ISGF
India Smart Grid Forum

ISGF White Paper

Urgent Need for Standardisation of Electricity Distribution Grid in India

Abstract

Rules related to electricity connections vary widely from state to state in India. While three-phase low tension (LT) connections up to 200 kW is allotted in Delhi, Andra Pradesh provides only 20 kW connections. Only nine states in India provide LT connections of 100 kW or above; and in majority of the states the limit is below 50 kW. For obtaining connections with higher power capacity, the customer has to pay the cost of 11 kV line cabling and distribution transformer. Public Charging Stations (PCS) for Electric Vehicles (EV) require more than 50 kW power. If every PCS has to bear the cost of cabling and transformers, that will not only delay the installation of PCS but also drive up the capital cost very high which will be the single most constraint in scalingup electric mobility in India. This paper examines the urgent need for common rules and standrads in electricity distribution sector from the perspectives of electric mobility, building flexibility in the grid and the growing power demand of customers to meet the cooling load.

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About India Smart Grid Forum

The India Smart Grid Forum (ISGF) is a Think-Tank of global repute on Smart Energy, Electric Mobility and Smart Cities. ISGF, established as a Public Private Partnership initiative of Government of India in 2011, is spearheading the mission to accelerate electric grid modernization and energy transition in India. ISGF is a Not for Profit Society under Indian Societies Act and have its registered office at CBIP Building, Malcha Marg, Chanakyapuri, New Delhi 110021.

1 Introduction

Although electrification started in India in late 19th century, at Independence in 1947, India had only 1362 MW of power generation capacity for a population of over 340 million. Independent India attributed due importance to country-wide electrification and both central government and state governments executed various focused programs towards universal electrification in the country. Presently, India operates the third largest power system in the world (after China and USA) with an installed generation capacity of 407,796 MW with 300 million electricity consumers spread across numerous cities, towns and 619,000 villages. This is nearly 310 times growth in 75 years which is unparalleled in the history of electrification in the world. The high voltage transmission grid in India is one of the most modern power grids with state-of-the-art control centers, communication systems and wide area monitoring systems. However, major parts of the distribution system (medium voltage and low voltage grid) managed by 72 distribution licensees are in poor condition with high network losses and frequent breakdowns owing to overloading, aging equipment and lack of timely maintenance.

Some of the key issues with the distribution grid are (i) very long medium voltage lines (11 kV lines which should ideally be 5-6 kilometer usually run 30-70 kilometer; and in some states even longer than 100 kilometer); (ii) poor quality of aluminum wire joints[1]; (ii) very low-capacity power connections allotted to households which gradually over-load the entire distribution network [2]; and (3) non-standard equipment[3] deployed**.** In this paper we are highlighting the urgent need for a centralized and standards-based approach for distribution grid modernization from the perspective of following requirements:

a. To allot higher power connections from the low voltage or low tension (LT) grid to Public Charging Stations (PCS) for electric vehicles (EV) that are mushrooming all around the country[4]
b. To address the cooling and cooking needs of every household by providing 3 kW to 5 kW power connections to all customers which will build redundancy in the system
c. To build flexibility in the distribution grid through network automation with equipment that can be remotely monitored and controlled leading to a self-healing grid

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[1] Aluminum wires used in LT lines have poor quality joints. Since linemen were not issued hydraulic crimping tools in the past to make proper crimped joints, they used twisted wire joints made with the help of simple tools. By one estimate, there are over 500 million such twisted wire joints in the country and on each of them there is minimum 10 watts of power loss happening 24x7! That alone is about 5000 MW loss every second. This needs to be addressed immediately by changing those old wire joints with properly crimped wire joints.

[2] During the mass rural electrification drives, electricity connections were given to households with average 200 to 250 watts of power. In some states it was even lower. 200 watts power is sufficient only for few light bulbs and one or two fans. Normally, soon after getting electricity connection, people buy more electrical appliances such as radio, television, grinder/mixier, electric iron, geyser and graduate to desert coolers and air-conditioners depending on their income levels. Even rural-households today require above 1 kW power. With cooling and electric cooking becoming very important, ISGF suggests that the distribution grid should be planned for minimum 5Kw for every household in urban/semi-urban areas and minimum 3 kW rural areas.

[3] Though REC has made standards and specifications for equipment to be used for rural electrification, most state utilities follow their own specifications which are not even common across a utility. As a result, we have a very vast distribution network with different types of equipment.

