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Enhancing Low Voltage Ride-Through Resilience using Empowering Solar Energy Strategies

Jenitha J[1], Sumathi S[2]

[1]Research Scholar, Department of Electrical and Electronics Engineering, Adhiyamaan College of Engineering, Hosur, Tamilnadu, India

[2]Professor and Head, Department of Electronics and Communication Engineering, Adhiyamaan College of Engineering, Hosur, Tamilnadu, India

Email: [1]jenithaantora@gmail.com, [2]sumathi_2005@rediffmail.com

Abstract

The rapid advancement of Low Voltage Ride-Through (LVRT) technology has been highlighted by the exponential rise of photovoltaic (PV) generation systems. An extensive analysis of LVRT methods specifically designed for PV generating systems is presented in this research. Important topics like main causes, current control schemes, power balance and overall solutions are the main focus of the review. Moreover, it provides comprehensive insights and elaborates on integrated solutions intended for large-scale PV systems. The objective of this research is to improve the resilience and reliability of renewable energy sources, especially solar photovoltaic systems, against grid disruptions and voltage changes by investigating LVRT approaches in solar power systems. Enhancing the integration of solar power systems into current electrical grids, reducing downtime, and optimizing system performance are the objectives in order to accelerate the shift to a more resilient and sustainable energy infrastructure.

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1. Introduction

The development of converters that smoothly integrate with the grid is currently receiving a lot of attention worldwide in an effort to improve performance in both normal operating settings and fault scenarios. In the field of interface conversion for renewable energy, this tendency is especially noticeable. To fulfill the demand for LVRT capabilities in wind turbine systems, for instance, many nations are currently supporting and revising LVRT regulations for PV generation systems. The penetration and capacity of PV systems are growing, and these requirements are changing with them.

For photovoltaic (PV) systems, the major goals of LVRT requirements are to guarantee that the inverter stays connected to the grid without creating overcurrent problems and to enable reactive energy to help the grid recover during breakdowns. These standards have gained broad acceptance because they have demonstrated major advantages for voltage restoration and frequency stability [1, 2]. It is important to note, nevertheless, that not much research has been done on how they affect the short-term stability of highly penetrated grids [3]. Although the necessity of enforcing LVRT laws is widely acknowledged, several nations have established differing norms and requirements. In general, systems like solar PV generators are required by the grid-code rules to stay connected to the grid and provide reactive current to the grid during a designated period of time whenever the voltage lowers. LVRTs, are required in order to prevent blackouts in the system. Countries' needs for reactive power assistance differ greatly from one another, depending on variables such the maximum reactive power demand and the ratio of reactive power to voltage drop depth. Apart from these basic standards, individual restrictions vary in reference voltages, recovery slope, reaction time, and other aspects. Furthermore, optimizing LVRT techniques for PV systems remains a substantial problem, despite extensive research on LVRT strategies for wind power systems [4, 5]. The difficulty arises from the basic distinctions between wind farms and PV systems, which lead to distinct features in the LVRT methodology of each system. In particular, as PV systems frequently control AC voltage inputs, back-to-back converters are commonly used for AC-DC-AC conversion. Whether wind power is generated entirely or in part, these converters are made to handle it. On the other hand, PV generation systems typically use DC energy inputs and use single- or two-stage full-scale DC-AC inverters as interface converters.

