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Role of technology advancement in promoting renewable energy based mini-grids

(Based on project experiences and lessons learned)

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Table of Contents

Table of Figures

Abstract

This paper aims to highlight the role of advancements in technology in enhancing the suitability and appropriateness of distributed power systems in rural/remote and urban/peri-urban locations. The paper uses the example of Solar Multi Utilities (SMU) and Smart Mini-Grids (SMG) to explore the design configurations, topologies, smart controls and meters that lead to these systems becoming more efficient, reliable and flexible and in improving their serviceability. The paper will also explore the costs and benefits of such system upgradation as compared to simple system designs. Lastly, the paper will highlight some of the main challenges faced by technology developers today and the possible areas of policy intervention that can aid in quicker dissemination of robust technologies on the field.

1. Context

India has a strong history of using renewable energy technologies for the last 30 years. Renewable energy sectors got specific attention in planning process in India since the Sixth Five Year Plan with specific allocated budget. In 7th plan, the focus was on development and dissemination of renewable energy systems, whereas from the 8th plan and onwards the emphasis is on developing integrated strategies to make renewable energy system techno- commercially viable. Mini-grid is one of the thematic areas within renewable energy sector which has got lots of focus because of its multiple advantages. However, mini-grids so far have been seen majorly from the point of view of providing minimum basic energy to the community in the remote, far-flung areas. Although there is a need of such mini-grids system in the rural areas, the scope of mini-grids should not be limited to the remote, scattered and far flung areas only. There is an equally large potential of mini-grids in the urban and peri-urban sectors such as in commercial and industrial complex, hospitals, shopping malls/ complexes, apartments, residential complexes, and educational institutions to ensure maximum flexibility, reliability and safety with enhanced efficiency of the overall electricity system.

In both the segments, technology plays a very critical role in providing the reliable, quality power at an affordable price. Reliable and quality power from any system is a function of optimised design, and not just design focusing purely on arriving at the least cost system. Often in the tendering and design process, decisions to reduce the up-front cost lead to a compromise on the efficiency, reliability and flexibility of a system; and this in most cases leads to high life-cycle costs of the system owing to frequent maintenance and repair, monitoring, outages, system failure and so on. In both cases, these systems provide energy for crucial activities starting at simple household tasks such as cooking and studying to more complex business activities involving productive applications. An unreliable system (and especially one that stops functioning suddenly and prematurely after a certain period of time) can adversely impact the lives and incomes of those using the electricity, and in cases of poor and rural users, lead to a complete lack of access to basic services which they have now got accustomed to, and which are aiding in their development. Looking back at the large number of examples of such failures, it is clear that if a system is being installed, its efficiency, reliability and flexibility are of foremost importance and designs should be developed not just to achieve the basic minimum performance but with the larger aim of creating robust systems, which is possible with technologies available today.

This discussion paper conveys *what role technology advancement and its up- gradation can bring for mini-grid system, applicable to both the segments (rural as well as urban/peri urban) and what steps can be followed in order to promote such systems at field.*

In this discussion paper, two case studies from TERI's own work and extensive research are considered, which describe how the advancement in technology and its innovative applications meet the energy requirement as per the local need.

2. Case study A: Effect of technology up gradation for solar based mini-grids to cater the energy need of the rural and remote locations

Currently, mini-grid dissemination in India is largely limited to donor and grant driven initiatives. In spite of huge potential of implementing such projects, private developers are unwilling to invest in mini-grid systems in such rural locations, because of two key reasons:

(a) They see lots of risk involved in getting the revenue back from such system and the risk factor is much more if the system operates unreliably owing to non-optimized designs and reduced performance due to uncertain resource availability and climatic conditions.

(b) They feel that the entire mini-grids will be redundant when the grid is extended to the site and thus leading to a loss for their business as users shift to less expensive grid electricity.

