Techno-economic Feasibility of Grid-tied Solar Mini-grids

POLICY NOTE

Background

The Grameen Vidyutikaran (GARV) dashboard indicates that India has about 3100 villages (17% of the 18452 un-electrified villages identified by Ministry of Power in 2015) which are yet to be electrified (as on September 5, 2017). The cumulative number of households waiting for power supply is close to 4 crore. Majority of electrified villages have huge demand-supply gap and access to power is unreliable or of low quality. In many rural areas, electricity is barely available for economic use and development.

Grid-tied renewable powered mini-grids can help improve reliability and augment supply to the central grid, effectively.

Introduction

Currently, mini-grids in India exist as off-grid systems or in-parallel with the central grid. Most of them use Renewable Energy (RE) such as solar Photovoltaic (PV) or biomass, and are supported by battery storage. Rapid expansion of the grid poses a threat to the operation of off-grid RE systems. Grid-tied mini-grids appear to be a promising solution going forward.

Opportunities

Grid interconnection of mini-grids gives an advantage of operating it without a large storage system, as the grid is available for support. It also helps support loads of higher magnitude in applications such as irrigation pumps and micro-enterprises. Mini-grids also help minimise distribution-end losses for Distribution Companies (DISCOMs) and enable localised generation and consumption of power. Through grid interconnection, excess power from the mini-grid can be exported back to the grid, thus improving plant utilisation. Moreover, the technology required to enable grid interconnection of mini-grids (including islanding) already exists. Islanding also allows seamless operation of the mini-grid in case of any natural calamity or disaster. In addition to promoting RE, making mini-grids a part of the mainstream grid can complement the government's effort in improving electricity access and socio-economic conditions in rural areas. Solar PV prices have decreased drastically in the recent past and this gives an opportunity for PV based mini-grids to make an impact.

Challenges

Currently, there is no national policy to promote mini-grids, although a draft policy by Ministry of New and Renewable Energy (MNRE) is in existence. Uttar Pradesh is the only state to have released a mini-grid policy. Lack of clarity on interconnection with the grid is a major issue. The mechanism of engagement between Rural Energy Supply Providers (RESPs), State Electricity Regulatory Commissions (SERCs) and DISCOMs is unclear. In addition, grid interconnection currently involves multiple stages of approval. Compared to the highly subsidised power in rural areas, cost of reliable power from mini-grids is expensive. This increases investment risk for RESPs and fails to attract the private sector.

Techno-economic Assessment

A preliminary analysis of PV and battery based grid-tied mini-grids yielded the following possible scenarios:

i) **Mini-grid supplies the local demand, exports and imports power to/from the distribution grid**
The source PV-based power supplies load and charges the battery. Power is exported whenever there is excess generation, and imported during times of deficit.

ii) **Mini-grid supplies the local demand and only exports power to grid**
There is no power imported from the grid and PV-based power is exported after supplying load and charging battery.

iii) **Mini-grid without storage; directly exports power to grid**
The net PV power generated from mini-grid (without storage back-up) is exported directly to the grid through a single point of power sale.

CSTEP's analysis is based on actual 11 kV rural feeder demand data from Karnataka and represents both domestic and commercial loads. The baseline data used in the analysis is described below:

- Hourly demand data from 11 kV rural feeder in Cowdalli, Chamarajanagar, Karnataka
- Demand scaled down to 15 kW peak; hypothetically shows power consumption in a village of approximately 100 households
- Variability in demand profile retained. Annual energy demand is around 55,000 kWh
- Battery dispatch restricted between 6 PM to 12 AM and designed to supply a maximum of 8 kW
- Cost of purchasing energy from grid during import assumed to be INR 5 per kWh
- Inverter life assumed as 10 years and lead acid battery (Tubular Gel) life calculated as 5 years for first two scenarios discussed

- Capital and operational expenditure and other project considerations based on discussions with RESPs and equipment suppliers, as shown in Table 1
- Calculations include battery and inverter replacement costs over 25 years.