Furthermore, unlike PV systems, wind power interfacing converters need to take into consideration the operational characteristics of wind rotor generators, which include elements like excitation and torque. This necessitates the use of different control algorithms. Furthermore, since PV systems do not have the revolving mechanical parts like wind turbines do, LVRT approaches do not require the consideration of inertia. This absence makes it possible to concentrate on elements like recovery during LVRT events, current reactive support, and detection speed. Unexpected disruptions can cause the grid to undergo major disruptions, which can then cause wind turbines to disconnect and result in instability. Grid codes have instituted particular measures to reduce these dangers. When problems occur, converter ratings may be exceeded by both rotor and stator currents, causing wind turbines to cut off from the grid. Therefore, grid codes require fault ride-through (FRT) capacity in order to reduce large power losses during failures, preserve uninterrupted service, reduce re-synchronization problems, and aid in grid recovery. This study categorizes the technical challenges related to LVRT in PV systems into four main areas: power balance, fault detection, current regulation, and other pertinent aspects. Accordingly, the review material is structured into multiple sections addressing these specific issues and their corresponding solutions. Respecting certain standards is necessary for an efficient LVRT control plan. First and foremost, it's critical to promptly identify voltage dips and to fully utilize the inverter's power capability. Furthermore, the maximum AC output current, maximum AC output voltage, and maximum DC-link voltage are crucial factors in guaranteeing the safety of the inverter. Therefore, it is imperative that any voltage support measures guarantee that these parameters stay within secure operational bounds. Furthermore, adherence to grid standards is essential. These rules include specifications about minimum injected current values and maximum voltage levels at the Point of Common Coupling (PCC). It is also beneficial for pursuing secondary objectives such as reducing the harmonic content of injected currents and attenuating voltage oscillations on the DC-link. Because flexible current control algorithms may handle several control objectives at once, they have gained interest as practical choices for implementing voltage support.

It's critical to understand how these problems are interconnected, since doing so may lead to more comprehensive solutions than addressing individual problems separately. Technical division and categorization try to give insight into the issue as a whole, rather than offering discrete answers [6, 7]. In recent times, there has been a notable surge in the integration of PV systems into power networks due to the worldwide quest for sustainable energy sources. But there are technological obstacles to this integration, especially when it comes to keeping the grid stable in the event of failures or voltage spikes. One major problem is implementing LVRT capabilities in PV systems. PV systems must continue to function within predetermined parameters and stay connected to the grid even in the event of a voltage drop or sag, which is usually brought on by abrupt changes in load or grid faults. To achieve LVRT, a number of technological obstacles must be overcome, including the creation of hardware and control algorithms that can quickly modify power output, support voltage, and inject reactive power. In recent literature, various intelligent algorithms have arisen to address constraints encountered in standard LVRT techniques. For instance, in [8] a fuzzy-based LVRT control method is proposed that delivers smoother output with lower ripple; however, adjustments are necessary to properly regulate the DC link voltage. In [9], a probabilistic wavelet fuzzy-based neural network controller is introduced to manage reactive power during grid breakdowns. Control systems in a variety of power generation systems, especially in renewable energy sources like wind turbines and PV systems, depend heavily on LVRT approaches. By allowing generators to stay connected to the grid in the event of faults or disturbances, these solutions maintain the stability and dependability of the grid. Because LVRT approaches can lessen the effect of voltage dips, sags, or interruptions on power generation systems' operations, they are very important. Synchronous generators in conventional power plants are naturally capable of withstanding voltage disturbances without cutting off from the grid thanks to their innate LVRT capabilities. This intrinsic ability is usually absent from renewable energy sources, including photovoltaic systems and wind turbines, because they depend on power electronic converters. The increasing integration of renewable energy sources into the grid is reflected in the widespread usage of LVRT techniques in control systems. Maintaining the stability and dependability of the grid in the face of intermittent renewable power becomes critical as governments and utilities around the world place a higher priority on the switch to clean energy sources. By improving the grid integration capabilities of renewable energy systems and reducing their influence on grid operations, LVRT approaches are essential to reaching this goal. Consequently, in order to improve LVRT approaches' efficacy and suitability for a variety of grid scenarios, research and development efforts are still concentrated on their advancement. LVRT approaches are essential for solar systems because they improve grid stability and dependability by maintaining a continuous grid connection even in the event of voltage fluctuations or breakdowns. LVRT facilitates increased levels of renewable energy penetration while enabling the seamless integration of solar energy into the electrical grid through fault management, grid integration, and regulatory compliance. All things considered, LVRT is essential to maintaining the dependability and robustness of solar power systems and advancing the cause of sustainable energy. Advanced control algorithms and protective features in PV inverters are used by LVRT methods specifically designed for PV systems to stabilize grid voltage during disturbances. Grid support equipment like STATCOMs can also improve resilience. The PV inverter maintains continuous operation by adjusting reactive power output to regulate grid voltage during a fault. As an example, imagine a situation in which a grid malfunction causes a sudden decrease in voltage in a photovoltaic system. With LVRT capabilities, the PV inverter recognizes the voltage disturbance and reacts by supplying reactive power to the grid to maintain voltage levels. This process aids in grid voltage stabilization, allowing the PV system to withstand the disruption and continue operating without interruption. LVRT techniques designed for PV generating systems include a range of important metrics and parameters, each with advantages and disadvantages of their own. The response time, which gauges how fast the PV inverter recognizes and reacts to grid disruptions, is one important characteristic. Rapid response times guarantee grid stability by enabling quick voltage support, but they may also necessitate more sophisticated hardware and control algorithms, which could raise system costs. The PV inverter's reactive power capability is an additional metric that establishes its capacity to sustain grid voltage in the event of a fault. System resilience is increased by high reactive power capability, which enables efficient grid support and voltage regulation. Reactive power injection overdoing, however, can cause overvoltage problems and degrade system performance. Furthermore, the PV inverter's voltage and frequency support range is crucial. Inverters are included into LVRT architecture in solar systems. Inverters transform DC power from solar panels into AC power for grid connection as shown in figure 1.1.