If we see the dominant design for solar photovoltaic systems in India today (Figure 1), it normally follows **a series configuration**, leading to the constant presence of the battery in the system loop. Since the battery is the ***weakest link in the system*** (*with the shortest life and potential to deep-discharge during rainy/cloudy months),* such a system configuration often leads to shut down of the entire system. TERI's own experience and other observations from the field show that with such system design, if the battery is in bad condition (low voltage owing to deep-discharge), it is likely that the entire system is also non-functional even on sunny days.

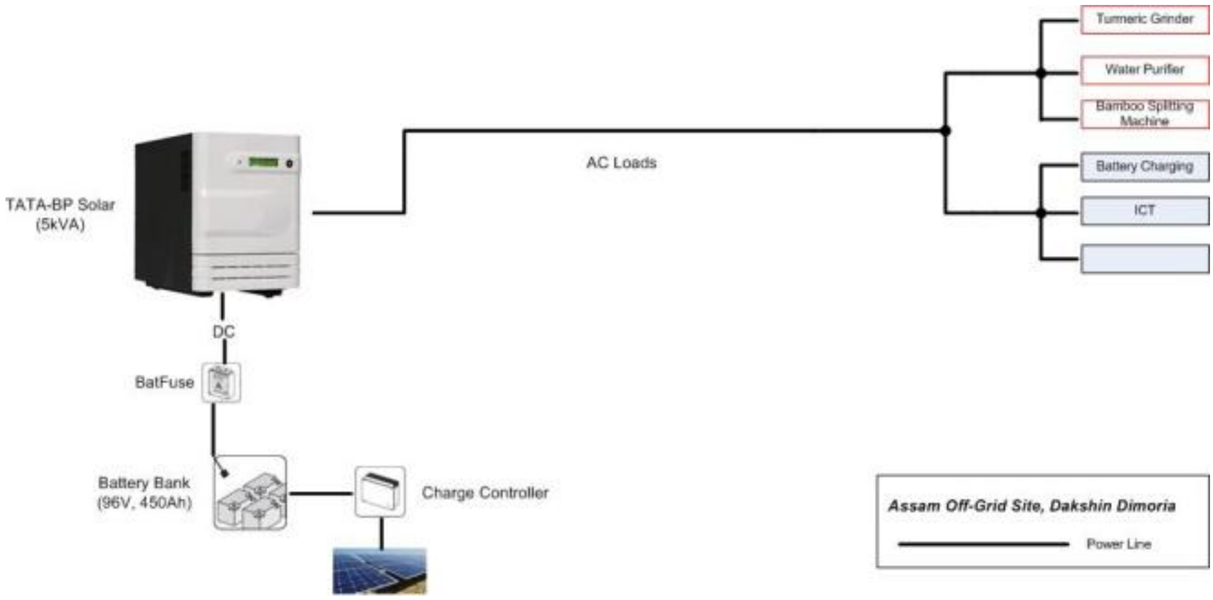

Figure 1: Dominant design for solar photovoltaic systems in India today

Since the battery is always in the loop, the overall efficiency of such system is also not optimal (considering maximum watt hour efficiency of battery) .Additionally, such designs often don't incorporate inverters that can easily feed electricity back into the grid, or integrate with other sources of energy, leaving it very in-flexible for adapting future requirement.

2.1. Lesson learned from such inflexible system design

- Needs a bigger battery bank and thus high replacement and maintenance cost
- Since these systems are not grid compatible, on the arrival of the grid, most components of the current system become redundant and have to be discarded and replaced with new components that are grid-compatible, significantly adding to life-cycle cost. Make the system highly unreliable due to the presence of a weak link (the battery) between the source and the load.
- Downtime of such system is quite high- forcing less services and income for the operator and users and high risk for investment for the developer.

