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Energy Infrastructure II

One of the key starting points for the new Indian government is to critically analyse its performance and achievements vis-à-vis the development of energy infrastructure in the country. Energy shortages in India have increased from about 7% in 2003/04 to nearly 12% in 2008/09, after nearly Rs 200 000 crores have been allotted to the power sector in the annual plans covered in this period. Not surprising, given that we have added a mere 6000–7000 MW a year in this period against the required capacity addition of 18 000–20 000 MW per year!

The Hon'ble Minister for Power, Mr Sushilkumar Shinde, recently stated that under its rural electrification programme, the Ministry has brought electricity to over 61 000 villages against targeted 1.18 lakh villages. We have struggled with the definition of rural electrification for decades moving from defining electrification as the presence of an electricity pole at a certain distance from a village to a small percentage of households in a village being connected to the grid! Today too, unfortunately, we seem to be happy with measuring progress as the relatively-easier-to-achieve physical infrastructure extension rather than measuring ourselves against the actual delivery of services that need to flow through this physical infrastructure or the impact on alleviating the drudgery of rural poor.

In the 2009/10 finance budget, the Government of India announced a major increase in the funding for the APDRP (Accelerated Power Development and Reform Programme). The allocation for the APDRP saw a steep 160% increase over the budget for 2008/09. While this is a positive development, it is also essential that these financial resources are used most efficiently. The APDRP, launched in 2002/03 has so far released nearly Rs 10 000 crores to the states. The aggregated technical and commercial losses however still hover in the range of 33%–35%.

Today, there is obviously a great emphasis on infrastructure development – both in recognition of its contribution to India's economic growth as well as the role it can play in creating a momentum for recovery from the financial crisis. With huge resources being earmarked for this purpose and concerted efforts towards accelerating the implementation of infrastructure projects, energy infrastructure projects in particular, India urgently needs to re-focus its metrics of performance and achievement to start making a real difference to the lives of people. So long, we have pursued a target-based approach to development, focusing on physical parameters with scant concern for quality of life issues. The Government, in its fresh lease of life, can make this quantum leap towards demonstrating its desire to bring real change instead of merely relying on statistical achievements.

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Ensuring energy security: challenges in power transmission

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The power grid infrastructure has a crucial role to play in ensuring sustainable development and optimal utilization of a country's energy resources. Its role is all the more important in large countries like India, which have uneven distribution of energy resources and high diversity in the pattern of demand across the country. Transmission of power through wire is becoming a better alternative than transportation of fuel in many cases, both from the economic and environmental points of view. Development of an efficient power grid that matches the growth in generation and demand is, however, a complex task and differs in many respects from other energy transportation networks.[1] The challenges in this regard have acquired further significance in recent years, with the opening up of the electricity market, and the consequent changes that are taking place in the industry and regulatory structure as well as in the commercial orientation of the utilities. How well we address these challenges will have a significant bearing on the success of our efforts towards building power grid infrastructure.

Prevailing scenario

The power grid network of the country today comprises an intricate web of transmission lines, with line length over 210 000 circuit kilometres and associated substations with capacity over 290 000 MVA, owned and operated by central sector and state sector agencies and a few private ventures, and spread over the five power regions of the country.[2] Four regional grids, that is, the Northern, Eastern, North-eastern and Western grids, are operating as one synchronous grid and are connected to the Southern grid through asynchronous ties. An inter-regional power transmission capacity of 20 750 MW has already been established. The power grid network also transcends the national boundary, being operational in Bhutan and Nepal.

There has been a need-based introduction of new technologies. The voltage levels of transmission systems have progressively increased with the growth in demand, quantum of power to be transmitted, and the spatial expanse of the network. A fairly well-knit 400 kV system constitutes the backbone of the national grid, which is supported by 765 kV and 500 kV HVDC (high voltage, direct current) systems. There is an increased use of power electronics and IT systems for better monitoring and control and to attain flexibility in operation.

The structure of the industry and the power market as well as the regulatory environment has gone through significant changes over the years. As mandated by the Electricity Act, 2003, vertically integrated utilities have been unbundled and power transmission is today purely an organized business regulated by the appropriate regulatory commissions. The transmission systems have to provide non-discriminatory open access to suppliers and consumers, and should cater to not only long-term power contracts but also to the requirements of the emerging short-term power markets. While long-term perspective plans are

[1] For example, in large interconnected networks, it is difficult to identify a clear 'contract path' for power flows between two entities because power flows in different parts of a network at any point of time are governed by the laws of physics, and are subject to changes as and when the patterns of generation and load or network topology change. Further, as electricity travels almost at the speed of light, any sudden change in the power flows, caused by internal or external factors, may affect the stability of the entire power system. Similarly, since the networks are mostly overhead issues related to ROW (right-of-way), landscaping and safety aspects are high.

