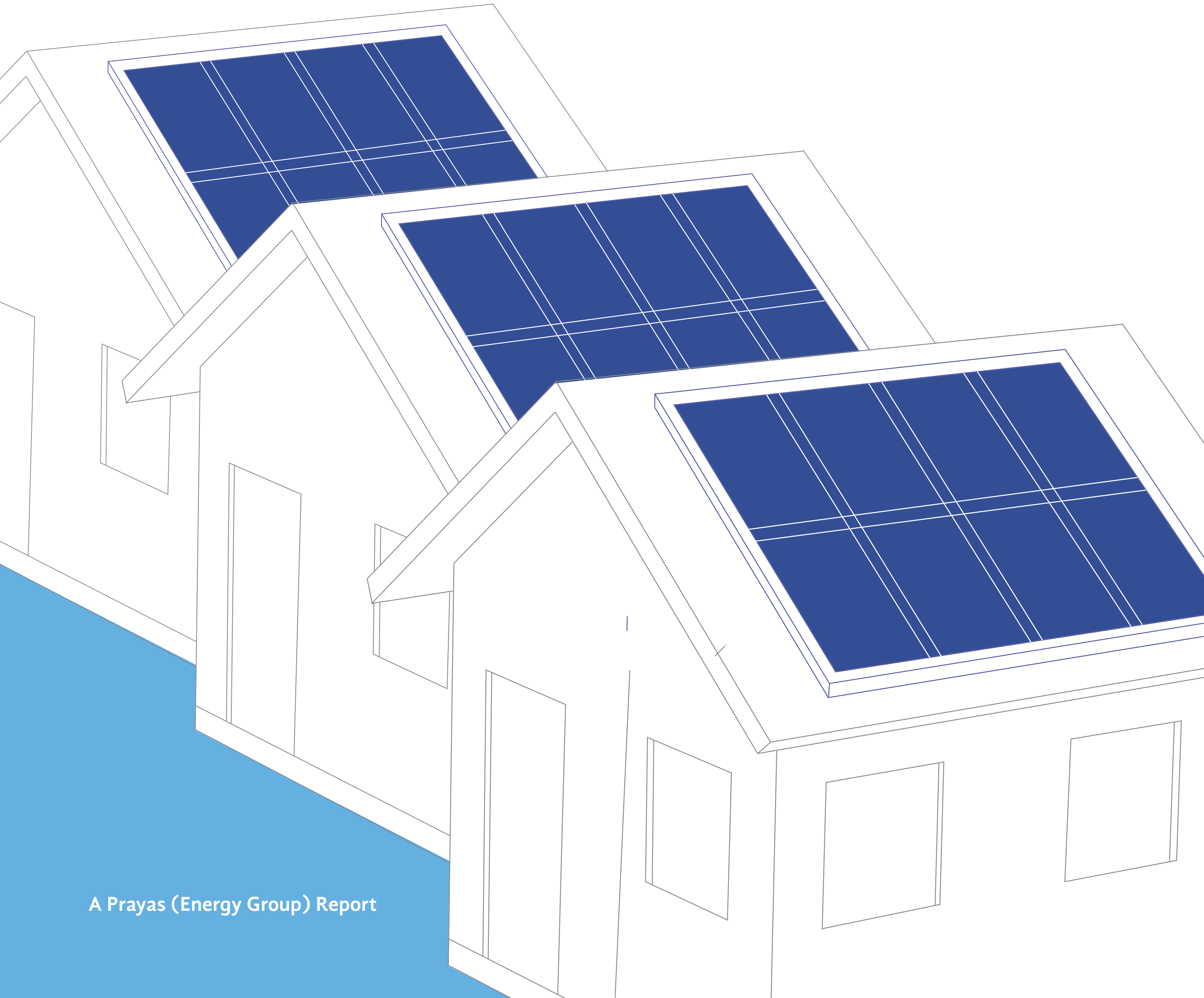
Grid Integration of Distributed Solar Photovoltaics (PV) in India

A review of technical aspects, best practices and the way forward

Summary of observations and recommendations for a way forward



A Prayas (Energy Group) Report

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A review of technical aspects, best practices and the way forward

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Report Summary

The full report can be downloaded at

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A Prayas (Energy Group) Report

Prayas (Energy Group)

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5 Summary of observations and recommendations for a way forward

Distributed solar PV (particularly the rooftop segment) is expected to grow significantly in the coming years due to increased economic viability for certain consumer segments (commercial, industrial and high-use residential) in particular geographical areas in India. While many states have already put in place favourable net metering policies, some state ERC regulations support rooftop projects through the feed in tariff route. By some estimates, India could install 3 - 5 GW[163] of distributed solar in the next three - five years.