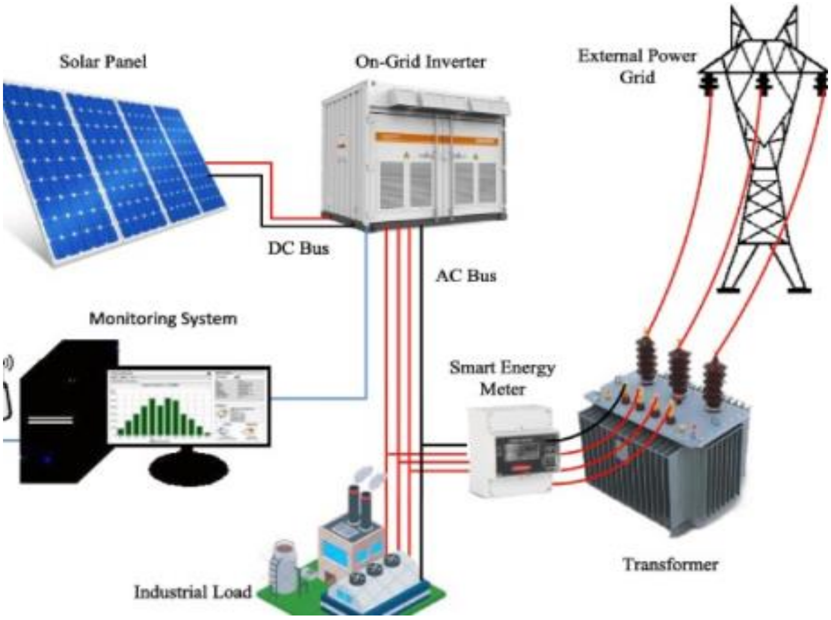

Figure. 1.1 Architecture of LVRT

Inverters are essential for maintaining system stability during voltage disruptions like grid breakdowns. Difficulties include limited inverter capacity and variations in voltage. Advanced control algorithms, energy storage integration, and inverter fault ride-through capabilities are some strategies for improving LVRT resilience. Greater flexibility in stabilizing grid parameters is made possible by a wider support range, yet ensuring grid codes and standards compliance may call for more complex control procedures. Moreover, system performance can be greatly impacted by how well LVRT techniques are coordinated with other grid support devices, such as energy storage systems or STATCOMs. These devices may add complexity and expense, but they also improve grid integration and system resilience. Grid stability during voltage disturbances is the main goal of LVRT approaches. Response time, efficacy during transient faults, and impact on power quality are important criteria. System flexibility and reliability are given priority in other resilience strategies, such as energy storage integration and sophisticated control algorithms. Compared to energy storage alternatives, LVRT systems may have slower response times, even though they excel in grid stability. Energy storage options, however, could be more expensive and require more upkeep. Solar systems operate at their most resilient when these elements are balanced.