[2] In the mid-1960s, the country was divided into five regions, namely, the Northern, Western, Southern, Eastern and North-eastern Regions. This led to the development of regional power grids, which have been progressively strengthened, along with the establishment of inter-regional interconnections. A national power grid is in the process of evolution.

formulated by the CEA (Central Electricity Authority) in consultation with all stakeholders, the systems are owned and operated by different agencies in the state, central, and private[3] sector.

Looking ahead

The power grid infrastructure of the country is poised to grow in a big way in the coming years. According to the Eleventh Plan targets, the transmission line lengths at 220 kV and above, and the associated substation capacity, are expected to increase to over 290 000 circuit kilometres and 440 000 MVA, respectively. The needs of the emerging power market are also likely to become more demanding. If these are not adequately met, it could result in poor grid reliability, higher losses and congestions in the network, with consequent adverse impacts in market development. The challenges in this regard are no doubt daunting and need to be carefully assessed. These relate to a host of issues like system planning, ROW (right-of-way) issues, transmission pricing, mobilization of finances, and equipment availability, which are discussed subsequently.

System planning

For the optimal planning of any power grid, reliable data on the schedule of generating capacity additions and growth in power demand are basic necessities. Past experience shows that there have been difficulties in this regard. Large lapses in generation capacity additions and wide variations in load growth, in terms of magnitude and location, are often noticed, leading to problems in power evacuation and recovery of costs. With around 80 000 MW capacity addition planned in the Eleventh Plan, the consequences of these lapses could be all the more serious. Similarly, increases in short-term transactions through the trader route and power exchange, and the establishment of MPP (merchant power plants), where the consumers are not identified in advance, are likely to add another dimension to the uncertainties. Pragmatic strategies are required to address these challenges. These include (1) adoption of scenario techniques; (2) periodic review of plans; (3) selecting technologies that would help upgrade the transmission capabilities and provide flexibility in operation; and (4) creation of power pooling points at suitable locations which could be connected to the MPP and other large power generating clusters, the national power grid, and respective end-use sectors.

Planning and implementation of transmission systems that ensure open access are also presenting some unique challenges, as the utilities are unbundled; for example, if an IPP (independent power producer) approaches the concerned transmission utilities for open access at a late stage when the construction of generation project has already commenced, as has been reported in a number of cases. It is important to note here that transmission systems have their own gestation period, depending on their length, terrain, and technology. The need for an agency to ensure coordinated development of generation and transmission facilities is apparent in this context. Yet another emerging issue relates to the likely need for increased grid penetration of generators based on renewable energy resources. This assumes added importance in the context of the conscious efforts the country has been making in recent years to promote renewable energy resources. Special considerations will be required in the planning and operation of grid-connected renewable generation in view of the intermittency in their output and location specificities.

Right-of-way issues

The ROW problems merit special attention in transmission system planning, as the lines traverse wide stretches of the country. These could be by way of forest areas, limitations in land availability, including priorities in usage, protected structures en-route, and so on. Past experience shows that many states have been facing problems in this regard even for laying minor lines. There have also been cases wherein ROW issues have led to time and cost over-runs in commissioning of projects and a need to re-route the lines or relocate substations.

[3] The sector was opened up for private participation in 1998. However, the response in this regard has been rather limited.

Compensation issues related to land and tree cutting, delays in obtaining statutory clearances from the Ministry of Environment and Forests and, in a few cases, law and order problems have also been of concern. The problems in this regard are likely to increase manifold in the context of supplying power from large hydropower stations in the Northern and North-eastern regions and importing power from Bhutan and Nepal. The establishment of UMPP (ultra mega power projects) and the fast growth of demand in already congested cities also present unique challenges in optimally utilizing the limited land route. Further, the route should cater to not only the power transfers presently projected but also to the needs that may come up in the future. The competing requirements of other infrastructure users for the same route should also be taken into consideration. In order to ensure requisite level of system availability, it may also be necessary to provide route diversity in certain sections depending on the terrain. It is, therefore, necessary to ensure that adequate route surveys are undertaken right at the planning stage and clearance procedures are streamlined. A long-term vision for the conservation of ROW also assumes importance in this context. The measures that merit consideration in this regard include (1) prospecting the power transfer requirements beyond the time horizon of the planning studies, considering a river basin approach in hydropower development, and likely addition of other large generation projects; (2) use of high loadability lines, compact towers, and substations; (3) adding flexibility in design, with possibilities of operating at higher voltages, if necessary in future, use of power electronic devices, and so on; and (4) use of underground systems in congested parts of cities, where required.

