Renewables in Microgrids
Challenges and Opportunities

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Microgrid - Definition

Interconnected loads, distributed generation and energy storage devices
Within clearly defined electrical boundary
A single controllable entity with respect to the grid with bidirectional power flow
Global Microgrid Capacity - 2014

Total Microgrid Capacity Market Share by Region, World Markets: 2Q 2014

- North America, 2,874 MW (66%)
- Europe, 544 MW (12%)
- Asia Pacific, 524 MW (12%)
- Latin America, 362 MW (8%)
- Middle East & Africa, 76 MW (2%)
- Antarctica, 13 MW (0%)

Total: 4393 MW
India < 200 MW

(from Navigant Research)

http://www.navigantresearch.com/research/microgrids
Classification of microgrids

- **Mode of operation**
  - Isolated
  - Grid Connected

- **Type**
  - AC
  - DC
  - Hybrid

- **Source**
  - Renewables
  - Diesel
  - Hybrid

- **Scenario**
  - Residential
  - Industrial
  - Commercial

- **Size**
  - <10kW
  - 10kW-1MW
  - >1 MW
Rural Electrification

Manoj and Banerjee, 2010
Solar Array
5X1 kWp

Charge Controller
40 A, 120 V

Inverter
7.5 kVA

AC load
2.5 kW

Battery
800 Ah

No. of house holds: 29
Connected load : 1.4 kW

5 kWp Solar PV power plant at Rajmachi Village, Maharashtra

Manoj Kumar M.V. , 2009
Bio-diesel based power plant of 10 kW rating (Raipur, Chattisgarh)
## Biomass Gasifier Examples

<table>
<thead>
<tr>
<th>Description</th>
<th>Hosahalli</th>
<th>Hanumanthanagara</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of establishment</td>
<td>1988*</td>
<td>1996</td>
</tr>
<tr>
<td>Size of village (number of households)</td>
<td>35</td>
<td>58</td>
</tr>
<tr>
<td>Population</td>
<td>218</td>
<td>319</td>
</tr>
<tr>
<td>Energy plantation (ha) raised</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Installed capacity (kWe)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Installed end-use capacity (load)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Drinking water</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Flour mill</td>
<td>5.6</td>
<td>5.6</td>
</tr>
<tr>
<td>Irrigation pump</td>
<td>18.5</td>
<td>25.5</td>
</tr>
<tr>
<td>Total installed end-use capacity</td>
<td>30.7</td>
<td>37.7</td>
</tr>
</tbody>
</table>

Biomass Gasifier Example

Arashi HiTech Biopower, Coimbatore

- 1 MW grid connected
- 100% producer gas engines
- Two gasifiers – coconut shells, modified to include other biomass
- Chilling producer gas with VARS operated on waste heat
Opportunities

- Energy Access – More than 30% of Households without access to electricity
- Energy and Peak Shortages
- Unreliable Supply – Load Shedding, Supply Disruptions
- Energy Security
- High growth rates in demand- large potential market
- Local Employment Opportunities
- Sustainable Energy Systems for the future
Historical Household Electrification Rates

GEA, Chapter 19
Challenges

- Supply- Demand Mismatch, Low Load Factors
- Affordability – Cost Reduction challenge - Technology development and R&D
- Financing Challenge
- Manpower and Capacity Building Challenge
- Institutional/ Organisational Challenge
- Operational and Maintenance Challenge
### Issues- Low plant capacity factor

<table>
<thead>
<tr>
<th>Name of the plant</th>
<th>PV Capacity (kWp)</th>
<th>Inverter capacity (kVA)</th>
<th>Charge controller (kW)</th>
<th>Battery capacity (Ah)</th>
<th>Battery Voltage (Volts)</th>
<th>Distribution Voltage (Volts)</th>
<th>Connected Load (kW)</th>
<th>Plant Capacity factor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dound II, Chattisgarh</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
<td>400</td>
<td>48</td>
<td>230</td>
<td>0.3</td>
<td>5.8</td>
</tr>
<tr>
<td>Latdadar, Chattisgarh</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>500</td>
<td>48</td>
<td>230</td>
<td>0.7</td>
<td>7.1</td>
</tr>
<tr>
<td>Chatal, Chattisgarh</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>800</td>
<td>48</td>
<td>230</td>
<td>0.7</td>
<td>4.4</td>
</tr>
<tr>
<td>Gudagarh, Chattisgarh</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>800</td>
<td>48</td>
<td>230</td>
<td>1.2</td>
<td>6.3</td>
</tr>
<tr>
<td>Rajmachi, Maharashtra</td>
<td>5</td>
<td>7.5</td>
<td>5</td>
<td>800</td>
<td>120</td>
<td>230</td>
<td>1.4</td>
<td>8.2</td>
</tr>
<tr>
<td>Sura, Udaipur, Rajasthan</td>
<td>17.25</td>
<td>15</td>
<td>20</td>
<td>1200</td>
<td>120</td>
<td>230</td>
<td>5.0</td>
<td>7.3</td>
</tr>
<tr>
<td>Nurda village, Jharkhand</td>
<td>28</td>
<td>20</td>
<td>25</td>
<td>1200</td>
<td>120</td>
<td>230</td>
<td>9.5</td>
<td>8.5</td>
</tr>
<tr>
<td>Anandgarh, Bikaner, Rajasthan.</td>
<td>34.5</td>
<td>2*15</td>
<td>2*20</td>
<td>2*1200</td>
<td>120</td>
<td>230</td>
<td>10</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Manoj and Banerjee, 2010
Measurements