2. Causes of LVRT events in PV systems can be caused by a number of factors

2.1 Grid Faults: Voltage levels can fluctuate quickly as a result of grid faults such short circuits or line disturbances. Such occurrences may cause the voltage at the point of common coupling (PCC) to fall below permissible thresholds, necessitating the use of LVRT in PV systems.

2.2 Voltage Dips and Sags: Sudden variations in load demand or distribution network problems can cause voltage dips and sags. In order to preserve grid stability, PV systems must have LVRT capabilities since these transient voltage fluctuations have the potential to momentarily lower the grid voltage below predetermined levels.

2.3 Cloud Passing: Variations in solar irradiance brought on by passing clouds may cause output from photovoltaic systems to fluctuate. Variations in solar power generation rate can have an impact on the voltage at the grid connection point, necessitating the use of LVRT capabilities to guarantee uninterrupted operation.

2.4 Reactive Power Imbalance: Voltage stability may be impacted by reactive power imbalance in the grid. Reactive power is usually added to the grid by PV systems in order to maintain voltage levels. But maintaining the required reactive power balance during grid failures or disruptions becomes essential to averting voltage collapse, underscoring the need of LVRT features. To address these issues and enable PV systems to dynamically alter their operation in response to grid conditions, assuring uninterrupted energy supply while maintaining grid stability, strong control algorithms and hardware solutions are needed [8,9].

3. Current management schemes

To allow LVRT capabilities in PV systems, various current management schemes are used:

3.1 Voltage Control: In order to adjust the output voltage in response to variations in the grid voltage, PV inverters can be equipped with voltage control algorithms. The inverter supports grid stability by adjusting its operating point during LVRT events to keep the voltage within allowable bounds.

3.2 Frequency Control: Certain PV inverters use frequency control technologies in addition to voltage regulation to adapt to variations in grid frequency. These inverters aid in grid stabilization during LVRT occurrences by modifying the output frequency in tandem with voltage regulation.

3.3 Active Power Curtailment: PV inverters have the ability to momentarily lower their output of active power in order to lessen the effects of voltage dips or malfunctions. In order to maintain the system's safe operating limitations during LVRT occurrences, active power curtailment solutions dynamically modify the power generation to meet the available grid capacity.

3.4 Reactive Power Injection: Grid stability and voltage support depend on reactive power injection. When voltage dips, PV inverters with LVRT capabilities can help restore and sustain voltage levels within an acceptable range by injecting reactive power into the grid.

3.5 Grid-Forming Inverters: These inverters can set the voltage and frequency of the grid and can function independently. By actively managing both voltage and frequency, these inverters can sustain the grid even during LVRT occurrences, improving the stability and resilience of the grid. PV systems can contribute to grid stability and reliability even under difficult operating situations by integrating these control algorithms into PV inverters and effectively achieving LVRT capability. To improve the efficiency and performance of LVRT control techniques in PV systems, more research and development in this area is necessary [10].

4. Power balance Control

Power balancing control for LVRT is an essential component of electrical grid stability and dependability, especially in situations where integrated renewable energy sources such as solar and wind power are used. Grid-tied inverters need LVRT in order to stay online in the event of brief voltage fluctuations, like dips or sags.

The following is how LVRT power balancing control can be put into practice:

4.1. Monitoring Grid Voltage: The grid voltage is continuously monitored by the inverter. The inverter enters LVRT mode in response to a disturbance, such as a voltage drop below a predetermined threshold.

4.2. Power Curtailment: The inverter lowers its power output in LVRT mode in order to keep the lower grid voltage in balance. In order to avoid overloading the grid during the disturbance, this reduction is often proportionate to the severity of the voltage dip.