Transmission pricing

Ideally, the approach to transmission pricing should be such that it is cost-reflective, with appropriate incentives for timely and efficient investments; reflects the actual use of network; facilitates development of a competitive market; provides appropriate signals for the location of new generators and loads; and, above all, is simple in implementation. But achieving all these goals is not easy. For example, as mentioned earlier, the power flows in a meshed network are always dynamic in nature, and hence, it is difficult to provide dedicated transmission facilities to different users over the entire grid, valid for a period of time. International experience shows that various approaches like national or regional postage stamps, zonal matrix stamps, nodal pricing, contract path or their variants are being followed. None of these approaches is perfect and each has its own merits and demerits. Traditionally, in India, we have been following a postage stamp approach by pooling the transmission charges in a particular region or state. A pseudo contract path approach is also adopted in some cases. Some notional distinctions are also being made between those availing transmission services on long- and short-term basis. These approaches are simple but do not meet the other objectives of tariff setting. There is also a need to develop rational approaches for sharing of transmission losses. These are the areas that require further debate and research, especially with increased commercial focus on system operation. No doubt, it will be prudent to adopt a rather cautious approach in this regard and to avoid hasty actions which could lead to intractable complications.

Grid operation

With the opening of markets, and more players getting into the business of generation, transmission, distribution, and trading, the task of grid operation has become extremely important. In fact, a recent report of the Expert Committee of the MOP (Ministry of Power)[4] has recognized this activity as 'mission critical activity' for uninterrupted and reliable power supply. It also acts as a 'facilitator' for an efficient electricity market; an 'optimizer' of precious power generating resources; an 'instrument' for equitable and fair use of the available transmission infrastructure; and an 'indispensable

[4] Report of the Committee on Manpower, Certification and Incentives for System Operation and Ring Fencing Load Dispatch Centres, August 2008

link' between the managers, administrators, planners, and regulators on one end and the physical system on the other end. Establishing a hierarchical network of load dispatch centres equipped with state-of-the-art facilities and ensuring that the centres function in an efficient, neutral, transparent, and accountable manner assume special significance in this context. While considerable progress has been made in this regard at the national and regional levels, much remains to be done in many states. This mismatch has to be corrected at the earliest, since the different load dispatch centres have to perform in an orchestrated manner. The recommendations of the MOP committee, which have since been endorsed by the state governments and state regulators, need to be closely followed up to achieve this goal. An ISO (independent system operation) agency manned by grid operators, who possess a high level of professional competency and ethical values, also merits emphasis in this context.

Mobilization of finances

Power transmission is a capital-intensive activity and hence needs adequate funds that are in consonance with the investments in generation capacity additions and commensurate with the reliability requirements. Estimates for the Eleventh Plan indicate requirements to the tune of Rs 1400 million. It is obvious that public sector entities alone cannot mobilize such large funds. Private sector participation, apart from creating competition, becomes essential in this context. Today, an adequate administrative and legal framework exists to attract private investment. Private sector participation can be in the form of either an independent private transmission company or as joint venture with a public sector company. MOP has also issued guidelines for competitive bidding, and an empowered committee has been set up for identifying projects and facilitating signing of requisite transmission service agreements. So far, however, very few projects have fructified. Special attention needs to be paid to address the constraints in this regard. Also, since the transmission systems of the future are likely to be owned and operated by a number of different agencies in an inter-meshed manner, it would be necessary to ensure that the technical parameters, including the protection and control facilities, are well coordinated. Considering this requirement as well as the ROW issues,[5] a public-private participation model appears advantageous for private sector participation in power transmission.

Equipment availability

The demand for power transmission equipment is expected to increase appreciably in the light of the projected growth in transmission capacity. The funds allocated for power transmission in the Eleventh Plan, which is about 2.8 times more than the allocation in the Tenth Plan, is also an indicator of this trend. Ensuring timely availability of transmission equipment assumes utmost importance in this context. In the past, there have been difficulties in this regard. As per reports, there is a dearth of suppliers for ancillary equipment like capacitors, reactors, and control systems, and there is high dependence on imports. There are also concerns about after-sales service (Thukral and Himani 2006). There is also a growing need for the induction of new technologies and for ensuring compatibility with existing equipment. This calls for concerted action on the part of manufacturers to accelerate growth of their domestic manufacturing base, besides establishing adequate testing laboratories and service facilities. Attention should also be paid to streamline the process of ordering for equipment, which would help the manufacturers to plan their production schedules better and meet delivery schedules in time.

Conclusion

Power transmission constitutes an important component of the energy supply chain and hence needs special focus in our quest to promote energy security. The Indian power sector has been, over the years, making concerted efforts towards building a robust national power grid. While the progress made is encouraging, much

[5] Unlike generation projects, which are generally confined to a defined area, transmission lines run cross-country and hence have a new dimension of challenges related to right-of-way.

remains to be done. The liberalization of the electricity market has also thrown up many challenges related to planning and operation of systems, ROW issues, regulatory approaches, mobilization of finances, and equipment availability. It has also brought into focus the need for a long-term vision, added flexibility in design, induction of new technologies, review of tariff setting principles, and increased private sector participation. Pragmatic policies suited to the specific needs of the situation are required to address these issues. The projected growth of transmission systems also points towards a fast growing market for power transmission equipment, which calls for an accelerated growth of the domestic manufacturing base. An exciting future can be foreseen for the power sector with many challenges and opportunities.