However, since the grid was not particularly designed for large scale distributed generation, utilities are concerned about the implications of variable solar generation on the power quality, its impact on the LT distribution grid and the safety of its work force. These apprehensions and fears are heightened due to a lack of clear documentation and understanding of these concerns and their potential solutions in the Indian context.

Distributed PV can provide various system benefits but at the same time, very high penetrations raise certain technical concerns with regard to the grid. Up to a point, DG solar can help in increasing the grid reliability (reducing peak shortages and loading on transformers), power quality (improving voltage and power factor profiles, etc.), deferring grid related investments (on transformers) and reducing T&D losses. However some of the common technical concerns at very high levels of penetration (India is far away from such a scenario) are tail end voltage control, excess generation leading to reverse power flows resulting in (a) transmission grid congestion, (b) voltage rise in long feeders, (c) over-loading of equipment in shorter feeders with high demand density and more complicated grid balancing due to the variability and partial unpredictability of solar generation. (See Annexure D)

In this study, we describe the technical issues involved, both for the PV system as well as the distribution grid, based on a review of global and Indian policies and regulations. Further, we document existing technical standards and practices, and propose a possible way forward. This study specifically addresses (1) the quality of the solar power being injected into the grid, (2) safety issues, (3) ways and means in which DG can support the grid and help its own reliable integration, and (4) the interaction of distributed solar PV and the distribution LT grid.

With this study, we hope to initiate a serious and objective discussion on the technical aspects of distributed solar PV. By beginning the discussion on the issues emerging from high DG penetration and learning from the international experience, India can manage the technical issues likely to emerge in due time better. A greater common understanding of the issues would help facilitate faster distributed PV deployment.

5.1 Key observations

5.1.1 Global context

There has been a strong growth of distributed solar PV across the world. Germany has been leading the way with 65% of its total installed solar capacity of 35.7 GW[164] in 2013 connected to the low voltage grid (240 V or 400 V)[165]. The USA (particularly California), China and Australia have also seen rapid growth in distributed solar in recent times. (See Annexure E.) A significant amount of knowledge generation through their experiences is available in the public domain, and a continuous process towards learning and improvement is underway. It is vital that India leverages this experience to create a facilitating framework allowing smoother and more efficient deployment of solar DG.

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163 BRIDGE TO INDIA market research and analysis
164 The Germany Federal Network Agency: bit.ly/1lNGi4o
165 Thomas Ackermann, "What matters for successful integration of distributed generation": bit.ly/1fv2OPz

5.1.2 Concerns of distribution utilities

Distributed kW scale solar PV plants (mainly rooftop) are only now beginning to be deployed in many states with the help of supporting policies and regulations. Hence utilities presently have limited experience in dealing with distributed solar PV systems connected mainly to the LT distribution grid. They have some valid concerns (listed below) regarding distributed solar PV as it is finally their responsibility to maintain reliable grid supply.

- Power quality: DISCOMs are apprehensive about the quality of the power being injected into their distribution grids. This is mainly to do with flicker, harmonics and DC injection.
- Safety: Utilities are rightly concerned about the safety of their personnel, especially while working around the possibility of the formation of an unintentional island from the operation of the distributed solar PV systems.
- Low voltage distribution grid: They are also concerned about the impact on the LV distribution grid (voltage levels, power factor, higher wear and tear of equipment, etc.) from high penetration of a large number of distributed solar generators.
- Transaction Costs: Another logistical worry for utilities is the significantly higher transaction effort in terms of metering, inspection and certifications.

5.1.3 Variation of some technical requirements across states

Many Indian states as well as the central government through the MNRE/SECI have been promoting rooftop photovoltaics (RTPV) for the last few years. While most state regulations have referred to national CEA interconnection standards ('Technical Standards for Connectivity of the Distributed Generation Resources', 2013) with regard to technical issues, there have been two areas where there are some variations across states. The first one is with regard to limits on system sizes and allowed inter-connection voltages. The details are provided in Table 10. These generally tend to be in line with state supply code regulations.