4.3. Voltage Support: By introducing reactive power into the grid during LVRT occurrences, certain inverters can offer voltage support in addition to lowering power output. This enhances the grid voltage's ability to recover from disturbances and stabilizes it.

4.4. Quick Response: In order to promptly respond to voltage disruptions, power balance control for LVRT needs quick response times. Usually, this calls for high-speed communication between the inverter and grid as well as complex control algorithms.

4.5. Grid Code Compliance: Specific grid codes that outline the standards for LVRT performance must be followed by grid-tied inverters in certain jurisdictions. These specifications must be met by power balance control algorithms in order to guarantee grid stability and dependability.

4.6. Testing and Certification: To ensure their operation under varied grid situations, inverters with LVRT capabilities must go through extensive testing and certification before being deployed. To verify adherence to regulatory standards, this frequently entails both laboratory and field testing.

In order to successfully integrate renewable energy sources into the grid and preserve grid stability and reliability even during voltage disruptions, it is imperative to implement an efficient power balancing management for LVRT.

5. Overall solution for LVRT

An entire LVRT solution incorporates several hardware and software components to maintain grid-tied inverters operational and linked to the grid during voltage variations. An extensive overview of one such solution is provided here [11, 12]:

5.1 Design of Grid-Tied Inverters: Inverters meant for grid-tied applications must have had LVRT capabilities from the start. Hardware features in this category include strong power electronics, fast-switching components, and voltage and current sensors for real-time monitoring.

5.2 Voltage and Frequency Monitoring: To identify anomalies like voltage sags or frequency fluctuations, it is imperative to maintain constant observation of the grid's voltage and frequency. Accurate sensors that measure these factors ought to be installed in inverters.

5.3 Control Algorithms: To control the inverter's reaction during LVRT events, complex control algorithms are needed. To preserve grid stability, these algorithms should be able to swiftly modify the reactive power injection and power output of the inverter.

5.4 Power Curtailment: The inverter should reduce its power output during a voltage dip to prevent the grid from overloading. Power curtailment strategies include things like lowering active power output, changing voltage levels, and limiting current injection.

5.5 Reactive Power Injection: Inverters can mitigate active power production during low-voltage reactive transmission events (LVRTs) by providing reactive power as well. Reactive power injection improves grid stability while maintaining voltage levels.

5.6 Advanced Voltage Support Features: A few inverters come equipped with features like voltage control and regulation. These features support LVRT performance and aid in maintaining grid voltage under variable operating situations.

5.7 Interfaces for communication: In order to coordinate their response to LVRT events, inverters need to communicate with grid operators and other grid-connected devices. Real-time coordination and control are facilitated by communication interfaces like grid management protocols or SCADA (Supervisory Control and Data Acquisition) systems.

5.8 Grid Code Compliance: The applicable grid codes and standards that specify LVRT requirements must be followed by inverters. Compliance testing verifies that inverters fulfill performance standards set by industry standards organizations or regulatory bodies.

Grid integration concerns, inverter constraints, and voltage fluctuations are the main implementation challenges with LVRT. Advanced inverter control algorithms, energy storage system integration, and inverter fault ride-through capabilities are some of the suggested solutions.

Table 1.1 Different Scenarios That May Occur in Power Systems.

Voltage Dip Condition	**Fault Detection**	**Grid Synchronization**	**Current Management**	**DC-Link Voltage Control**
Balanced Voltage Sag	Relay Protection, Voltage Monitoring Systems	Grid-Supporting Devices (STATCOM, SVC)	Current Limiting, Fault Ride-Through (FRT)	DC-Link Capacitors, Voltage Regulation
Unbalanced Voltage Sag	Sequence Component Analysis, Monitoring Systems	Phase-Locked Loops (PLL)	Current Balancing, Negative Sequence Comp.	DC-Link Voltage Ripple Reduction
Shallow Voltage Dip	Voltage thresholds are usually used in fault detection. - Phase-locked loop (PLL) techniques may be used for grid synchronization.	The slight dip may mean that the current limiting methods are not required.		- The shallow dip has little effect on DC-link voltage regulation.
Moderate Voltage Dip	Detection of faults may use thresholds for both voltage and frequency. - Complex grid synchronization methods, such PLL with frequency estimation or synchronization to the	Limiting fault currents or momentarily reducing power output are two examples of current management techniques.		Control of DC-link voltage may be important to maintain stable functioning during the drop.