[4] Per McKinsey estimates, in the present policy scenario there could be 1 million chargers in India by 2030 growing to 3 million by 2040; and in the accelerated scenario there could be 2 million chargers growing to 7 million by 2040 – McKinsey Report "Decarbonising India: Charting a pathway for sustianble growth, October 2022.

These are described in details in the following sections.

1.1 Standardization of Power Connection Capacity to Support EV Charging Stations

While Delhi allots up to 200 kW power from for a three phase LT connection (at 415 Volts), Andhra Pradesh gives maximum 20 kW. Only nine states in India (Chhattisgarh, Gujarat, Jammu & Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu and West Bengal) give 100 kW or more from an LT connection. Most other states give connections up to 50 kW[5] or lesser. With electric vehicle charging stations coming up all over the country, the existing rules related to power connections will be the biggest show-stopper for scaling up electric mobility. Hence, there is an urgent need for standardizing the power connections across the country. In order to give higher power connections from the distribution network, larger size of cables (or wires) and higher capacity distribution transformers are required which is a one-time investment that would take care of the load growth for few decades. In urban and semi-urban areas where underground cabling is carried out for laying distribution lines, lion-share of the total cost of cabling is the municipal charges against right of way (ROW) for digging the roadside. For example, the ROW charge is about INR 6 million per kilometer in Delhi while it is over INR 10 million per kilometer in Mumbai. The actual cost of cables and distribution transformers is about INR 2.5 million per kilometer. Hence, it is beneficial to invest in higher capacity of the equipment to build redundancy in the network than upgrading it year after year. If a Public Charging Station (PCS) for electric vehicles (EV) require 100 kW connection in Gurgaon or Noida (both just on the outskirts of Delhi), they have to pay for the cost of new 11 kV cabling from the nearest substation and the cost of a new distribution transformer (DT). As indicated, the cost of a new DT is not much, but the total system upgradation cost including ROW charges will be prohibitively expensive. If every PCS in the country has to incur such expenses, that will ultimately be passed on to the EV charging tariff which will make it expensive for the EV drivers.

Power connections given by utilities in different states are presented in Table 1 below. For a fair comparison, we have compiled the rules related to power connections in few other countries which is presented in Table 2.

Table 1: Power Connections allotted by Utilities in India

Details of Power Connections given by Utilities in India						
Sl No	State	DISCOM	Maximum Power per Connection (kW)			
			Low Tension (LT)		Medium Voltage	
			Single Phase (230 Volts)	Three Phase (415 Volts)	11 kV	33 kV
1	Andhra Pradesh	All DISCOMs	5	20	1350	4500
2	Assam	APDCL	5	25	1700	8500
3	Bihar	All DISCOMs	5	70	1350	9000
4	Chandigarh	Electricity Department	3	75	450	9000

[5] Karnataka used to give maximum of 30 kW from a 3-phase connection until recently; and in 2022 it has been increased to 150 kW under the Ease of Doing Business initiatives after ISGF brought this matter to the attention of senior management in BESCOM

5	Chhattisgarh	CSPDCL	3	112	450	13500
6	Delhi	All DISCOMs	10	200	3600	> 3600
7	Goa	Goa Electricity Department	5	90	4500	4500
8	Gujarat	All DISCOMs	6	100	3600	>3600
9	Haryana	All DISCOMs	5	50	4500	13500
10	Himachal Pradesh	HPSEB	15	50	2000	10000
11	Jammu& Kashmir	J&K PDD	5	100	900	9000
12	Jharkhand	JBVNL	5	85	1350	18000
13	Karnataka	All DISCOMs	5	150	1800	6750
14	Kerala	KSEB	5	90	2700	10800
15	Madhya Pradesh	All DISCOMs	3	112	240	8000
16	Maharashtra	All DISCOMs	10	160	22 kV: 2700	[6]9000
17	Odisha	All DISCOMs	5	63	999	9000
18	Punjab	PSPCL	7	100	3600	18000
19	Rajasthan	All DISCOMs	5	125	1350	4500
20	Sikkim	Energy and Power Department	5	22	>45	>45
21	Tamil Nadu	TANGEDCO	4	112	2700	9000
22	Telangana	All DISCOMs	15	56	2250	9000
23	Tripura	TSECL	5	50	1800	9000
24	Uttar Pradesh	All DISCOMs	4	48	2700	18000
25	Uttarakhand	UPCL	4	25	2700	9000
26	West Bengal	All DISCOMs	6	112	6kV: 2500	>2500
Many states have specified the ratings in kVA which is converted to kW considering the power factor at 0.9.						

