Blackout under bright sunshine. Quality of solar electricity in rural areas in emerging markets

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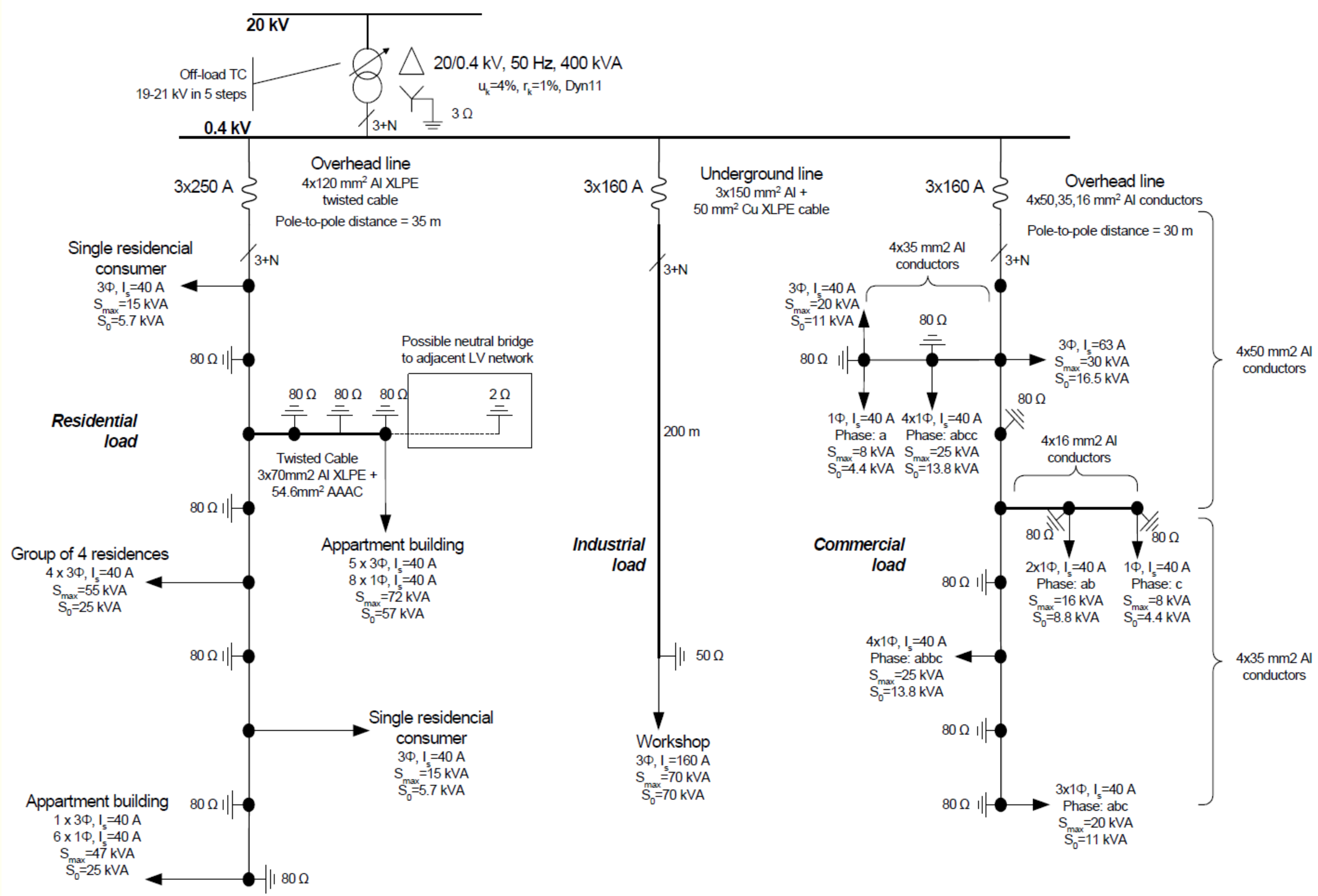
New Global

Photo: DFID / Abbie Trayler-Smith



Source: EC FP6 MicroGrids (ENK5-CT-2002-00610 N)