	fundamental frequency		
Deep Voltage Dip	A large voltage deviation makes fault detection more difficult. In order to synchronize to a severely distorted grid voltage, specific procedures can be needed for grid synchronization.	In order to minimize overcurrent conditions and safeguard equipment, current management becomes essential. Some strategies to consider are a major drop in power output or a temporary detachment from the grid.	For the system to remain stable and avoid overvoltage or under voltage situations, active regulation of the DC-link voltage becomes necessary.

Voltage waveform, frequency, and magnitude can all be monitored to detect voltage dip circumstances. Dips last milliseconds to seconds and vary in magnitude from 10% to 90% of the nominal voltage. Voltage magnitude, waveform analysis, and frequency monitoring are examples of parameters. Inverter shutdown, decreased power output, grid instability, and equipment damage are among the effects on LVRT. The goal of LVRT techniques designed for PV generating systems is to improve grid stability in the event of breakdowns or voltage dips. Ride-Through Time (RTT) and Voltage Dip Depth (VDD), which establish operating thresholds and system resilience, are important factors. Interoperability is ensured by adhering to grid codes, however doing so may raise expenses and complexity. Benefits include more integration of renewable energy sources and enhanced grid stability, although more system complexity and regulatory requirements provide difficulties. With careful evaluation of these factors, decisions may be made that optimize PV system design and operation for a consistent supply of renewable energy while balancing performance, cost, and compliance.

6. Future trends in LVRT requirements

In the future, LVRT requirements are expected to concentrate on several important areas as the integration of renewable energy sources grows and changes. These areas include [13]:

6.1 Stricter Requirements: As renewable energy sources become more prevalent, grid operators may set more stringent LVRT standards to maintain the stability and dependability of the system. This might entail stricter performance standards for grid-tied inverters and tighter limits for voltage and frequency during disruptions.

6.2 Dynamic Requirements: As grid circumstances and operating demands change, future LVRT requirements may also change more quickly. This can entail modifying LVRT thresholds and reaction parameters in real-time in response to variables including network topology, grid load, and generator mix.

6.3 Harmonization and Standardization: There will probably be ongoing efforts to standardize LVRT regulations among various jurisdictions and regions, which will make it easier to install grid-tied inverters in a variety of markets. Determining uniform performance indicators, testing protocols, and compliance standards for LVRT may be the main goals of standardization initiatives.

6.4 Integration with Grid Services: Inverters connected to the grid that possess LVRT capabilities have the potential to be utilized more frequently to offer grid support services that go beyond voltage ride-through. This could include auxiliary services that improve the grid's flexibility and resilience, like reactive power control, voltage support, and frequency regulation.

6.5 Improved Communication and Control: Upcoming LVRT regulations might place a strong emphasis on grid-tied inverters' increased capacity for communication and control. Standardized communication protocols, improved grid monitoring systems, and sophisticated control algorithms may be necessary to provide smooth coordination between grid operators and inverters.

6.6 Resilience to harsh Events: Future LVRT regulations may place a higher emphasis on the resilience of renewable energy systems due to the increasing frequency and intensity of harsh weather events and natural disasters. This can entail building grid infrastructure and inverters to endure harsh environments and bounce back swiftly from interruptions.

6.7 Grid-Forming Inverters: Future LVRT requirements may be impacted by the development of grid-forming inverters, which can operate in islanded mode and create independent microgrids. Inverters with grid-forming capabilities have the potential to significantly improve grid resilience and sustain vital loads in the event of prolonged power outages.