Table 2: Power Connections allotted by Utilities in Foreign Countries

Details of Power Connections given by Utilities in Some Countries						
Sl No	**Country**	**Utility**	**Maximum Power per Connection (kW)**			
			Single Phase	**Three Phase**	**11 kV**	**33 kV**
1	China	SGCC	-	100	6.6kV: 1200 10kV: 2000	35kV: 10,000

2	Canada	Toronto Hydro	120V: 38	240V: 115	13.8kV: 500	27.6kV: 750
3	USA, California	PG&E	90	270	Different power limits for different voltage levels	
5	South Korea	KEPCO	100	500	NIL	22.9 kV: 10,000
6	Italy	ENEL	10	100	10,000	
7	Chile	ENEL	-	250	2000	-
8	UAE	ADDC	9	500	5000	15000
9	Brazil	ENEL		75	2500	

Several thousand EV charging stations are being installed in the country by different agencies. As per Ministry of Power rules, all public charging stations should have DC Fast Chargers (DCFC) of 50kW or more capacity. In USA, Europe and China, the DCFCs of 240 kW and 350 kW are widely deployed. The new EVs being launched have batteries capable of fast charging in 15 to 30 minutes.[7] For fast charging an EV with a 50 kWh battery in 15 minutes (4C battery), 200 kW charger is required. The investments being made today in PCS should be planned in such a way that those are not going to be obsolete in few years. People would not like to stay in a charging station for hours and most EV charging stations now being installed do not have basic facilities for the drivers – no waiting rooms, no toilets, no coffee/tea vending machines etc. Majority of them do not even have a shade to protect from rain and sun[8]. In fuel stations vehicles are refueled in less than 5 minutes; still most fuel stations have such facilities which is missing in EV charging stations. The latest trend in North America is super-fast charging with high power chargers and people are willing to pay higher fee for it. In certain instances, with fast driving and fast charging, energy cost of EV is higher than that of a diesel/petrol car[9].

1.2 Grid Strengthening to Meet the Increasing Cooling and (expected) Cooking Loads

The summer temperature has been on the rise constantly all across India. The maximum temperature in Delhi has increased by 7 degrees Celsius in the past three decades to exceed 49 degrees in 2022. At this rate before 2030, the summer temperature could be well over 50 degrees Celsius making it almost impossible for people to live, work or commute without cooling. Traditionally, space cooling in buildings is provided with room (window) air conditioner (AC) or centralized AC plants. With increasing economic prosperity, urbanization and rising temperatures, sale of AC units is set to increase exponentially. Installed stock of room ACs in India increased from two million units in 2006 to 30 million units in 2017 and is

[7] Battery's charging speed is referred as C-rate. If a battery can be fully charged in 1 hour, it is a 1C battery; and if it can be charged in 30 minutes, it is a 2C battery. Present generation of EVs in India have 0.3C batteries meaning it takes 3 hours to charge. New generation of EVs are likely to have 4C batteries that can be charged in 15 minutes; and the solid-state batteries that may be commercialized in the 2030s will have 10C or higher ratings

[8] At many EV charging locations in USA, Tesla has setup fancy lounges with toilet/resting facilities where people can buy food/drinks and children can play games. The tariff for charging in such places is more than the tariff at regular charging locations

[9] In USA, electricity cost per kWh at a Tesla Super Charger (240 kW) varies from US$ 0.24 to 0.59 per kWh depending on the location of the charger, the local utility's electricity tariff and the charging time (in some places time of use or ToU tariff is applicable). When an EV is driven at faster speeds (>100 kmph), the energy consumption is much higher than that at normal speeds

expected to be between 55 - 124 million by 2030. While nationally less than 10% of the urban households' own room ACs, in Delhi almost 30% households own ACs. Presently, ACs are accounting for up to 60 percent of the summertime electricity use in Delhi. Per another estimate, about 700 million new ACs by 2030 and 1.6 billion units by 2050 are expected to be added globally. 100 million ACs will be about 150 GW load on the grid[10].