Manoj and Banerjee, 2010
# Integrated design-Summary

<table>
<thead>
<tr>
<th>Name of the plant</th>
<th>Connected Load (kW)</th>
<th>Plant Capacity</th>
<th>Distribution loss (%)</th>
<th>Plant capacity factor (%)</th>
<th>Energy cost Rs / kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Existing Designed</td>
<td>Existing Designed</td>
<td>Existing Designed</td>
<td>Existing Designed</td>
<td>Existing Designed</td>
</tr>
<tr>
<td>Solar PV, Rajmachi</td>
<td>1.4 5 kWp 4 kWp</td>
<td>4.6 0.5</td>
<td>8.3 11.5</td>
<td>32 25</td>
<td></td>
</tr>
<tr>
<td>Biomass gasifier, Dissoli</td>
<td>6.9 10 kW 10 kW</td>
<td>12.3 2.0</td>
<td>8.8 12</td>
<td>29-37 21-25</td>
<td></td>
</tr>
</tbody>
</table>
| Biomass gasifier, Lonarwadi | 10.7 20 kW 10 kW | 14.6 2.7      | 5.6 14                | 43-54 16-25

Manoj and Banerjee, 2010
Telecommunication site with hybrid off-grid power solution

Energy source e.g. wind, etc.

PV modules

Panel antenna

Microwave dish (to the public telephone switch)

Shelter

GPRS

MXI
MCU
MCS

BTS

48 V

BTS: Base Transceiver Station
MXI: Communication interface
MCU: Modular Central Unit
MCS: Modular Current Sensor
GPRS: Modem
Shunt: For current measuring

Source: Phocos AG

Source: Phocos: pv magazine, 2011
Cost of Electricity Generation

Capital cost Rs/kW

<table>
<thead>
<tr>
<th>Biomass Gasifier</th>
<th>Solar PV + Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>65,000</td>
<td>1,25,000</td>
</tr>
<tr>
<td>90,000</td>
<td>1,55,000</td>
</tr>
<tr>
<td>1,15,000</td>
<td>1,90,000</td>
</tr>
</tbody>
</table>
Selco Case study – Innovative Financing

- For profit company – Solar Home systems – started 1996 – sold about 100,000 SHS
- 90% of products – credit schemes
- Partnership with 9 banks – interest rates between 12-17%
- Financing Institutions pay 85% of the amount- monthly payments of Rs 300- 400 over a period of 5 years
- Financing/ repayment options – tailormade to end users – paddy farmers – repayment schedule based on crop cycle, street vendors – daily payments – Rs 10
- Funding from REEP – meet margin amount for poor customers, reduce interest rate

Source: SELCO, 2011
Sunderbans Microgrids - Organisation

17 micro grids

Source: Ulsrud et al (2011)
DESI Power

- Biomass based power solutions – Bihar- 25 kW to 100 kW
- Local distributors – decide pricing
- Registered under CDM and sold CERs to Swiss buyer
- MNRE funds, Promoters Equity, ICICI Loan
- Monthly rate based on no of bulbs / loads, Circuit breaker to limit consumption
- Irrigation pump users Rs 50/ hour, Household Rs 120- 150 per month
- Underground trunk wiring-distribution
- Enabling micro-enterprises – battery charging station, flour mill, workshop etc
- Tie up with Telecom towers – increasing capacity factor
Husk Power

- Initial funding – prize money
- 30-100 kW – biomass gasifiers- based on rice husk
- Energy audit of households
- Focus on household demand for lighting
- Lower production, operating costs – use of bamboo, asbestos
- Overhead pole wiring
- Directly reach end user
Wind Power Output Variation

2006-7 Tamil Nadu

Power generated in MW

0 4 8 12 16 20 24

hours

January
June
July
August
September

Power generated in MW

0 200 400 600 800 1000 1200 1400 1600 1800 2000

January
June
July
August
September

Graph showing the variation of wind power output from January to September 2006-7 in Tamil Nadu.
Typical Daily Electricity Generation Variation

March - Best Month for Asansol, ...