6.8 Advanced Testing and Certification: The testing and certification processes for grid-tied inverters may become more intricate and thorough as LVRT regulations change. Improved modeling studies, field testing procedures, and validation standards might all be part of this to guarantee dependable performance in a range of operational scenarios.

In general, it is anticipated that future developments in LVRT standards will mirror the dynamic environment of renewable energy integration, grid modernization initiatives, and the growing significance of grid resilience and dependability in the face of new difficulties.

7. Real world examples supporting the use of Low Voltage Ride-Through Techniques for Solar Power Systems

The following two case studies demonstrate how LVRT techniques are applied in solar power systems

7.1 Hawaii Case Study on Solar Energy Integration

Background: Because of its plentiful sunshine and government incentives, Hawaii has a high penetration rate for PV installations. The sporadic nature of solar energy, however, can make the grid less stable, particularly when there are faults or drops in voltage.

Implementation: To maintain grid stability during voltage dips, Hawaiian Electric Company (HECO) established LVRT standards for solar PV projects. This required adding cutting-edge inverters with LVRT capability to solar arrays located all across the islands [14].

Results: By allowing solar PV installations to withstand voltage dips without tripping offline, the LVRT capabilities helped to maintain grid stability.

7.2 Case Study on European Solar Integration

Background: The number of solar PV installations has increased quickly in a number of European nations, including Spain and Germany. Grid codes in these areas include requirements for solar inverters to have LVRT functionality in order to handle grid integration issues [15].

Implementation: In order to comply with grid rules, European solar PV developers and manufacturers have included LVRT capability into their inverters. To enable inverters to tolerate and ride through voltage dips, sophisticated control algorithms and hardware design are required.

Results: Solar PV systems in Europe have helped maintain grid stability during voltage dips and failures by applying LVRT techniques. Large-scale solar output has been easier to integrate into the grid as a result, helping to meet renewable energy targets and lessen dependency on fossil fuels.

8. Conclusions

Criteria for LVRT are essential for guaranteeing the stability and dependability of electrical grids, especially when it comes to the integration of renewable energy sources. LVRT capabilities are vital to the continued adoption of grid-tied inverters because they allow these systems to continue operating and staying connected to the grid even in the event of voltage fluctuations. Robust hardware and advanced control algorithms are essential for LVRT in order to efficiently manage the inverter's response to grid disturbances. In addition, compliance and interoperability across many countries and regions depend on adherence to regulatory standards and grid codes. More stringency, dynamic adaptation to shifting grid conditions, harmonization and standardization, integration with grid services, improved communication and control capabilities, resilience to extreme events, and sophisticated testing and certification processes are predicted to be the main focuses of future trends in LVRT requirements. The development and use of grid-tied inverters with strong LVRT capabilities can be encouraged by stakeholders by addressing these trends and obstacles. This will improve the electrical grids' resilience, flexibility, and stability as they transition to a more sustainable energy future.

References

[1] Marinopoulos, Antonios, Fabio Papandrea, Muhamad Reza, Staffan Norrga, Filippo Spertino, and Roberto Napoli. "Grid integration aspects of large solar PV installations: LVRT capability and reactive power/voltage support requirements." In 2011 IEEE Trondheim PowerTech, pp. 1-8. IEEE, 2011.

[2] Varma, Rajiv K., Shah Arifur Rahman, Vinay Sharma, and Tim Vanderheide. "Novel control of a PV solar system as STATCOM (PV-STATCOM) for preventing instability of induction motor load." In 2012 25th IEEE Canadian Conference on Electrical and Computer Engineering (CCECE), pp. 1-5. IEEE, 2012.

[3] Yagami, M., and J. Tamura. "Impact of high-penetration photovoltaic on synchronous generator stability." In 2012 XXth International Conference on Electrical Machines, pp. 2092-2097. IEEE, 2012.