Room ACs emit heat to the atmosphere creating heat islands in many localities in a city and increase the overall ambient temperature. District cooling systems (DCS) are being successfully implemented in many parts of the world and have evolved as a matured technology. The DCS presents an opportunity to address the space cooling challenge effectively in India[11] and also provides thermal storage that augment the flexibility of the electric grid. As mentioned in the beginning, the power connections given for rural electrification is 250 to 300 Watts which is not sufficient to run even desert coolers. Households and businesses will acquire desert coolers and ACs as their income level increases. The distribution grid strengthening being undertaken as part of the RDSS program[12] with the main focus to provide 24x7 reliable electricity supply should consider the potential growth of cooling load.

Another important factor to be considered is the shift to electric cooking. Globally, around 3 billion people cook using firewood, charcoal, biomass, dung cake or kerosene; and in India about 63 percentage of the rural and 18 percentage of the urban households use firewood or biomass for cooking. Over 1 million people die prematurely each year due to household air pollution in India as indoor PM2.5 in rural household's ranges from 106 to 512 µg/m³. Having electrified all the villages and connected 99 percentage of the households with the grid, transition to electric cooking is the way forward. Today, a large range of electric cooking appliances are available at affordable prices that can cook almost all items of any regional cuisines in the country[13]. Electric cooking is included in the GO ELECTRIC program of Government of India led by Bureau of Energy Efficiency (BEE). It is only a matter of time that households in urban and rural India will adopt electric cooking as it is the cleanest and cheapest method of cooking. The capital expenditure to strengthen the electric grid to provide minimum 3 kW to 5 kW connections to all households (3 kW in rural areas and hilly regions where air conditioning is not a key priority; and 5 kW in urban areas) in order to meet their cooking and cooling loads is a one-time expenditure and is much cheaper than the cost of laying piped gas connections to households[14]. Electricity is surplus during many time-slots during the day and it can be provided at discounted rates to customers during such periods of surplus generation. People can remotely operate their cooking appliances with the help of smart plugs[15] connected to the home WiFi. To meet Net Zero target, India must reduce or eliminate emissions from kitchens.

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[10] 100 million ACs would have a combined load of 150 GW considering average AC rating at 1.5 kW

[11] ISGF White Paper on DCS – https://indiasmartgrid.org/reports/ISGF%20White%20Paper%20on%20District%20Cooling%20Systems_Dec20.pdf

[12] RDSS is the new program launched by Government of India in 2021 with an investment of Rs 3.04 trillion that envisages to modernize the distribution grid and provide smart meters to 250 million customers on fast track

[13] The range of appliances include electric pressure cooker, induction cooktop, hot plate, kettle, microwave oven, electric oven, electric rice cooker, steam cooker, air fryer etc. Induction cooktops have a thermal efficiency of up to 84% which is twice of than that of gas cooktops; and electric pressure cooker has emerged as the most energy efficient device for cooking

[14] To provide piped LPG connections in urban and semi-urban areas, the cost of piped gas distribution network is estimated to be around INR 25,000 per household; and the gas need to be imported

[15] Smart plugs sold in India cost around INR 1000; and it can be connected to home WiFi and control remotely from the mobile apps

1.3 Importance of Network Automation and Self-Healing Grid

According to IEA projections in 2021, Indian power system is set to grow to 823 GW by 2030 and 1584 GW by 2040. Out of 1584 GW, 869 GW is expected to be renewable energy (RE) resources, mainly solar and wind. Considering the larger share of RE in the generation portfolio, IEA estimates ±85% flexibility for the Indian power system by 2040 which will be a huge challenge to manage. The grid modernization being undertaken as part of the RDSS program may be designed to enhance the capability of the grid to support flexibility in both generation and demand. Therefore, strengthening of distribution grid should focus on grid modernization to build flexibility in the power system which require equipment and systems that are interoperable, and capable of remotely monitoring and controlling. In order to achieve these functionalities, it is imperative to have standard specifications for all equipment and systems acquired under this scheme.[16]

A decade ago, MOP launched the RAPDRP program with two components – Part A: IT Enablement; and Part-B: Electric Network Strengthening. The Part-A of RAPDRP had a very detailed System Requirement Specifications (SRS) prepared by MOP, but there was no guidelines or specifications for Part-B for distribution network strengthening such as renovation of 11 kV substations and transformer centres, load bifurcation, feeder separation, load balancing, HVDS; and SCADA/DMS. In the absence of standard specifications, each eligible towns in a DISCOM prepared different Detailed Project Reports (DPR) and submitted to Power Finance Corporation (PFC), the then nodal agency for RAPDRP for allotment of funds. Though there was certain level of equipment price moderation done at PFC level, there was no standardization of equipment even at DISCOM level. The SCADA/DMS projects under RAPDRP also did not follow any standard specifications and as a result most of the SCADA/DMS projects implemented under RAPDRP are dysfunctional now. Drawing from the lessons of RAPDRP and the huge challenges in managing a rapidly growing power system with increasing share of RE resources, it is important to have standard technical specifications for key equipment and systems for grid strengthening under RDSS. This will ensure uniformity of technologies deployed for grid modernization and its compliance with applicable standards.