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Tackling the challenge of distribution losses

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Introduction

Almost all State Electricity Boards/Distribution Companies in India are facing financial crises and continue to be plagued by energy shortages and poor quality of supply. One of the main reasons for this precarious situation is the high level of T&D (Transmission and Distribution) losses. According to the CEA (Central Electricity Authority), the electricity lost in transformation, transmission and distribution systems, and electricity unaccounted for, has been estimated to be around 27% during the year 2007-08. Out of this about 7% can be safely assumed as transmission loss. From the balance 20% distribution losses in the country, about 60% are losses due to commercial reasons, and the remaining losses are due to technical reasons.

However, the total system loss level in India varies in the range of 14% to 70% in various states/distribution companies whereas losses reported in other developed and developing countries range from 4% to 15%.

Existing scenario

The resurrection of the power sector depends to a large extent on how fast and by how much distribution losses can be reduced. It is well known that high distribution losses are the result of factors like inadequate investments in distribution facilities, lack of proper distribution planning, defective metering, unmetered supply, pilferage, and so on. Pilferage or theft is a significant contributor to this and causes a financial loss of approximately 10 billion rupees a year to the nation. Studies have shown that theft is not restricted to slums, unauthorized colonies, and so on, but also extends to posh localities, and large commercial, industrial establishments. The means adopted may vary from simple hooking to open wires and other ingenious ones.

Anomalies in distribution loss computation

A substantial portion of distribution loss including theft of electricity gets attributed to agricultural/un-metered consumption. Most of the agricultural consumption is unmetered and is estimated to be around 20%–25%. Therefore, the distribution utilities tend to manipulate these estimates to increase/decrease the distribution loss to suit their convenience.

Further, distribution losses are being computed taking into account electricity bills issued to consumers and not on actual collection. Therefore, the distribution loss figure does not capture the gap between billing and collection, apart from large amount of theft.

To tide over this problem, the concept of AT&C (aggregate technical and commercial) losses has been introduced. The estimation of AT&C losses involve following estimation.

1 Distribution and billing losses - Difference of units input and units billed.
2 Collection efficiency - Ratio of amount collected and amount billed.
3 Units realized - Product of units billed and collection efficiency.
4 AT&C losses - Difference of units input and units realized.

AT&C losses reported in the country were estimated to be about 32% during 2006–07.

Factors contributing to high distribution losses

Distribution losses can be further bifurcated into technical and commercial components. A clear understanding of the magnitude of technical and commercial losses is the first step in the direction of reducing them.

Technical losses

Technical losses are due to energy dissipated in conductors and equipment used for transmission, transformation and distribution of power. These result from

- improper construction and maintenance of distribution lines/transformers and inadequate investment on technology up-gradation of old distribution systems.
- Haphazard growth of sub-transmission and distribution systems with short-term objective of extension of power supply to new areas which leads to inadequate layout of feeders and uneconomic conductor size.
- Large-scale rural electrification through long 11kV and LT (low tension) lines.
- High LT:HT ratio.
- Uneven distribution of load on various feeders and sub-stations.
- Inadequate reactive compensation during low voltage conditions of network.
- Poor quality of construction material used in equipment manufacturing (specially for equipment used in agricultural pumping in rural areas).

Commercial losses

Commercial losses are caused due to pilferage, defective meters, and errors in meter readings and estimation of unmetered supply of energy. Theft and pilferage account for a substantial part of distribution commercial losses in India. Anti-social elements avail unauthorized/unrecorded supply by hooking or tapping bare conductors of LT feeder or tampered service wires. Some of the bonafide consumers wilfully commit pilferage by way of damaging and/or creating disturbances to measuring equipment installed at their premises.

Some of the modes for illegal abstraction or consumption of electricity are mentioned below.

- Unauthorized extensions of load.
- Changing the sequence of terminal wiring and changing current transformer ratio
- Errors in meter reading and recording.
- Improper testing and calibration of meters.
- Unmetered consumption for agricultural purposes.

Steps taken to reduce losses

The ongoing reform programme lays special emphasis on curbing theft through various technical measures as well as appropriate legal and legislative measures. The Electricity Act 2003 as amended recently by Electricity (Amendment) Act 2007 also addresses this issue comprehensively. Section 135 of the Act lays down penalties for unauthorized use of electricity. Alongside, the governments and utilities have also taken a number of innovative steps to curb power theft.

The National Tariff Policy addresses issues related to T&D losses.

- Loss reduction to be incentivized;
- Imposition of area/locality specific surcharge for greater ATC loss levels which could generate local consensus for effective action for better governance;

- Incentive and disincentive scheme for the staff of utilities linked to reduction in losses, and segregation of technical losses and reduction of technical losses to be treated as distinct from commercial loss reduction.

That losses are a major concern for viability of electricity distribution is reflected in the pages of the Act and in other policies.