The second is with regard to metering requirements. Some state regulations mandate meters of a higher accuracy class in comparison with the CEA metering regulations, 2006 (with the 2013 amendment for renewables). Both these variations have a direct bearing on the cost, especially for small kW scale installations.

Table 10: Comparison of technical norms of system size and interconnection voltages by states

Voltage (Volts)	State	240	240/415	415	11,000	11,000/33,000
System size (kW)	Gujarat	< 6		6-100	> 100	
	Uttarakhand	< 4		4-75	75-1500	1500-3000
	Tamil Nadu		< 4	4-112		> 112 (HV/EHT)
	Delhi (draft)		< 10	10-100		> 100 (HV/EHT)
	Kerala	< 5		5-100	100-3000	
	Punjab (draft)	< 7		7-100	>100	
	Karnataka	Up to 5		5-50	> 50	
	West Bengal	LV or MV or 6 kV or 11 kV or any other voltage as found suitable by the DISCOM				
	Chhattisgarh			50-100	100-1000	
	MNRE[166]	Up to 10		10-100		100-500
	SECI Scheme		Up to 10	10-100		> 100 (incl 66 kV)

166 MNRE guidelines for grid connected rooftop and small solar power plants programme: bit.ly/Vikmqb

5.1.4 Inverter and power quality

The inverter is at the heart of the solar PV system ensuring power quality and grid integration. The three important technical parameters which can affect the quality of the power being injected into the grid are harmonics, flicker and DC injection. In each of these three parameters, existing CEA regulations follow global best standards (See Section 3.1) as noted below.

- Harmonics- IEEE 519, wherein THD < 5%
- Flicker- IEC 61000
- DC injection - IEEE 1547 standard, wherein the maximum permissible level is 0.5% of the full rated output at the interconnection point.

Our market survey shows that today's inverters are capable of meeting these standards, thus addressing the power quality concerns of distribution utilities.

5.1.5 Inverter functioning range

Apart from the three basic parameters mentioned above, the solar system is allowed to function only within a certain range of voltage and frequency and is thus subject to the quality of the grid. These ranges vary from country to country. The CEA presently permits the system to function within a range of 80-110% of the nominal voltage, and between a 47.5-51.5 Hz frequency band. (See Sections 3.1.4 and 3.1.5.)

Presently, the moment the grid parameters move outside this range, the solar system is required to stop injecting power within a certain time frame. However advanced standards allow solar generators to remain connected to the grid if the voltage or frequency excursions are only temporary, thus avoiding nuisance tripping of the system. These are called Fault Ride-Through (FRT) functionalities (See Sections 3.2.2 and 3.2.4), namely the Low/High Voltage Ride-Through (LHVRT) and the Low/High Frequency Ride-Through (LHFRT).

5.1.6 Inverter support to the grid

Today's inverters are capable not only of reliably integrating with the distribution grid and maintaining the power quality mandated by it, but can also provide additional support to improve some grid characteristics and assist in fault recovery. Through the LHVRT and LHFRT functions, inverters can stay connected to the grid in times of momentary grid faults/failures. Inverters can provide grid supporting functions like power-frequency droop (See Section 3.2.3) (helping grid recovery) and reactive power support (See Section 3.2.1) to help maintain local grid parameters within their normative limits, at times in a more cost effective manner than centralised options. Such smart functionality in inverters comes practically at no extra costs in most cases and can be activated and incorporated without serious technical challenges.
A significant share of the string inverter market in India is already capable of providing most of these functionalities.

The IEEE 1547 (the reference guideline for DG) is being revised, and many of these functions considered above are likely to be included. A draft version (IEEE 1547a) already allows some of these functions. More advanced functions, some of which may require communication capability (between inverter and utility/energy markets) are being considered in some countries. Examples of such functions are: limiting maximum active power upon instruction from the utility, supporting instructions to connect/disconnect, ability to update default settings in response to changing grid conditions, etc[167].

