grid's peak load, and the power losses in the transmission and distribution feeders.

3.1.3 Fixed or Switched Capacitor

One of the innovative mitigation strategies to identify the issue of voltage regulation in LV distribution grids during increased PV penetration is reactive power control of PV inverters. Houman Pezeshki, Ali Arefi, Gerard Ledwich, and Peter Wolfs [32] described that he load reactive power need can be satisfied by making adjustments in the substation or by adding capacitor banks next to the feeder. Mainly, there are two types of capacitor banks: fixed (permanently connected) and switched (connected when needed). This lowers both the voltage drops across the feeder and the overall current flowing through it. Fixed capacitor power factor correction is not a feasible method for voltage regulation because PV power and load requirements change. This may lead to overcompensation of the feeder and cause overvoltage on the feeder. The overvoltage due to overcompensation may be reduced by the additional voltage regulator in the substation. Capacitor banks are not a practical option for voltage regulation in LV power distribution systems as a result of these shortcomings. Furthermore, strong currents must flow in distribution feeders for reactive power consumption, which might result in extra losses.

3.1.4 Active Power Curtailment

Active power curtailment techniques in PV systems are feasibly applicable to overvoltage conditions [22]-[27]. When the overvoltage occurs, the PV controller will stop the MPPT tracking algorithm and starts limiting the active power to avoid reverse power flow. This technology is based on the control of real output power using a volt-watt curve. Knowing the maximum PV output power under different atmospheric conditions is crucial for better curtailing of the PV output. This becomes difficult when solar irradiations vary very quickly. This method is only suitable for over-voltage issues and not viable for the under-voltage problem. The power curtailment stratagems can be categorized into two, which are static and dynamic power curtailment techniques. Regarding the static power curtailment technique explained by Wesam Rohouma, Robert S. Balog, Miroslav M. Begovic, Aaqib Ahmad Peerzada [35], we can limit the PV output at a specific point by controlling the grid inverter. The technique of dynamic power curtailment allows the amount of PV power regulated along the feeder to be regulated at the same level or varied by means of the voltage droop method. The main disadvantage is that, at week nodes in the feeder, the customer has to reduce PV outputs to improve the grid voltage.

3.2 Emerging Mitigation Techniques

The emerging mitigation techniques include, FACT devices, load side management and distributed energy storage systems [22]-[27].

3.2.1 FACTS Devices

Reactive power compensation using fixed capacitors is not a feasible solution for voltage fluctuations as it is very difficult to provide an accurate amount of reactive power with variable PV power and loads. FACTS (Flexible AC Transmission System) devices can be used to overcome this issues [32]. They provide fast response, increase utilization of lowest cost generation, flexible operation, etc. FACTS devices can generally be divided into the following categories based on the connection: Series controllers, Shunt controllers, combined series-series controllers combined series-shunt controllers. FACTS devices comprise D-STATCOM, Static Var Compensator (SVC), Thyristor-Controlled Series Capacitor (TCSC), Static Synchronous Series Compensator (SSSC), Unified Power Flow Controller (UPFC), and Synchronous Condenser (SC). Wesam Rohouma, Morcos Metry, and Robert S. Balog were investigates a different matrix converter-based distribution static synchronous compensator (D-STATCOM) for distributed low-voltage networks with large PV penetration. This technology can increase service life by employing inductors as an energy storage medium [33] – [35]. But FACT device approach's primary flaw is that, it is much more expensive due to the large DC bus capacitors and high-power switches. [37]-[45].

3.2.2 Load Side Management

Jiefeng Hu, Zilin Li, Jianguo Zhu, and Josep M. Guerrero [22] described that load-side management is the management of loads by the distribution system operator (DNO) to promote power flow and control energy use when PV generation is at its highest. Direct load control, peak shaving, peak shifting, and other load management systems can be used to manage the load. Shih-Chieh Hsieh [41] shows that the use of direct centralized control of electric water heaters (EWH) minimized the import and export of peak loads in the control area. Demand response (DR) technology was proposed by the authors Qi Wang, Quan Yuan, Yi Tang, Zijun Yang, and Chen Li [50] to address the timing imbalance between load demand and generation. The net power that the PV inverter delivers to the grid decreases as local usage rises. As a result, it may result in a larger overall PV installation on the grid. Enxin Yao and al. [51] explained that the benefits of this technology are reduced electricity bills, improved cost efficiency, and reduced voltage rise by making the load side more flexible. However, the drawback of this method is that the load side can be controlled and reshaped will makes it unreliable.

3.2.3 Distributed Energy Storage Systems

One of the viable and constructive methods to manage the system voltage instability is by supporting the sudden change in energy requirement using distributed energy storage systems. When solar energy production is at its highest, the energy storage system will take in the surplus power and send it to the utility grid when utility demand is at its highest. So, we can limit the voltage at PCC.

When an electric vehicle uses grid electricity and a solar power plant injects power into the grid, the power flow in the utility grid is shown in Fig. 6. A field study was conducted on the charging process of the TATA Nexon EV car having a 30kWh power bank from a 10kWp PV plant at Umayanallor, Kollam on 21/04/2022, which is shown in Fig.7 in a detailed manner.