The following steps are integral to technical and commercial loss mitigation

Technical

- Strengthening of distribution network.
- Use of low loss transformers.
- Introduction of HVDS (high voltage distribution system) network.
- Reducing LT line lengths by relocation of distribution sub-stations/installation of additional sub-stations.
- Smoothening the unbalancing of loads.
- Undertaking comprehensive energy audits to identify high loss areas.
- Preparation of long-term plans for phased strengthening.

Commercial

- Extensive public awareness campaign covering print and electronic media.
- Setting up vigilance squads to check and prevent pilferage of energy.
- Imposition of severe penalties for tampering with meter seals.
- Theft cases to be followed up vigorously at appropriate forums.
- Energy audits to be made obligatory.
- Installation of tamper-proof meter boxes and use of tamper-proof numbered seals.
- Installation of tamper-proof meters.
- Schemes for incentive awards for utilities which are able to reduce T&D losses beyond a certain pre-fixed limit.
- Prevention of collusion with meter readers of distribution companies.
- Exemplary punishments and stringent penalties for power theft.

Results from some utilities

Some utilities in various states of the country have shown marked improvement in reduction of losses. Utilities in Andhra Pradesh, Delhi, Karnataka, West Bengal, and so on, have achieved good results. This has been made possible with intensive checking of meters, surprise inspections, technological upgradation, extensive public awareness programmes and administrative support from the authorities. Many more utilities have initiated activities geared towards loss reduction.

Recommendations

- In the absence of a realistic estimate of T&D losses, it is not possible for Regulatory Commissions to correctly estimate revenue requirements, formulate tariffs, and implement multi-year tariffs. The aim of Regulators must be to encourage the utility to make every effort to reduce losses while at the same time ensuring that the viability of the utility is not threatened.
- Utilities should be provided with incentives to reduce T&D losses.
- It should be made mandatory for all big industries as well as utilities to carry out energy audits of their systems in order to identify high loss areas, and take remedial measures to reduce the same.
- The central or state governments should draw plans to provide financial support to utilities for installation of meters on at least all distribution transformers in a phased manner.
- Financial institutions should be encouraged to provide easy loans to utilities for taking action to reduce T&D losses.
- Publicity campaigns should be carried out to make the consumer aware of the high penalties for unauthorized use of electricity.
- Utilities should prepare realistic power master plans for their systems to develop a strategy to meet the growing electricity demand of different sectors of the state's economy over the next 15 years.
- An MIS (Management Information System) should be built for collecting and maintaining energy data, consumer data, network data, and equipment parameter data.

Conclusion

Power distribution is an important aspect of energy security, and therefore needs special attention. Inadequate planning and lack of investment in the electricity distribution sector has resulted in high distribution losses. The recommendations indicated above would help in reducing distribution losses to an acceptable level thereby improving the quality of supply and increasing availability of power.

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Improving rural electricity access through distributed generation

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Introduction

'Electricity' is a concurrent subject in the Constitution of India, with both Parliament and the state legislatures empowered to make laws on the subject. Both the central and state governments made conscious efforts since the beginning of planned economic development in the country in 1951 to make substantial improvements in the electricity infrastructure in terms of availability and access. Over the years, a number of programmes (such as Kutir Jyoti, Minimum Needs Programme, Accelerated Rural Electrification Programme, and so on) attempted to enhance electricity access either as part of overall rural development or specifically targeting rural electrification. However, the multiplicity of programmes made funding for each programme inadequate, and programme implementation lacked coordination. Though the rural electrification level has increased considerably in terms of coverage, from 1500 villages in 1947 to about half a million villages in 2008, there are still problems in terms of increasing energy and peak shortage, high AT&C (aggregate technical and commercial) losses, and, above all, low rural electricity access and per capita consumption.

Rajiv Gandhi Grameen Vidyutikaran Yojana: underlying objectives

To improve access and achieve complete electrification in the country, the Rajiv Gandhi Grameen Vidyutikaran Yojana, or RGGVY, was launched in April 2005 for attaining the goal of providing access to electricity to all households, electrifying about 115 000 un-electrified villages, and providing electricity connection to 23.4 million BPL (below poverty line) households by 2009. The RGGVY attempted to address common constraints such as poor network, lack of maintenance, low load density with high AT&C (aggregate technical and commercial) losses, high cost of delivery, and poor quality of power supply. Instead of only village electrification, RGGVY emphasized on rural development, employment generation, and poverty alleviation by endeavouring to provide electricity access to all rural households (inclusive of BPL households), catering to the requirements of agriculture, small and micro enterprises, cold chains, health care facilities, the education sector, and the information technology sector. The RGGVY is in its fifth year of implementation and statistics on access to electricity services indicate that only 62 520 un-electrified villages and 6 252 890 BPL households have been covered as of 1 July 2009,[1] out of the targeted BPL households.