Power outages remain an important issue despite improvements in the quality of equipment and maintenance of the grid over the years. Recurring outages such as trees falling on power lines or vehicles knocking down poles and lightning strikes are ongoing challenges. Extreme weather events are occurring more frequently and are creating negative impact on the grid. Aging infrastructure leads to more outages and higher operational costs for utilities. All these factors lead to reduced reliability, cause inconvenience to customers and adversely impact the reliability indices (SAIDI, SAIFI, CAIDI, CAIFI[17]). Further complicating matters is the rapid growth of distributed energy resources (DER) with bidirectional power flows making outage restorations more difficult. Self-healing grid is the solution to address these issues effectively. A self-healing grid uses distribution automation to quickly isolate the affected area when a fault occurs; and restore power to rest of the areas immediately. Deployment of automation equipment such as auto-reclosers and sectionalizers, improves feeder segmentation, resulting in much fewer outages for customers upstream of the location of the fault. Sending maintenance crew to repair a fault or to perform

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[16] If it is difficult to have one standard specification for all equipment and systems across the country, at least one common minimum requirement/features must be introduced on fast track

[17] These are reliability indices of a utility monitored by regulators. SAIDI – system average interruption duration index; SAIFI – system average interruption frequency index; CAIDI – customer average interruption duration index; and CAIFI – customer average interruption frequency index

manual switching takes hours or sometimes days depending on the site conditions. With a self-healing grid, these faults are immediately identified, isolated, and restored to customers without any human intervention. The restoration logic is predefined and resides in the field devices themselves, which makes it fast, reliable, and easily scalable. Such systems use advanced controls, network communication, and distributed intelligence to quickly isolate a fault and then restore service to the maximum possible customers. The distributed approach places logic inside devices, improving scalability and enabling decisions to be made at the edge of the grid. Because communications are between local devices, decisions are made faster and more reliably, allowing for restoration times of less than a minute. Real-time loading and phase-loss isolation[18] features are also offered by all leading OEMs of self-healing grid solutions; and these systems offer interoperability with a wide array of new and existing compatible intelligent electronic devices of all makes.

DER can be managed efficiently by the distributed self-healing systems with islanding features. In addition to supporting bidirectional power flows and fault current, these systems can send and receive transfer trip commands to remove the distributed generation from the circuit when necessary. The distributed self-healing systems offer a wide variety of benefits to the utilities in terms of (i) Faster fault location, isolation and self-restoration of networks with no dependence on a complex centralized system, (ii) Interoperability with existing equipment, (iii) Support for post-restoration load management, (iv) Scalability, (v) Management of DER on the distribution grid; and (vi) Fast and easy system configuration tools with fault replay facility for training. The cost of the self-healing systems is only marginally higher with attractive payback period. As demand for such systems increases, there will be local production which will further drive down the cost.

2 Conclusion

ISGF invites the attention of policy makers and regulators to review the norms for electricity connections and take immediate steps to standardize the connection norms and equipment specifications. All new equipment deployed on the grid should have the features for remote monitoring and control so that the emerging green grids have adequate flexibility to accommodate distributed intermittent generation resources. Government of India has allowed private 5G networks for captive use and utilities must build their own private networks at marginal cost and connect all grid equipment and control them effectively in real time. Although we understand the diversity in load density[19] across a vast country like India, it will be beneficial in the long run to strengthen the distriubution grid to supply 5 kW to all customers in urban area and 3 kW to all in rural areas.

[18] Realtime Loading feature prevent overloading of the network during restoration after a fault. Phase-loss isolation feature use voltage sensing and peer-to-peer communications to detect and isolate potentially broken conductor or other conditions that cause loss of one or two phases

[19] While load density in Delhi is several MW per square kilometer area, is less than 100 kW in rural areas

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