167 'Recommendations for updating technical requirements for inverters in Distributed Energy Resources': bit.ly/1hIYkaz

5.1.7 Inverter and safety

Islanding refers to the condition in which a distributed solar system continues to energise the circuit even when the grid power from the utility is unavailable. Islanding can be dangerous to utility workers, who may not realise that a circuit is still powered when working on repairs or maintenance. To ensure safety, most countries including India mandate the anti-islanding (See Section 3.1.6) functionality, which requires the PV system to stop energising the grid as soon as grid power is unavailable. An emerging function is 'intentional islanding' which allows distributed solar PV to continue to power certain loads when the grid is down with adequate safety considerations. This is of utmost relevance in India where load shedding or power cuts are common in most DISCOM service areas.

5.1.8 Distributed PV penetration

An important aspect of distributed solar pertains to its safe and reliable integration into the LT grid, especially with regard to very high penetration levels at the distribution transformer level. In California (one of the first jurisdictions to adopt behind-the-meter distributed solar PV at a significant scale) the rationale behind its primary solar PV penetration thresholds was that as long as maximum DG generation on a line section was always below the minimum load, issues such as unintentional islanding, voltage deviations etc. would be negligible[168]. Based on this rationale and considering that typical distribution circuits in the US had their minimum load at roughly 30% of peak load, California adopted a conservative 15% penetration threshold. (See Section 4.1.) This penetration limit was the first checkpoint for supplemental studies and not an upper cap on deployment. The 15% screening under rule 21 has been recently updated to allow DG solar penetration automatically up to 'minimum daytime load' on any feeder. Minimum daytime load tends to be significantly higher than the minimum 24-hour load.

However global experience shows that there is no cause for worry even at much higher penetrations.

> *"In many cases, even when PV penetration is substantially above 15%, the supplemental studies do not identify any required system upgrades. There are many circuits across the United States and Europe with PV penetration levels well above 15%, where system performance, safety, and reliability have not been materially affected."* [169]

Significantly higher penetrations are also being managed effectively. Germany presently has an installed capacity of 35,700 MW (as of December 2013). 65% of this capacity is at the LV level (230 V / 400 V) and 35% at the MV level (11 to 60 kV)[170]. More significantly, maximum instantaneous power provided by PV in comparison to the load between May and September (varying between maximum of 67.7 and minimum of 34.7 GW) has already reached 49%. However, since most of the solar is concentrated in southern Germany, many LV grids have PV capacity, which can exceed peak load by factor of 10![171] As can be seen, there is no one safe reliable penetration number with international consensus, as it is a function of a variety of variables including load patterns, grid quality, consumer behaviour, etc.

As far as India is concerned, the CEA has not stipulated any penetration limit in its regulations. However some SERCs are specifying penetration limits in terms of a percentage of the DT's rated capacity. Tamil Nadu mandates that the penetration of distributed PV into the grid shall not exceed 30% of the distribution transformer (DT) rated capacity while Delhi and Punjab have proposed 15% and 30% respectively[172]. Kerala, on the other hand, had initially proposed a limit of 50% of the DT capacity but has finalised a different metric allowing up to 80% of minimum daytime (8am-4pm) load. (See Section 4.2.)

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168 "Updating Technical screens for PV System Integration": http://1.usa.gov/OuZisW
169 Ibid
170 IEA, "What Matters for Successful Integration of Distributed Generation": bit.ly/1fv2OPz
171 "Time in the Sun: The Challenge of High PV Penetration in the German Electric Grid", Power and Energy magazine, IEEE, March-April 2013: bit.ly/1oMcia6
172 Numbers for Delhi and Punjab are still in the draft stage and subject to finalisation.

A safe penetration threshold is a factor of various variables like load patterns, grid quality, consumer behaviour, etc. and hence will vary from place to place. The learnings and experiences in these states would be very valuable to other states.

5.1.9 Potential solutions to increase hosting capacity of distribution grid under very high penetrations

In many cases, studies conducted for medium-high penetrations may reveal that no system changes (equipment or protection settings) are needed to allow for higher DG deployment. In some cases, it may be that only protection settings and/or protection equipment needs modification. To further increase the hosting capacity of the network, several options exist. A detailed study on such technical solutions was carried out under the project PVGRID[173]. Some of the important solutions are noted below.