The RGGVY also faces the critical challenge of supplying electricity through the newly created and/or upgraded distribution infrastructure – a challenge that needs to be addressed for the programme to continue in a meaningful manner. Given the current and projected demand-supply scenario, there are concerns over providing sustained electricity supply to rural areas and ensuring the minimum lifeline consumption of 1 unit (kWh) per household per day as a merit good by year 2012, as envisaged under the Rural Electrification Policy of the Government of India. Even a dedicated centralized generation capacity may not ensure supply to its villages. A possible solution lies in the RGGVY scheme itself, which includes the implementation of DG (distributed generation) projects. Though the scheme only provides for implementing DG projects for electrification of villages/hamlets, where grid supply may not be techno-economically viable, renewable-energy-based DG projects could also be tried in public-private partnership model in areas where adequate renewable energy resources are available to support these projects.

Despite a rich history of promotion of decentralized renewable energy technologies in the country, the DG component has not been given due importance during the initial phase of the RGGVY. Reasons may include limited experience of the mainstream power sector in using DG technologies, lack of an efficient network for supply and post-installation maintenance, variation in renewable resource availability, and so on. However, one of the critical reasons appears to be the notion that renewable energy needs to be promoted only by the concerned ministry and departments. This approach has restricted the market for renewable-energy-based DG for rural electrification and has also left the problem of 'last mile' connectivity in the RGGVY unaddressed. The guidelines for village electrification through decentralized DG under the RGGVY in the Eleventh Plan were released in January 2009, for villages where grid connectivity is either not feasible or not cost-effective. Though the implementation of DG projects under the RGGVY has been restricted to stand-alone mode only, it is expected that grid-connected DG systems based on local resource availability will also be mainstreamed in the national rural electrification programme of India in the near future, so as to address the issues of availability and quality of power in rural India.

What is distributed generation?

The expression DG is used very widely in the relevant technical literature on the subject. In the literature, a large number of terms and definitions are used in relation to DG. Arthur D Little has defined DG as integrated or stand-alone, small, modular electric generation device close to the point of consumption (Little 1999). The IEEE (Institute of Electrical and Electronics Engineers) defines DG as the generation of electricity by facilities that are sufficiently smaller than central generating plants so as to allow interconnection at nearly any point in a power system (Dondi, *et al*. 2002). A review of the various definitions of DG leads to the broad definition proposed by Ackermann, *et al.* (2001), who defined DG in terms of connection and location rather than in terms of generation capacity. Ackerman, *et al.*, suggested that DG be defined as the installation and operation of electric power generation units connected directly to the distribution network or connected to the network on the consumer site.

In India, the first attempt to define DG was made by the Gokak Committee. It defined DG as modular power generating technologies that can be combined with energy management and storage systems, and used to improve the operations of the electricity delivery systems, whether or not these technologies are connected to an electric grid.

[1] <http://powermin.gov.in/bharatnirman/pdf/MIS_of_RGGVY.pdf>, last accessed on 20 July 2009.

Advantages of DG

The advantages of DG can be summed up as follows.

- DG can generate and distribute power to supplement the grid and ease the problem of peaking shortages.
- The DG units are closer to consumers, so T&D (transmission and distribution) costs and losses are reduced.
- The transmission grid benefits by way of reduction in upstream congestion, optimal use, and improved grid reliability.
- DG units can improve tail-end voltage through better energy and load management, and ensure faster response to new power demands, thereby improving distribution system reliability.
- DG projects can be set up with lower gestation period.
- The renewable-energy-based DG technologies are generally without any environmental impacts.

Although there are many technologies (either based on the prime movers used, such as engines, turbines, fuel cells; or based on fuel sources, both renewable and non-renewable) available for DG schemes, the solution to electricity access does not lie in selecting the winning technological innovation alone, but also in developing mechanisms for effective delivery of services.

Why distributed generation?

DG, both decentralized and grid-connected, is very relevant for India to assist in achieving cent percent village and household electrification, and to supply quality power at more economical rates on cost to serve/avoided cost basis. Though there are many challenges, it will supplement and compliment the RGGVY in the following manner.

- For meeting 'last-mile' challenges in the RGGVY, which refers to those villages where grid extension is currently not cost-effective or feasible.
- For managing periods of low demand.
- For providing electricity in de-electrified villages.
- For preventing de-electrification of newly electrified villages by improving supply.
- For augmenting need-based electricity supply in electrified villages for achieving better health care, education, and community services.
- For providing dedicated power to livelihood activities such as food processing, rice hulling, and so on.
- For meeting universal service obligations by improving household electrification level in electrified villages where households are scattered.

Grid-connected vis-à-vis stand-alone systems

Even though both grid-connected and stand-alone decentralized systems have their own advantages and disadvantages, the choice depends on a number of factors. Connectivity to the grid enables setting up relatively large-scale systems, and hence, they can operate at high plant load factors, improving the economic viability of operation. Therefore, low load factors, which are typical characteristics of the rural electricity scenario, do not affect grid-connected systems, since the grid acts as storage unit, facilitating continuous operation of the system and also eliminating additional costs on storage batteries in case of wind and solar PV (photovoltaic). As a result, the overall efficiency of a grid-connected system is better than the efficiency of a stand-alone system. In grid-connected mode, two types of systems can be used. In the first type, the priority is to cater to the local needs for electricity, and any surplus generation is fed into the grid, and when there is shortage, electricity is drawn from the grid. In the second option, projects are installed in the same way as large electric power plants. The output of these power plants is fed into the central utility grid, without paying heed to local needs.