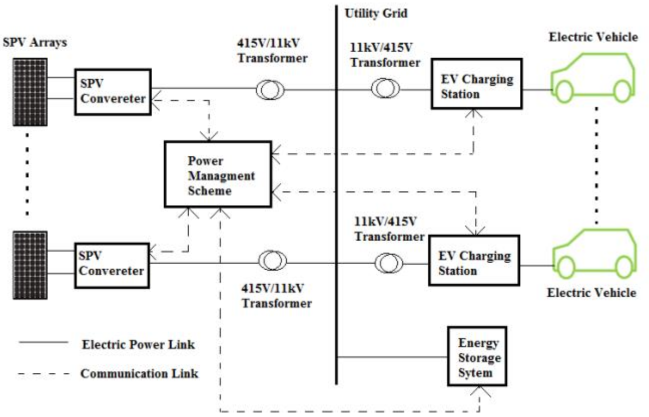

Fig. 6. Distribution system with an energy storage system for the mitigation of voltage instability

The study was conducted at around 4.30 in the evening. Since it was off-peak time, the power generation from the solar power plant was around 2.5 kWp. The solar power plant was connected to the 'Y' phase with a line voltage of 220.17 volts. At the same time, The TATA Nexon Electric car was connected to the same phase for charging and it was found that the voltage drops to 212.59 volts. For collecting further details about grid stability, the solar power plant was switched off, and noted that the line voltage further drops to 198.27 volts. From these findings, we could note that the stability of the grid is highly affected due to the penetration of electric vehicles and solar power plants. In order to keep the system stable, it is necessary to control the flow of power via the grid [52]-[54].

Fig. 7. (a) Charging process of the TATA Nexon EV car; (b) KSEB line voltage with PV integration; (c) Line voltage when EV connected to the same phase for charging; (c) Voltage drop during charging; (d) Inverter display with alarm indication.

A Comparison of merits and demerits between various overvoltage mitigation techniques under the influence of higher PV penetration is summarized in Table 2.

Table 2. Comparison between various overvoltage mitigation techniques for higher PV penetration.

Methods	Merits	Demerits
Reconductoring	A very effective technique for reducing the voltage drop.	Higher cost.
On-load tap changer	Fast response and reduced maintenance costs, and more robust.	Frequent tap changing of OLTC may cause arc generation, so it needs information and communication technology (ICT); therefore, they have a higher cost.
Fixed or switched capacitor	Reduce the feeder's overall current flow to prevent feeder voltage drop	The fixed capacitor may lead to overcompensation of the feeder and cause overvoltage on the feeder.
Active power curtailment	Cheap and easy to implement	Only useful for overvoltage problems and adversely affects PV revenues.
FACTS devices	Provide power factor and power transfer capability improvement. Fast response to regulate voltage variation.	Large capacity dc bus capacitors and high-power switches make them significantly more expensive.
Load side management	Decreases the electricity bills, cost-effective and will limit the voltage rise by enhancing the flexibility of the load side. Provide reduction in Energy-loss.	It might be controlled and reshape the load side that making it unreliable.
Distributed energy storage systems	Much more effective and reduced energy loss.	Expensive.

Therefore, Mehdi Zeraati and al. [21] concluded that production and consumption should be monitored and controlled with the help of a suitable power management scheme through the penetration of distributed energy storage system. Batteries, thermal (heat) energy storage, thermochemical energy storage, magnetic energy storage, chemical energy storage, hydrogen energy storage, compressed air energy storage, and pumped energy storage are all possible forms of energy storage. The output power of energy storage systems was managed using several control mechanisms. Droop control is a decentralized power-sharing technique that is frequently employed; however, it has a delayed dynamic reaction. An advanced model predictive power control technique was summarized by the authors T. Morstyn, B. Hredzak, R. P. Aguilera, and V. G. Agelidis [55] to smooth out photovoltaic (PV) output and stable DC bus voltage while taking battery limits into account. But battery energy storage is still highly expensive. Nikhila S, and P Kanakasabapathy [56] also concluded that the voltage stabilization of the distribution network can be further enhanced by allowing penetration of properly distributed energy storage systems.

4. Conclusion

By the end of 2050, 62 % of the energy generation will be expected from renewable sources. But one of the major challenging factors in power electric grid is the increase in integration of renewable energy sources. This is because under changing weather conditions, such renewable and distributed power sources produce very inconsistent power generation and there are many spontaneous interruptions in the operation of the system such as instability in power balancing, over-voltage, under-voltage, etc. Recent developments in the field of electric vehicles (EVs) and their use of grid power also contribute to grid disturbances. Similar to power grids, microgrids also need to maintain an energy balance between supply and consumption at all times to avoid the chance of blackouts.

This study conducted a thorough literature analysis on the various impacts of higher PV penetration on the distribution system voltage. Similarly reviewed the existing and emerging mitigation techniques with their merits and demerits. In the field study, discussed in this paper, the survey information gave an idea of PV power generation during variable weather conditions, which conclusively show that SPV power generation systems unpredictability in their output, which is brought on by the changes in their input sources, such as solar intensity. The same 10 kWp PV plant was also used for a study on charging process of EV with 30kWh power bank. These studies demonstrate that the dependability of gird on SPV and high penetration of EVs are negatively impacted by their frequent usage. In this sense, it is necessary to regulate the grid power flow between SPV and EVs to maintain the system stability. By this way voltage stabilization can be improved with proper energy management and a coordinated control strategy in the future.

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