The experiences clearly says that clean energy systems in rural and remote locations need to be designed taking into account that ***access to frequent service, repair and maintenance is difficult,*** that is, the system should be reliable. Also, since the capital cost of clean energy systems is high, ***it is imperative that the efficiency of such systems is optimized*** so that cost per every unit of electricity generated is optimum. Lastly, the system should have a ***significant level of flexibility*** such that both the grid (when it is eventually extended to an off-grid site) and other sources of energy can be coupled with the existing system as and when required. Therefore, the option to easily connect to the grid and earn revenue from sale of electricity must exist.

The above requirement can be met not through huge investment in capital cost but mainly through proper planning, optimum design and reconfiguration of the system. The incremental cost involved here can be easily repaid through the kind of efficiency reliability and flexibility such system gives in long run.

Proper planning involves categorization of load (day load, night load) with load profile, type of load, how critical the load is (such as vaccine refrigerators) and so on. Although such planning does not involve any cost, but it helps in optimally designing and sizing the energy storage/battery system. An optimal design leads to reduction in capital cost as well as in replacement and maintenance cost, while significantly improving system performance

Again, changing the configuration (moving from series to parallel configuration), adds more flexibility and probability of supply of power, even in poor weather and local operational conditions.

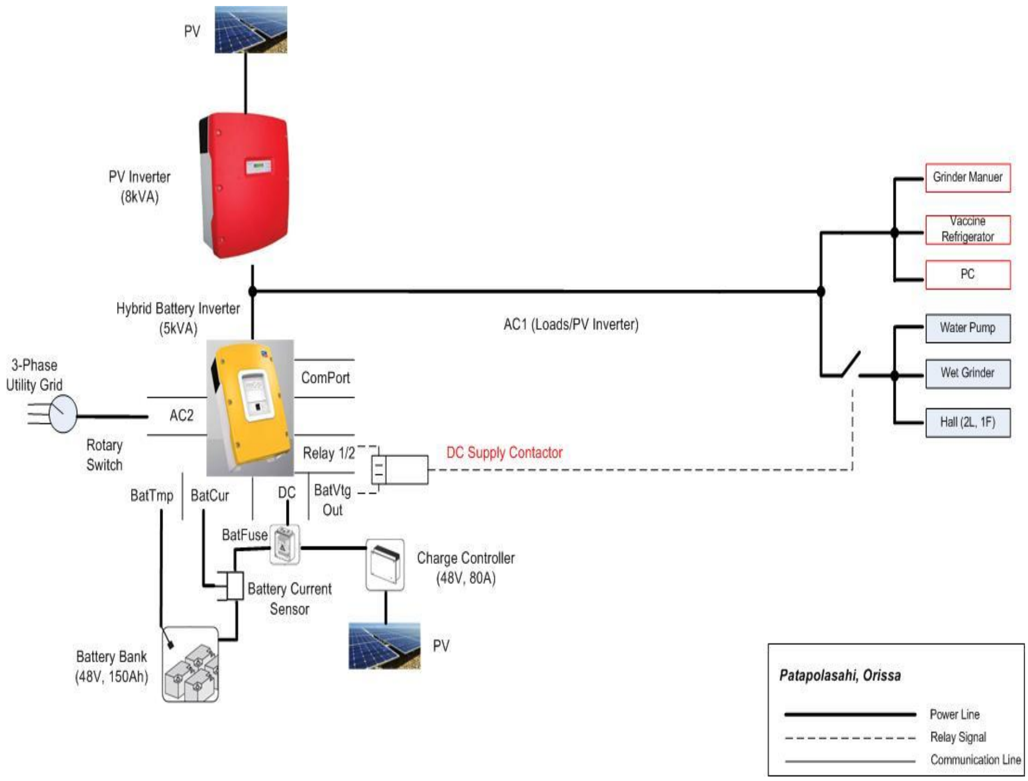

Figure 2: Typical parallel configuration with solar PV system

One of the probable designs **used in few TERI's pilot sites, implemented under Norwegian Framework Agreement is shown in (Figure 2).**Here the design is such that it splits the inverter into two; (as per the requirement of the load) **and includes a few smart and advanced techniques to allow these inverters to** manage the load as per the resource availability through coordinated control. Such inverters are selected in such a way that grid integration and integration of additional renewable energy sources at a later stage are feasible. In addition to this, these inverters are made with remote monitoring features through which daily output and utilization data can be recorded remotely. Such data is especially useful for planning of future systems in areas where cloudy and rainy weather conditions are prevalent for long periods of time.