Stand-alone systems are preferred when accessibility is the central issue, and the extension of the grid to hilly and remote places becomes prohibitively expensive. Some of the important DG technologies available for use either in grid-connected or stand-alone mode, along with their features, are summarized in Table 1.

Table 1 Comparative description of different decentralized technologies

Technology	*Features*	*Suitable mode*
Small and mini hydropower	The system is classified as small hydro if the system size varies between 2.5 MW and 25 MW; size of the mini hydro is hydropower typically below 2 MW; size of micro hydro schemes is below 200 kW and that of pico-hydro is below 10 kW capacity. The PLF (plant load factor) is usually, low with cost of electricity varying between Rs 2/kWh and 4/kWh, depending on sites.	Both grid-connected and stand-alone (micro grid).
Solar PV (photovoltaic) power	Efficiency of commercially available solar photovoltaic varies between 7% and 12%. Because of its high initial investment, cost of generation per kWh becomes high (Rs 15-20/kWh), making it unaffordable. Solar PV is highly dependent on local weather conditions and requires battery storage for stand-alone mode.	Usually stand-alone; grid-connected projects being installed in the country.
Wind power	Similar to PV systems, wind energy systems are also site and season specific, with low PLF. Wind energy systems mostly operate in grid-connected mode, but isolated systems are operated to provide electricity for water pumping in few villages only.	Grid-connected
Biomass gasification	Producer gas is the consequence of modern use of biomass and its conversion to higher forms of gaseous fuel through the process of gasification. System size ranges between 10 kW and 1000 kW, with electric conversion efficiency in the range of 15%–25% and specific fuel consumption 1.4–2.0 kg biomass/kWh. In dual fuel system, biomass can replace about 50%–70% of diesel consumption. Cost of generation is between Rs 3/kWh and 8/kWh, depending on capacity utilization factor.	Usually stand-alone
Co-generation/ biomass combustion	The important co-generation technologies are bagasse co-generation, steam turbine combined heat, and gas turbine combined heat. The average electric conversion efficiency of such systems is estimated to be 20%–40%. The application range is 5-50 MW, with cost of generation in the range of Rs 3-4/kWh.	Usually grid-connected
Biogas	The gas that is produced through anaerobic digestion of biomass and other wastes like vegetable residues, animal dung, and so on is called biogas. Biogas generally is 60% methane and 40% carbon dioxide.	Usually stand-alone

Figure 1 (based on a study by TERI in rural Rajasthan in 2004) presents the relevance of DG sector in the current scenario, where the aspirations of rural communities and status of the electricity sector per se demand innovative approaches that go beyond past experiences of using renewables either in isolated energy projects or off-grid mini-grids meeting limited requirements of the community.

Viability of DG

The relative economics of renewables-based DG is important in normal electrification scenarios. DG becomes techno-economically viable and attractive where cost to serve is high such as areas with low load density, high T&D losses, and chronic shortage of supply or cases where physical barriers such as swampy land, mountain ranges, rivers, or protected forests hamper the extension of the grid. The viability can be increased further if DG projects can be