Availability and reliability of power

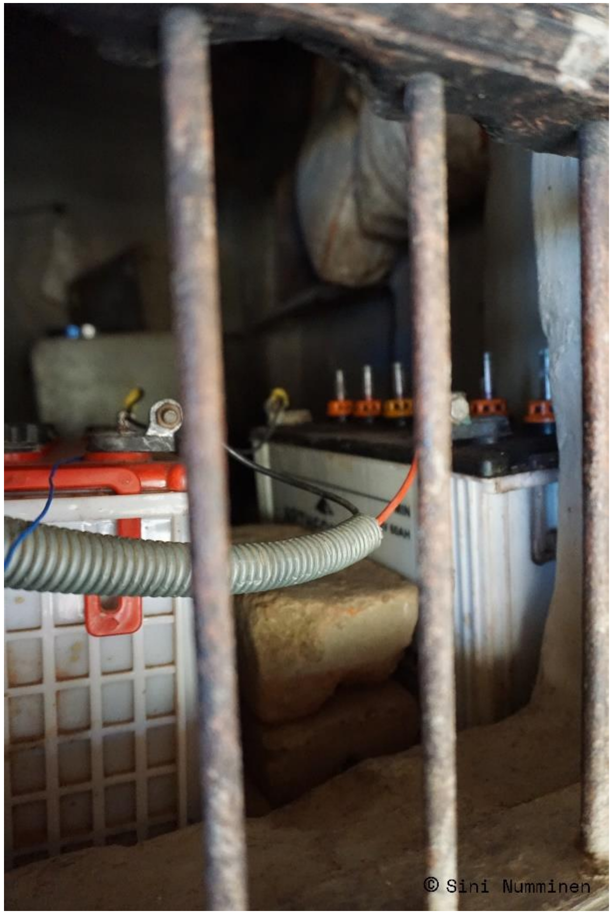
Power grid	Promised	Realized
FIN DISCOM	24/7	24/7
UP DISCOM	24/7	12/6, unscheduled power cuts
Solar micro-grid [1]	24/7	21/7 (measured!) • 8 unscheduled power cuts per month (between 4 and 11) • Majority longer than 3 h
Another solar micro-grid [2]	7 hours (evenings)	"Maybe 10 or 9 hours per month the grids are not operating"
Another solar micro-grid [2]	24/7	"Occasional downtime in December"

[1] Numminen, S., Lund, P. D., Yoon, S., & Urpelainen, J. (2018). Power availability and reliability of solar pico-grids in rural areas: A case study from northern India. *Sustainable Energy Technologies and Assessments, 29*, 147-154. https://doi.org/10.1016/j.seta.2018.08.005
[2] Numminen, S., & Lund, P. D. (2019). Evaluation of the reliability of solar micro-grids in emerging markets - Issues and solutions. Energy for Sustainable Development, 48, 34-42. https://doi.org/10.1016/j.esd.2018.10.006

Working in resource-constrained settings

How to deliver
- Spare parts?
- Repair personnel?

When do they arrive?



Remoteness of villages complicates and prolongs transportation of spare parts and repairing workforce

Power theft takes various forms. Stealing power directly from battery results in power insufficiencies and blackouts in all village. It also contributes to the premature degradation of the battery.

Thick clouds of fog cover the state of Uttar Pradesh in December leading to power insufficiency and blackouts in PV-only power systems. Air pollution reduces PV power production (in large cities).

Table 1

Design, installation and management problems effecting service reliability in micro-grids, and suggested solutions. N = number of companies that mentioned the problem having occurred either once or more times.

Reliability problem	N	Width of the outage	Nature of the occurrence	Duration of the outage	Possible design solutions (non-exhaustive) to keep up power supply
Electrical design aspects					
Capacity not sufficient for 365 days a year due to alternating local weather conditions	10	All village	Abrupt during low irradiance seasons	Depends on the number of days of system autonomy	Hybrid energy solutions; seasonal frugal use or energy; load prioritization
Unexpected failure of a critical component e.g. inverter due to low quality	5	All village	Abrupt	Depends on the availability of spare parts and technical workforce	Choosing system units with sufficient quality; buying critical components or their spare parts to storage; systems requiring simpler maintainability
Unexpected power losses due to internal inefficiencies of electrical equipment	0	All village; a node	Covertly in the background[a], then abrupt	Depends on repair buffer investment among other things	Choosing energy efficient system units; careful installation work
Practical design aspects (installation)					
Low quality installation work	0	All village; a node; household only	Abrupt	Depends on technician availability	Careful installation work; well-chosen mounting elements and fasteners
Accidental human/animal intervention with crucial components	4	All village; a node	Abrupt	Depends on how ESCO handles the situation	Prohibiting or complicating access
Plant management aspects					
Overloading with high-consuming appliances	9	Household only (or a node supplied from a distribution box)	Covertly or abruptly (depending on load limiter configuration and supply capacity)	Depends on customer agreements (if household only), otherwise maintenance rules	User education; load limiters; DC distribution (less loads available); higher system capacities; system topologies that build peer pressure against theft
Experimenting with critical components such as control units, distribution boxes or energy meters	8	All village, a node, or a household only	Abrupt	Depends on how ESCO handles the situation	User education; consumer satisfaction; safety stickers for visual inspections; placing system intelligence in inaccessible places; tamper-proof devices, for distribution boxes see e.g. (Patel & Mishra, 2016)
Power tapping directly from supply components (battery)	6	All village	Background or abrupt (depending on supply capacity and the mode of discharge)	Depends on the quality of the protective installations	Prohibiting access (metal boxes, not wooden); user education
Power tapping from distribution lines	3	All village (or a node)	Covertly or abrupt (depending on supply capacity)	Depends on how ESCO handles the situation	DC distribution; protecting cables with rubber bands; underground cabling; load limiters in distribution cables; system topologies that build peer pressure against theft
Exceptional events					
Extreme weather conditions (heavy rain, storms etc.)	6	All village (or a node)	Abrupt		Weather monitoring; back-up supplies