Although such systems involve some additional cost, in this case, more than the cost, it is the way the system is selected, designed and configured that improves the overall system performance. And field experiences show that whatever additional cost is involved, it is adjusted in the cost which would have been invested for local monitoring, manual intervention for managing the fluctuating load, larger battery size and thus cable size, bigger construction and other associated cost.

So this is basically a choice between **relative high capital cost but substantial low life cycle cost Vs relatively low capital cost but substantial high life cycle cost**.

3. Case study B: Smart Mini-Grids (SMG): Innovative, intelligent solutions for urban, peri-urban sectors

Given India's current power scenario, with the demand far outpacing supply, several power stations of very high capacity need to be installed in order to meet the exponentially growing and projected energy requirements. By their very nature, these large scale power plants are centralized, that is, the power is generated centrally and distributed far and wide. A significant amount of power, given the existing average transmission & distribution losses of around 30%, would be lost before delivering at the required sites, thereby also reducing the overall efficiency of the electrical system. Even if the resources for such power plants - in terms of financial, fuel, and real estate- suddenly became available (current headlines would beg to differ), the centralized power option is not feasible from many cases in India. Most of the cities and towns face black-outs and brown-outs throughout the year, especially in summers. The campuses and condominiums have to depend on captive DG set based power generation, which apart from being expensive, is polluting as well. Recent failures of the northern grid and multiple grids also suggest that the focus should be on smarter local grid or Smart Mini-Grids .Hence, while waiting for the overall power situation to stabilise and provide sustained electricity access, it is prudent to explore other viable options for obtaining cost effective, clean, green, and most importantly, reliable electricity.

Campuses and complexes generating and distributing their own power through distributed generation and renewable energy (RE) resources- in essence through personalized Mini Grids-are therefore a more dependable, feasible, controllable, practical, and greener solution. Furthermore, these mini grids are easily set up to seamlessly interface with the existing utility grid. (Officially, a mini-grid is defined as an electricity distribution network operating at below 11 kV levels, which is sometimes connected to the wider utility grid.)

A mini-grid system can be operated through a combination of multiple energy resources, both renewable such as solar, wind and biomass, and conventional such as diesel .If a mini-grid is powered solely from renewable energy sources, however, the intermittent nature of these renewable generators does not always provide the flexibility of utilizing the power as per the requirement of the industry or community. This means that periods of high renewable energy generation might not coincide with high demand, and similarly in the case of non-availability of renewables. This will result in an undesired mismatch between resources and loads (usage), loss of extra power when available, and requirement of expensive conventional power sources during other times.

Hence, for a urban , peri urban segment , where the requirement of availability of reliable , quality power over cost is more important, the more appropriate solution is a Smart Mini-Grid (SMG) system which can optimally, and intelligently manage the load (usage) and distributed generation resources. A Smart Mini-Grid system thus utilizes digital information technology to intelligently balance multiple and varied energy supply resources against the dynamically varying and complex loads of the system. The SMG communicates within itself and with external networks, seamlessly resolving problems and delivering uninterrupted energy service. In addition, an SMG not only increases the overall efficiency, but also helps improve the overall power quality of the system.

SMG controlled distributed energy sources can then be added to increment generation capacity, whenever and wherever required. These systems can not only deliver power to the local areas (such as campuses, complexes, etc.) more efficiently and reliably, but can also feed excess power into the utility grid.