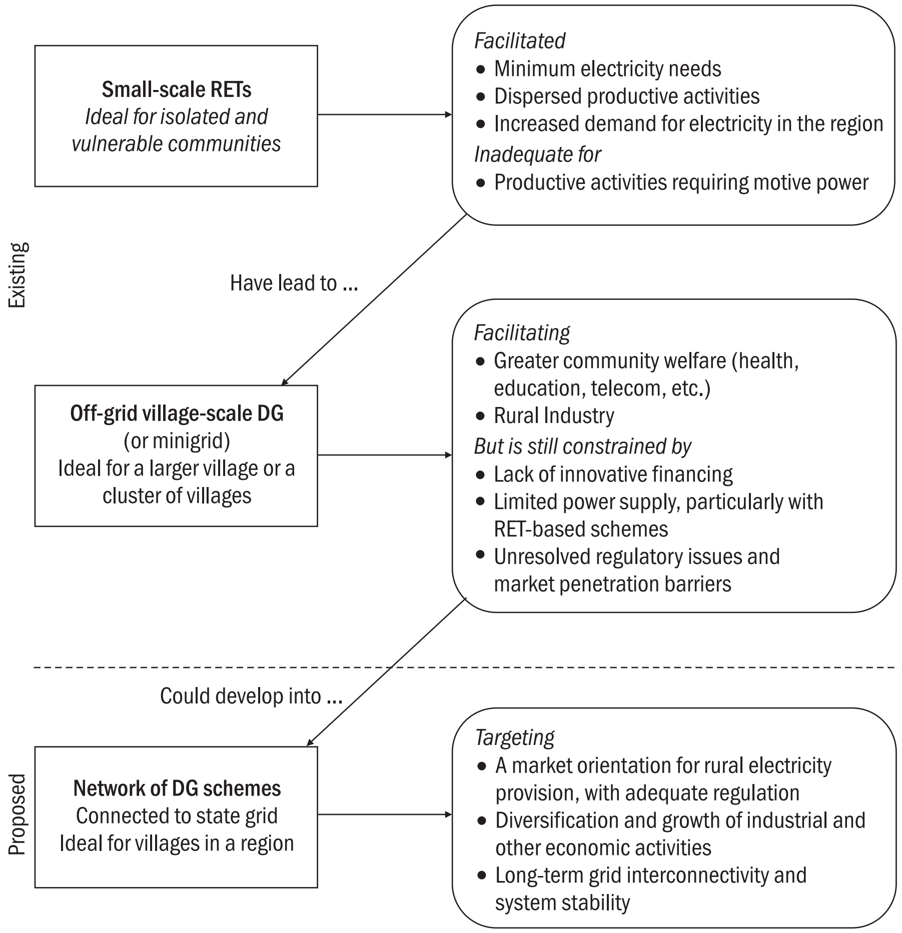

Figure 1 Framework of DG schemes for electricity provision in remote rural areas

developed in hybrid mode either with the grid or hybrids of different DG technologies (such as solar-biomass gasifier, solar gasifier-wind aero generators, gasifier-micro/pico hydro, and so on) can be employed, depending on the resources available at a particular location. In case of grid-connected DG systems, the cost of power could be determined on weighted average basis of power supply from the grid and DG, based on average hours of supply from the two sources. This combination will also help in the optimal use of the available renewable energy resources. Renewable-energy-based DG projects also have the added benefit of carbon finance through bundling or programmatic CDM (Clean Development Mechanism) to increase its viability. Even as a pre-electrification option in remote areas, DG would be a viable option on account of the following.

- In a time span of five years (say) till the grid reaches a particular village, a 50 kWp biomass gasifier project would have generated about 0.6 million kWh of electricity (operating at about 80% of the rated capacity and eight hours of operation/day) or would have saved 0.75 million kWh of electricity (considering a T&D loss of about 25% to take the power to a remote village from the nearest transmission substation), which can be used by the utility for some other applications.
- If these saved units are given to the industry, which currently depends on diesel generation systems, it would amount to a saving of about 250 000 litres of diesel fuel.
- If the grid reaches the village, the plant can be (1) synchronized with the grid, employed for feeding electricity to the grid, and used to provide tail end voltage support to the grid; (2) used as a DSM (demand side management) option to run some dedicated loads; or (3) shifted to an alternate site where grid is not available.

- In a time span of five years, the DG plant would have facilitated the creation (or growth) of loads that would enhance the viability of grid extension in the future.
- In the time span of five years, the cost to society and to the nation of not having an opportunity for socio-economic development would justify the investment on the DG project today.
- Being modular in nature, the capacity can be enhanced for any additional load that may develop within the five-year time frame, without actually losing money on dismantling old equipment or on the distribution network.

The way forward

The RGGVY works on the cost recovery approach, for which true cost to serve needs to be correctly estimated, and the implementation strategy for DG projects should be based on the cost to serve/avoided cost basis. If investment decisions are made on the basis of cost to serve figures, grid extension may not be found viable in many of the remote villages in India. Bundling of delivery of other services and establishing linkages with other developmental and entrepreneurial programmes can further enhance the revenue sustainability of such projects.

Project developers from both private sectors and NGOs can be involved for setting up DG projects. While project developers can take the overall responsibility of implementing and operating DG projects, the existing rural electricity distribution franchisee's role can be extended to the DG project. In such an arrangement, the franchisee not only benefits by adding more energy services to its portfolio, the operation and maintenance aspects can be taken care of by them too. Eventually, the input-based franchisee can set up the DG plant and supply electricity directly to the consumers in notified rural areas, where no distribution license is required. Such an institutional model will also ensure single point accountability for providing electricity services, irrespective of the technology or the option used.

However, for any such decentralized systems to fulfill the demand of the consumers, adequate measures have to be taken to make the supply chain effective and reliable. The creation of such an infrastructure and maintaining the required degree of reliability are undoubtedly difficult. The strengthening of the financing, distribution, and after sales service chain, by facilitating the development of local capabilities to micro finance, assemble, supply, and service the systems, will not only facilitate enterprise development on the supply side, but will also potentially enhance livelihood activities that can be linked to the provision of electricity services. The opportunities have to be seen not only from the point of view of rural electrification but in the larger context of sustainable development, with the country attaining much needed energy security in the process.

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Centre for Research on Energy Security

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