[a] The effect takes place in the background, even unnoticed by the operator and the users, until one day may be demonstrated as a blackout.

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Consider asking the following info from the engineer or the management

- **Availability of solar energy**
  - When the sun is not shining?
    - *System autonomy: how does the battery capacity cope the issue?*
- **Repair service**
  - Time to start repairing
  - Average time of repair
  - Maximum time to repair
- **Load prioritization functions**
  - Which customers are first cut off when there is a failure or no sunshine?
- **Description of**
  - O&M procedures
  - Power theft prevention measures and procedures

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Reliability assessment table for project partners

Table 2
Reliability assessment framework for renewable off-grid power systems.

Reliability aspect	Note	Unit
Energy service description (company promise)		
Supply schedule	Start and end of power supply in daily cycle per customer group	Daily schedule (hours and minutes)
Power and energy levels	Power amount per customer group	Watts (W) or Watt-peak (Wp)
Maintenance schedule	Schedule of no-supply hours due to regular maintenance	Dates or weekdays and schedule (hours and minutes)
Load prioritization functions	Priorities set between customer groups during energy insufficiency or technical failure	(Descriptive)
Energy reliability		
Loss Of Load Hours LOLH	Number of hours of no supply due to energy insufficiency divided by the number of hours promised	%
Number of lost customers	Percentage of customers disconnected during low power	%
Schedule of low supply seasons	Seasonal periods when renewable supply does not meet the load	Dates. share of no-supply days per year (%)
System autonomy	Storage ability to supply in periods of low power	Number of hours
Technical reliability		
Mean downtime MDT	Total time of no supply due to component breakup, repair or system maintenance divided by the total time promised	%
Mean time to start repairing, MTSR	Speed of repair personnel to arrive after first notice (also first-aid service rapidity)	Number of hours
Mean time to repair MTTR	Speed of repair operations	Number of hours
Maximum time to repair MTR	Replacement or repair time of components with lowest availabilities	Number of hours
Protection measures	Anti-theft and other measures implemented against illegal behaviour and exceptional external events	(Descriptive)
Component degradation and system lifetime		
Battery lifetime (nominal and real)	Nominal and an estimation of the real lifetime in the actual use environment	Number of days
Vulnerable components	Description of vulnerable blocks in the energy system installed	(Descriptive)
Total reliability		
Total estimated system downtime	Approximate annual time of no power out of the scheduled supply = LOLH + MDT	%

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Solar power systems are not maintenance-free

- Important design aspects
  - Choice of components of sufficient quality necessary in harsh conditions
  - Coping local problems (weather, power theft etc.)
- Important O&M aspects
  - Resourcing technical repair workforce
  - Availability of spare parts
  - User education against power theft
- More reliability thinking needed!
  - 100% reliable, 24/7 power availability is not a default setting
  - Operating company should be requested reliability-related data for technical details and O&M practices
- Reliability of solar electricity is in the interest of all involved parties (customers, donors, investors, operating company, environment)

Consider delivering power when promised

- Energy access
- Sustainable energy access
- Economic sustainability
  - Happy customers
  - Happy donors
- Reputation of solar energy
- Less e-waste

<u>Do not leave reliability for the system engineer only</u>

References

- Numminen, S., Lund, P.D., Yoon, S., Urpelainen, J., (2018). Power availability and reliability of solar pico-grids in rural areas: A case study from northern India. Sustainable Energy Technologies and Assessments 29, 147-154. https://doi.org/10.1016/j.seta.2018.08.005
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Thank you!

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