Institutions, campuses, localities applying an SMG for **secure power availability can ensure the maximum utilization of renewable energy (RE) resources through careful coordination between energy demands and the electricity production.** This enables a relatively lower installed RE capacity- and in conjunction possibly decreased battery sizes-which result in reduced upfront capital costs. **The SMG system also helps minimize the use of any fossil fuel based generation by an intelligent management of loads through smart controls and techniques**. This allows for reduced ongoing operating costs while simultaneously improving power quality, efficiency, and flexibility of the overall system.

SMGs are applicable not only for remote or rural applications, but are powerful solutions for the reliable energy requirements of campuses such as office complexes, factories, residences, hospitals, hospitality institutions, shopping complexes, and even suburban neighbourhoods.

Essential Features of Smart Mini-Grids

- Intelligent load and energy resource management through smart controllers and advanced control techniques
- Accommodation of multiple Distributed Energy Resources and Energy Storage into the common grid
- Self-healing, self-configuring, plug and play (*the grid has the ability to rapidly detect, analyse, respond and restore itself from any disturbances*).

Benefits of Smart Mini-Grids

- Foster Demand Side Management and Demand Side Response
- Reduce power outages: Increase reliability, efficiency & safety of the grid
- Reduce carbon footprint, minimize fossil fuel consumption
- Provide better autonomy to customers to govern their electricity needs

3.1. TERI's Smart Mini Grid

A one of its kind SMG was setup at TERI's campus just outside Delhi at Gual Pahari in 2011. The unique features of the SMG system at TERI include:

- Optimum renewable energy utilization i.e solar, wind, and biomass at different operating conditions to serve the required energy service
- Improved efficiency flexibility and ensuring supply of reliable good, quality power and of the system through incorporation of smart, intelligent tools and techniques, allowing for automatic adding or removing of the loads and resources based on their availability and set priorities.