Distribution Grid Adaptations:

- Network reinforcement and increasing cable and transformer capacity, thereby directly increasing the grid's PV hosting capability
- Voltage control through On Load Tap Changer for MV/LV transformer and booster transformers along long feeders
- Reactive power support though Static VAR Compensators (SVC)

Consumer Side Adaptations:

- Additional inverter functions (LHVRT, LHFRT, power-frequency droop characteristics, reactive power support as a function of local voltage, etc.) supporting grid integration of distributed solar and providing grid support. "Advanced inverters can mitigate voltage-related issues and potentially increase the hosting capacity of solar PV by as much as 100%"[174].
- Reducing injection of solar PV power into the grid to overcome voltage and congestion issues through
  - increased self-consumption of PV
  - curtailment of power injected at PCC by limiting it to a fixed value
  - storage during periods of peak solar generation
  - load shifting through tariff incentives or demand response

Interactive Adaptations:

- A communication protocol and platform[175] between DISCOMs/SLDCs and solar systems. This allows SLDCs to directly control PV generation in emergency situations by sending appropriate signals. Similarly, reactive power support can also be initiated in response to utility signals rather than as a part of a pre-set function. Such communication is also helpful in changing any operational set points.

India is presently far away from the high penetration scenarios found in California, Italy, Germany, etc. In spite of the high penetration of distributed solar PV in California, the state still does not have support functionality like LHVRT, LHFRT, reactive power support, power-frequency droop control, etc. Hence it is important to understand that the technical issues noted here are only to

173 The PVGRID project publications: bit.ly/UnxXwm

174 Barun et al., "Is the distribution grid ready to accept large-scale photovoltaic deployment? State of the art, progress, and future prospects", 2011

175 In Germany, according to §6 of the German renewable energy act (EEG), PV systems with an installed capacity of more than 100 kW must participate in feed-in and grid security management. The BDEW stipulates this for all plants feeding in at the medium voltage level. The grid security management requirements in Germany are: remote-control reduction of feed-in capacity in grid overload situations via a radio ripple control receiver, limitation of feed-in power in up to ten adjustable levels (for example, 0%, 30%, 60%, 100% of the agreed installed active power), setting of the required target value in less than one minute and gradual increase of power at a maximum rate of 10% per minute.

initiate a discussion in India to facilitate preparatory work. In a nutshell, till the distributed solar penetration becomes very high (at the substation level), concerns regarding safety and supply quality at the local grid level can be addressed through easily available technical solutions in a cost effective manner by way of changes in technical standards and ERC regulations. Making changes to standards early in the development of the sector will ease grid integration challenges and lower costs in the future by avoiding the need to make any retroactive changes.

5.2 Recommendations for a way forward

Based on our analysis and comprehensive stakeholder consultation thus far, we propose some technical suggestions for a way forward for faster and more effective deployment of distributed PV.

5.2.1 Amendments to the CEA's 'Technical Standards for Connectivity of the Distributed Generation Resources' Regulations, 2013

a. Modifications in existing voltage/frequency functions and new additional functions:

The CEA at present permits the system to function within a range of 80-110% of the nominal voltage and between a 47.5-51.5 Hz frequency band. (See Sections 3.1.4 and 3.1.5.) While these ranges are appropriate for existing solar penetration, based on further studies, the CEA can consider extending the operating voltage and frequency range to better reflect Indian operating conditions [176] if this helps in grid recovery after faults. On the low voltage side, the inverters may be allowed to remain connected at voltages slightly below the present limit of 80%, if they support the grid by supplying reactive power.

Earlier it was thought that in order to handle distributed solar with regard to grid disturbances, it was necessary to mandate immediate disconnection. This belief is also reflected in IEEE 1547. However, present day inverters can support the grid during low voltage and low frequency transients and assist in grid recovery following large grid disturbances. Hence LHVRT and LHFRT should be allowed under sections 5 [11] [6] [a,b]. When the technical standards are updated, fault ride through capabilities should be implemented and the safe operating range should be revisited. Anti-islanding specifications should also be updated to be in synergy with these FRT capabilities.

Similarly additional functions like reactive power support for voltage support and power-frequency droop for over-frequency regulation support should be considered as the cumulative deployment increases. Similarly, re-connection of distributed PV systems to the grid after faults would need to be done in a soft manner to avoid voltage or frequency spikes and oscillations if all systems were to reconnect at the same time. This can be achieved in two ways, either by gradually increasing active power output, or randomly re-connecting within a small time window.