[4] Ezzat, Marwa, Mohamed Benbouzid, S. M. Muyeen, and Lennart Harnefors. "Low-voltage ride-through techniques for DFIG-based wind turbines: state-of-the-art review and future trends." In IECON 2013-39th Annual Conference of the IEEE Industrial Electronics Society, pp. 7681-7686. IEEE, 2013.

[5] ardenas, Roberto, Rubén Peña, Salvador Alepuz, and Greg Asher. "Overview of control systems for the operation of DFIGs in wind energy applications." IEEE Transactions on Industrial Electronics 60, no. 7 (2013): 2776-2798.

[6] Liu, Yanan, and Lijun Tian. "Research on low voltage ride through technology of grid-connected photovoltaic system." In 2016 International Conference on Smart Grid and Clean Energy Technologies (ICSGCE), pp. 212-216. IEEE, 2016.

[7] Tian, Hao, Feng Gao, Cong Ma, Guoqing He, and Guanghui Li. "A review of low voltage ride-through techniques for photovoltaic generation systems." In 2014 IEEE Energy Conversion Congress and Exposition (ECCE), pp. 1566-1572. IEEE, 2014.

[8] He, Yufei, Minghao Wang, Youwei Jia, Jian Zhao, and Zhao Xu. "Low-voltage ride-through control for photovoltaic generation in the low-voltage distribution network." IET Renewable Power Generation 14, no. 14 (2020): 2727-2737.

[9] Ellis, Abraham, and Sigifredo Gonzalez. "Implementation of voltage and frequency ride-through requirements in distributed energy resources interconnection standards." (2014).

[10] Li, Jun, Dujiang Li, Lei Hong, Chuan Xie, and Guozhu Chen. "A novel power-flow balance LVRT control strategy for low-speed direct-drive PMSG wind generation system." In IECON 2010-36th Annual Conference on IEEE Industrial Electronics Society, pp. 748-753. IEEE, 2010.

[11] Mahela, Om Prakash, Neeraj Gupta, Mahdi Khosravy, and Nilesh Patel. "Comprehensive overview of low voltage ride through methods of grid integrated wind generator." Ieee Access 7 (2019): 99299-99326.

[12] Kim, Chunghun, and Wonhee Kim. "Enhanced low-voltage ride-through coordinated control for PMSG wind turbines and energy storage systems considering pitch and inertia response." IEEE Access 8 (2020): 212557-212567.

[13] Din, Zakiud, Jianzhong Zhang, Yaodong Zhu, Zheng Xu, and Ahmed El-Naggar. "Impact of grid impedance on LVRT performance of DFIG system with rotor crowbar technology." IEEE Access 7 (2019): 127999-128008.

[14] Piwko, Richard, Leon Roose, Kirsten Orwig, M. Matsuura, D. Corbus, and Matt Schuerger. "Hawaii solar integration study: Solar modeling developments and study results." In Proc. 11th Int. Workshop Large-Scale Integr. Wind Power Power Syst, pp. 1-8. 2012.

[15] Eicker, Ursula, Ece Demir, and Daniel Gürlich. "Strategies for cost efficient refurbishment and solar energy integration in European Case Study buildings." Energy and Buildings 102 (2015): 237-249.

Author's biography

Jenitha J received the B.E (EEE) degree from Government College of Engineering, Bargur in the year 2017 and ME (Power Electronics and Drives)from Government College of Technology, Coimbatore in the year 2019. Currently pursuing Ph.D in Adhiyamaan College of Engineering, Hosur. Area of interest :Power electronics and Control System.

Dr.S. Sumathi passed her B. E. (Electronics and Communication Engineering) from Bharathiyar University, Coimbatore in the year 1994 and M. E. (Applied Electronics) from Anna University, Chennai in the year 2004. She did her Ph.D. from Anna University in the specialization of VLSI Signal Processing and awarded in the year 2009. She has more than 20 years of teaching and research experience. Presently she is serving as Professor and Head in the Department of Electronics and Communication Engineering in Adhiyamaan College of Engineering.Area of interest:VLSI Signal Processing, Embedded system.