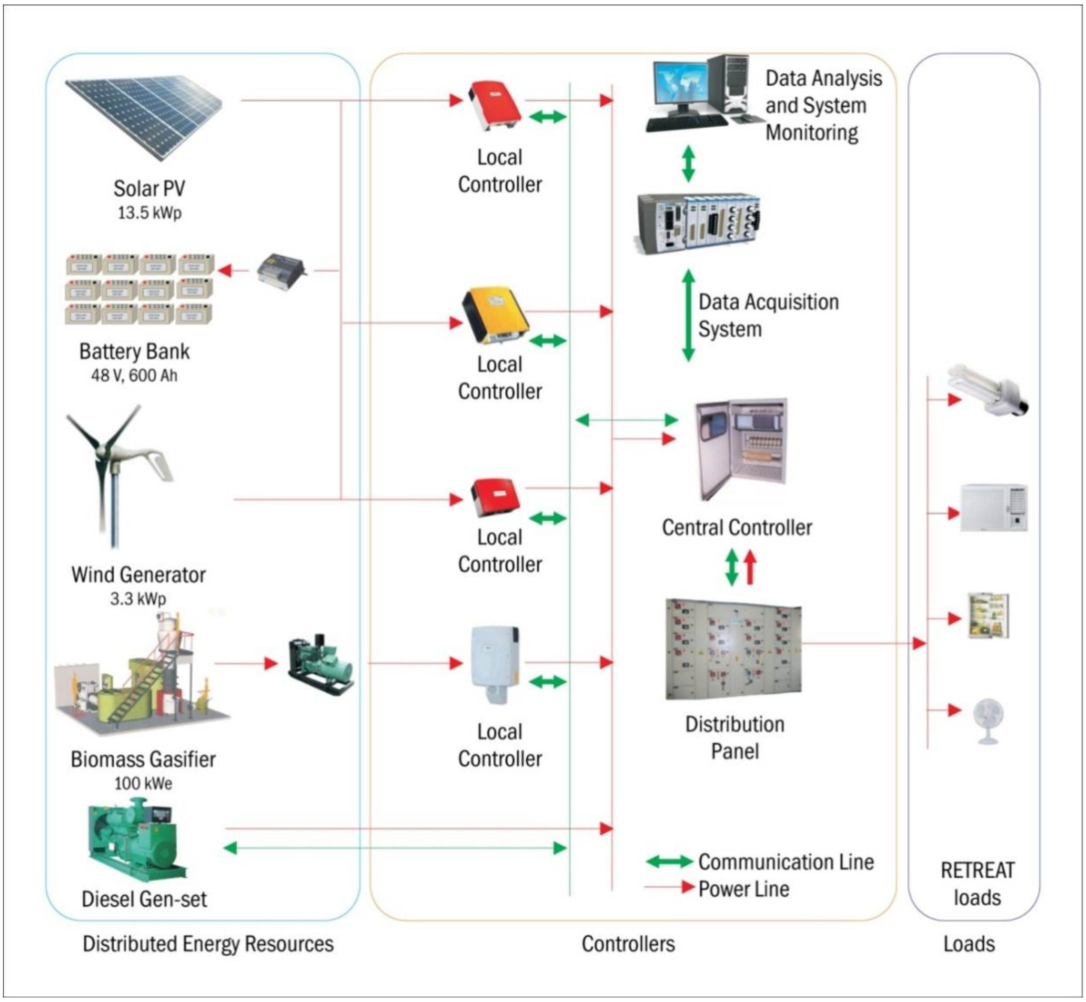

Figure 3: Schematic diagram of the SMG at TERI

The following energy resources are available at the facility:

1. 12.5kW solar PV system (crystalline solar module) system
2. 2kW Solar PV system (crystalline solar module)
3. 1kW thin-film solar PV system
4. 3.3kW wind electric generator
5. 10 kW/100kW biomass gasifier system
6. 600Ah, 48V storage battery
7. Diesel generator backup

Such smart, reliable systems can be set up at any campus or facility and will go a long way in decreasing reliance on the main grid while increasing the consumption of cheaply and locally generated renewable energy. ***Through the implementation of SMG technology, communities and complexes will be empowered to better manage and utilize their energy resources while also decreasing costs across the board. Many such SMGs setup across the country will eventually lead***

to the grounds-up smartening of the main grid while simultaneously reducing the need for larger, expensive, and environmentally damaging centralized power plants.

4. Possible steps for promoting mini-grids for different sectors

For the mini-grids at rural setup

- Although earlier designs are economically more feasible but the analysis of Cost Vs Reliability should be done with futuristic vision of supplementing the mini-grids with main grid and the project cost should not be decided only on the basis of minimum performance of the system. Therefore there is a need to look at the scope for re-designing and re-configuring the system.

- There is also a need of developing Standard Operating Procedures for proper installation, operation and maintenance of the mini-grid system.

- Training , awareness generation workshop on application of new technology and techniques, exchange and exposure visits etc. are very much required to implement the appropriate, new generation, yet cost effective technology.

- R&D focus should not only be on hard-core component level research but also on applied research on system integration, re-engineering and so on.

For the mini-grid at urban and per-urban setup

- Large scale implementation of such smart mini-grid systems in the country can be well integrated with the existing programs of Ministry of New and Renewable Energy (MNRE) such as Jawaharlal Nehru National Solar Mission (JNNSM) as well as the National Rural Electrification program.

- Smart mini-grids are evolving as enabling technologies for future dynamic energy needs. Hence they need the support of a conducive policy and regulatory regime for the concept to flourish and the market to develop. Since smart mini-grids encompass lots of advantage in terms of its multi-sectoral benefits, currently the focus should be to implement projects with these innovative technologies, develop the sustainable business model along with cost benefit analysis.

- There is a need of finalizing the guidelines and best practices for integrating renewable energy based minigrid system into the main conventional grid.

- There is also a need of a consistent, long-term policy to encourage open access, incentive to allow the use of advanced technologies that increase capacity, improve efficiency and reliability. Also mechanisms such as pilot demonstrations need to be created to bring together numerous industries including power, information and communication technology, manufacturing, government etc towards advancing this agenda, creating a roadmap for successful implementation of smart grids.