All such functionalities can be initiated in a pre-determined auto-response mode and do not need any communication infrastructure. Our review indicates that all these capabilities are easily available at practically no extra costs in inverters available in the market today. The CEA should mandate such functionality on systems only above a certain size (say 10 kW) to avoid any cost disadvantage on smaller systems. This size threshold may vary from function to function.

Technical standards need to recognise system benefits of such changes and mandate them for new installations in the next round of update of technical standards. If such changes are not made in due time, retrofits can become very costly (as in 50.2 Hz case in Germany (See Section 3.2.3), and logistically difficult since distributed solar growth can be very fast. Data acquisition systems for larger plants (> 100 kW) can help monitor compliance.

176 The standard operating voltage range (80-110%) specified for distributed solar PV operation is often violated in India due to a number of reasons.

b. Consider allowing intentional islanding:

An additional function of special relevance in India (with occasional black/brownouts during daytime) is 'intentional islanding'. This feature allows the solar PV system to disconnect from the grid in the event of a grid failure and continue to supply pre-decided critical loads on the consumer side of the meter[177]. This is possible in two ways, (a) the hybrid inverter works in an off-grid mode, and continues to charge batteries which power certain loads or (b) the inverter continues to function in grid-tied mode in synergy with the larger backup system, most likely diesel based generators. The second option is more feasible for larger loads, most of which have existing diesel generation backup facilities. Utilities are well versed with such backup facilities, which already have the required safety features which prevent energising the local grid (reverse flow). Using distributed solar PV in such an intentional island mode is technically feasible and can also reduce costs compared to costlier diesel generation. This intentional islanding feature is mentioned as a note in the CEA 'Installation and Operation of Meters', 2006 draft[178] amendment regulation released in 2013, but is omitted in the final CEA 'Technical standards for connectivity of the distributed generation resources', 2013 regulations. The CEA should consider allowing this functionality in the future based on appropriate studies and pilot projects. Adequate technical specifications for safe automatic isolating equipment at appropriate locations, challenges around anti-islanding control for multiple distributed generators within a micro-grid[179], safety concerns for personnel and legal liabilities with regard to intentional islanding are crucial issues which merit serious discussion.

c. Distribution transformer level penetration:

Global experience indicates that a 15-30% threshold is a relatively conservative benchmark and that significantly higher penetration can be reliably integrated with existing technical solutions. **Hence the CEA should recommend SERCs to automatically allow distributed PV interconnections with a simplified approval process on a First Come First Served (FCFS) basis up to the threshold of 15-30%.** For such a process, utilities will need to have updated information on penetration levels of distributed solar and available capacity on their DTs in the public domain. Importantly, such a penetration limit should not be interpreted as a fixed upper limit, but as the first checkpoint for additional screening and technical studies. At present, section 4 (6) (a,b) of the CEA standards mandates that the utility should undertake an inter-connection study to determine maximum net capacity of DG at a particular location. This should be modified so that such studies are to be taken up only after the first check-point penetration limit of 15-30% of rated DT capacity is reached.

Once the penetration threshold (15-30%) is reached, utilities can perform some preliminary screening checks based on ratios such as minimum load to generation ratio, stiffness factor, fault ratio factor, ground source impedance ratio, etc. (See Table 13, Annexure F) to ascertain if the system effects of the distributed PV have become significant enough to warrant additional detailed technical studies. It may well be the case that there is no problem in increasing the present threshold. Changes may be needed in safety settings or hardware upgrades to further increase the hosting capacity of the local grid. A larger penetration may be allowed, based upon DT capacity and on studies which assess anti-islanding ability, ground fault over-voltages (if generation is not effectively grounded), over-current device co-ordination and voltage regulation. Detailed loading, voltage profile and fault studies may need to be conducted based on the preliminary screening checks to further understand the impacts of distributed PV on the grid and its hosting capacity.

Annexure F has some potential outlines to help DISCOMs monitor the health of the distribution grid based on certain metrics and conduct further detailed studies. The CEA can specify a broad template (outlining the parameters and methodology) for such technical studies.