Results of the modelled scenarios such as system reliability, electricity supplied or imported from grid and LCOE (levelised cost of energy) corresponding to each scenario are shown in Table 2. Out of all the combinations of PV and battery simulated, the ones with lowest LCOE for the three scenarios are shown in Table 2.

Observations

- When the mini-grid operates in import/export mode, system reliability improves significantly and LCOE increases by approx. INR 2 per kWh, as compared to the 'Export only' case.
- Without storage, LCOE is lower; however, reliability of supply suffers.
- The analysis can be extended for different solar zones; various innovative integration strategies can be tested.

Possible roles and responsibilities of RESP and DISCOMs during grid-interconnection could include:

- RESPs can conduct site surveys to estimate rural demand including domestic and commercial loads
- Plant commissioning and maintenance can be RESP's responsibility
- RESP must follow safety procedure to isolate (island) the mini-grid as per DISCOM safety guidelines
- RESPs can be responsible for training and capacity building activities for plant operator or village electrification committee.
- Revenue collection can be carried out at an additional cost by RESPs to improve billing efficiency
- RESPs can help create awareness in the village and optimise use of power wherever necessary
- DISCOMs need to define point of interconnection, based on mini-grid capacity
- DISCOMs should minimise disturbances in the upstream part of the grid to prevent isolation of mini-grids.

Table 1: Assumptions for techno-economic analysis

Parameter	Value	Component	Cost	Unit
Project Life	25 years	Module with structure	32	INR/W_p
Debt to Equity Ratio	70:30	Balance of System	10	
Debt Interest Rate	10%	Transportation and Installation	7	
Return on Equity	14%	Civil & Electrical work	7.5	
Pre-Tax Discount Rate	11.20%	Distribution Network	20	
Debt Repayment Period	13 years	Battery	9.5	INR/Wh
Annual Escalation in O&M Costs	5%	Inverter	15	INR/kW
Book Depreciation	5.28% for first 13 years & 1.78% for next 12 years	Annual O&M cost including manpower, insurance, land lease	1,66,000	INR/year
		Contingency	5	% of equipment cost

Table 2: Summary of scenarios for grid-tied mini-grids

Scenarios	Configuration			Reliability (hours of supply)	Units Supplied (kWh/ Year)	Units purchased from the grid (kWh/Year)	LCOE (INR/ KWh)	Total system cost (INR, lakh)
	PV (kW_p)	*Battery (kWh)*	*Inverter (kW)*				*With 30% Subsidy*	
Both import & export	50	100	50	~ 22 – 23	64355	26844	16.69	56.71
Export only	50	100	50	~ 14 – 15	64355	NA	14.60	56.71
No storage	50	NA	50	~ 6– 8[1]	84336	NA	8.30	37.11

[1] It implies that reliability would be low because of PV availability only during sunshine hours and no storage provision.

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Policy Recommendations

- Adopt the model where both import and export of power from mini-grids along with storage is allowed. However, to make the project viable and attractive for the private sector, a tariff of approximately INR 18 per kWh will ensure 10% internal rate of return (IRR) for the project.
- If cost to consumers is an average of INR 5 per kWh, the government or DISCOM will have to bear the remaining cost component, approx. INR 13 per kWh. Rural sites where cost of supplying power is comparatively high today can be earmarked for grid-tied mini-grid development.
- Subsidies are currently required to promote mini-grids. However, a combination of capital and operational subsides will ensure sustained operations and accountability for RESPs. Soft loans with 5% debt interest could help reduce LCOE by INR 0.5 per kWh.
- Clear technical and policy directives are needed to enable grid interconnection. DISCOMs and RESPs have to work jointly at sites to optimise costs further.
- Single window clearance should be set-up to simplify approval procedures and attract private sector investment. An identification linked, one-stop digital platform could be leveraged to transfer subsidies/grants directly to the end user.
- Promotion of mini-grids could become an integral part of the government's rural electrification programme. Collaboration between MNRE and Ministry of Power is highly recommended to consolidate the existing discrete policies on to a single platform.

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