177 Rocky Mountain Institute (RMI), "Microgrids: Providing safe harbor in a storm", 10th January 2013: bit.ly/1qf7afv
178 CEA, Draft Installation and Operation of Meters, 2013: bit.ly/1fqC3ab
179 Green Tech Media (GTM), "Grid Edge Report", 2014: bit.ly/VzQsOg

As cumulative distributed solar deployment picks up, utilities should periodically conduct sample studies at high penetration pockets to ascertain if a higher threshold in comparison to the recommended starting point of 15-30% would be technically appropriate. They can go a step forward and proactively conduct studies in potential high penetration areas before the thresholds are reached. In addition to factoring in DG deployment into network planning, such steps would allow for faster deployment[180]. From a purely technical perspective, the hosting capacity can always be increased to accommodate more PV (See Section 5.1.9), but cost and cost sharing arrangements would need due considerations.

d. **Advanced future inverter functions:** There are certain advanced inverter functionalities[181] (such as limiting maximum power output, providing status and measurements on current energy and ancillary services, supporting utility commands to connect/disconnect, etc.), which can be useful for grid management in high penetration scenarios. Most of these advanced functionalities need communication protocols in place to communicate with the utility or power markets. Such communications possibilities also allow changing pre-set inverter parameters in response to changes in the power system. A committee headed by the CEA including utilities, manufacturers, developers, NCPRE, Central Power Research Institute (CPRI), etc. should critically look into all such advanced functionalities and recommend revisions to technical regulations from time to time.

e. **Testing:** Section 5 (8) (2) of the CEA regulations mandates measuring DC injection, harmonics and flicker prior to commissioning and once a year thereafter. This should be made applicable only above a certain project size (say > 100 kW).

5.2.2 Uniform technical standards across states

As seen in earlier sections, technology is more than capable of reliably and cost-effectively integrating large amounts of DG into the LT distribution grid resulting in significant systemic benefits. One of the most important supporting role that can be played by the government in facilitating this transition is assisting in moving towards uniform technical standards (to the extent possible) across all states. State technical regulations should mirror CEA regulations and need not be more stringent. Non-standard technical regulations, procedures and specifications across states can act as a strong barrier, resulting in additional costs for manufacturing and deployment and thereby slowing down the growth of this sector. This is especially important for metering regulations.

5.2.3 Solar system size and connection voltages

Most states limit the size of the solar system with respect to inter-connection voltages. Single-phase connections are allowed up to 5 or 10 kW, while three phase inter-connections are limited roughly between 50-100 kW. Systems larger than this size are mandated to inter-connect to an 11 or 33 kV system. These tend to be in line with state supply code regulations and such an approach has also been seconded by the Forum of Regulators[182]. However, to get the maximum benefit out of distributed generation at a lower cost (when solar system size is smaller than the minimum daytime load), a larger system may be allowed to be connected at the LT level on a case by case basis as long as it is meeting all the technical requirements. DT capacity, anti-islanding ability, ground fault over-voltages (if generation is not effectively grounded), over-current device co-ordination, and voltage regulation would need due consideration in such cases. Mandating inter-connection to a higher 11/33 kV voltage in such cases does not benefit the system in any way, but only results in higher costs.

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180 IREC, "Integrated Distribution Planning Concept Paper", May 2013: 1.usa.gov/TxZ2Ms

181 'Recommendations for updating technical requirements for inverters in Distributed Energy Resources': bit.ly/1hIYkaz

182 Forum of Regulators, Minutes of the 39th meeting: bit.ly/1r3nCAE

5.2.4 Certifications and inspections

After achieving grid parity and with a facilitating policy framework, growth of distributed solar can be exponential (as is seen in Germany having over 1.4 million systems with an installed capacity of 35.7 GW which has been achieved only in the last few years) and can overwhelm the utility management system in terms of procedural logistics with regard to permissions, inspections, certification, etc. Hence the process for certification/permitting has to be graded in nature with smaller systems having a simpler process - being allowed to self-certify[183]. Accredited third party validators could help the utility in this process. Safety with regard to the anti-islanding feature and other protection devices, and compliance of the equipment and system with the CEA standards, are the two most important checks to be performed. Such certification processes have to be coupled with random checks with heavy fines/blacklisting for non-compliance. A possible framework is suggested in Table 11. See Annexures G and H for more information.

Table 11: A possible framework for certification and testing

System size	0 - 10 kW	10 - 100 kW	> 100 kW
Equipment certificates, especially for inverters	Standard test certificate from accredited laboratory declaring conformity with CEA standards[184].		
System installation certificate (pre-commissioning)	Self-certification with appropriate declaration for safety.	Certified Energy Auditor/ Licensed Electrical Contractor/Self-certification for MNRE accredited channel partners (1A certification)	Certified Energy Auditor/ Electrical Inspector
Annual testing	NA	NA	Only for high penetration zones

Note: System owners would need to provide an appropriate declaration for safety with the system installation certificate.

5.2.5 Best practices and safety guidelines

India presently has a set of generic standard safety codes that are applicable to all power plants. The CEA in consultation with industry experts should formulate comprehensive safety guidelines and best practices for installation, testing and commissioning tests for distributed solar systems. However, a solar PV specific safety and certification protocol is absent. The National Electrical Code (NEC) codes of the USA (detailed in Annexure I) provide a good starting point for the development of such a solar specific safety code. This is of paramount importance considering the growth of the sector and the entry of a high number of new developers and system integrators in the market. Apart from safety guidelines, a manual on best installation and O&M practices could be brought out by industry associations.

183 Germany has no active permitting process for installations smaller than 30kW and does not require visits by the distribution grid operator or other local permitting authorities. Some of the procedures can be done online. Similarly in England, certified installers can directly connect to the system to the grid and notify the utility thereafter.

184 For Germany, "A unit certificate confirming conformity with all requirements of the medium voltage directive has become mandatory for each generation unit (i.e., each inverter type) at the same time as the dynamic grid support capability. The manufacturer receives this certificate following comprehensive testing of the respective device by specially authorized testing institutes. A simulation model, which may be used to simulate the behaviour of the inverter in the event of an error, is also part of the respective certificate. In addition, the date of commissioning is decisive for the certification obligation." From SMA, 'PV grid integration', 4th revised edition, May 2012: bit.ly/1qf86Ri

5.2.6 Database

Section 4 (8) of the CEA regulations mandates the utility to send information (capacity installed, generator capabilities, commissioning date etc.) to the state transmission utility (STU) and further to the state load dispatch centre (SLDC). This is a welcome step and all utilities should maintain such a database on DG projects in their jurisdiction. An appropriate authority should collate all such utility databases into a national database. Such a database would be very valuable for future grid planning.

5.2.7 State regulations

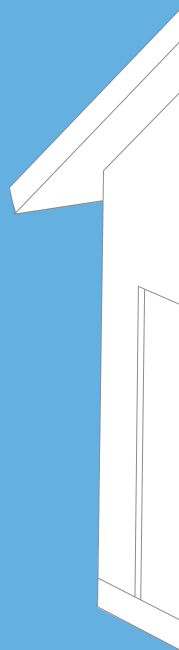
The SERCs should issue distributed solar PV regulations to integrate all the above aspects and help bring in clarity with regard to emerging technical issues and potential solutions. It should also clearly lay out a procedural framework to facilitate effective and quick deployment.

Since distributed solar penetration in India is still very low, it is well placed to learn from the global experience, revise its technical regulations appropriately and stay ahead of the curve. An institutionalized consultative process with all stakeholders would greatly help to critically assess the evolving technical challenges and their solutions, and facilitate a clear technical framework for distributed solar PV deployment.

Distributed solar photovoltaics (PV) is expected to witness significant growth in India owing to increasing economic viability and a facilitating policy-regulatory framework in most states. Distributed Generation (DG) can provide various system benefits in terms of improved grid reliability and power quality, deferring grid in vestments, reduction in T&D losses, etc. However,since the distribution grid was not designed keeping in mind the potential high penetration of DG, there are valid technical concerns from utilities about power quality and the general impact of DG on the low-tension distribution grid.

To address these concerns, the report documents existing technical standards and practices both on the PV system side and on the distribution grid side based on a review of global and Indian policies and regulations. Further, the report outlines potential solutions and proposes a possible way forward for a structured and effective grid integration of distributed PV.

With this study, we hope to initiate a serious and objective discussion on the technical challenges and potential solutions of large scale distributed PV. A greater common understanding of the issues would help facilitate faster distributed PV deployment in India.



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