Capacity Factor for Mumbai

1-Axis Tracking
Fixed Tilt @ 19 deg.
Annual Average with 1-Axis Tracking
Annual Average with Fixed Tilt @ 19 deg.
Identified Microgrid Scenarios

- Industry
  - Raw Material Extraction
  - Manufacturing Industry

- Commercial
  - Malls/Offices
  - Data Centres/Service Industries

- Residential
  - Villas/Flats/Electric Vehicles

- Isolated
  - Remote areas with no grid access
## Microgrid Scenarios Indian context

<table>
<thead>
<tr>
<th>Sector</th>
<th>Scenarios</th>
<th>Ratings</th>
<th>Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial</td>
<td>Small and Medium Scale Industries</td>
<td>100kW-1MW</td>
<td>Grid+ Combined Heat and Power+ Renewable Energy Technologies</td>
</tr>
<tr>
<td></td>
<td>Large Scale Industries</td>
<td>1 MW-50MW</td>
<td>Grid+ Combined Heat and Power+ Renewable Energy Technologies</td>
</tr>
<tr>
<td>Commercial</td>
<td>Urban Areas-Malls, Offices, Educational Institutions</td>
<td>100kW-10MW</td>
<td>Grid+ Renewable Energy Technologies + Diesel Generator</td>
</tr>
<tr>
<td></td>
<td>Rural Areas-Community Centre, Shops, local business, small manufacturing units</td>
<td>5kW-50kW</td>
<td>Grid+ Renewable Energy Technologies</td>
</tr>
<tr>
<td>Residential</td>
<td>Urban Areas</td>
<td>50kW-1MW</td>
<td>Grid+ Renewable Energy Technologies</td>
</tr>
<tr>
<td></td>
<td>Rural Areas</td>
<td>5kW-50kW</td>
<td>Grid+ Renewable Energy Technologies</td>
</tr>
<tr>
<td>Remote or Isolated</td>
<td>Rural Areas with no grid access</td>
<td>1kW-100kW</td>
<td>Renewable Energy Technologies + Diesel Generator</td>
</tr>
</tbody>
</table>
Large Industry with Combined Heat and Power Generation - Fertilizers and Chemicals, Travancore

Total Load = 23 MW
Captive Generation = 22 MW
ST-Extraction Cum Condensing Steam Turbine

Ref: M.Tech Thesis (Jani Das)
Large Industry with Combined Heat and Power Generation (Data as on 8th October 2011)

Total Load

Load Profile of the Udyogamandal And Petrochemical Division of Fertilizers and Chemical, Travancore

Hour of the day

Ref: M.Tech Thesis (Jani Das)
Medium Industry with Combined Heat and Power Generation
Kurnool District Milk Producers Cooperative Union Limited, Vijaya Milk & Milk Products, Nandyal

- Grid
  - 33/11 kV
  - 11kV/400 V
    - 750 kVA
  - 11kV/400 V
    - 750 kVA
- G1
- G2
  - 200 kVA
  - 100 kVA

- RMRD
- Processing
- Refrigeration
- Deep Freeze
- Powder
- Boiler
- Pre Pac
- Butter, Water and Ghee
- Colony
- Land F

"Mathematical modelling of DSM and Batteries applied to a Medium Scale Milk Industry", P. Ravi Babu V.P.Sree Divya
Medium Industry with Combined Heat and Power Generation

Load in kW

Hour of the day

“Mathematical modelling of DSM and Batteries applied to a Medium Scale Milk Industry”, P. Ravi Babu V.P.Sree Divya
Commercial Microgrid

Three phase Transformer

Grid Tied
Commercial Microgrid

Grid

Solar PV system
Inverter

Wind Turbine System
Inverter

DB

Ground Floor
2.2kW Light and fan loads
38.85kW AC Computers and Printers
4kW

DB

First Floor
Light and fan loads 6.4kW
Projector loads 8kW

DB

Second Floor
Light and fan loads 1.28kW
Projector loads 1.6kW 2.2kW
AC Computers and Printers 1.6kW
Commercial Sector-
Urban Area (IIT Bombay)

Distributed 1 MW Solar power plant@IIT Bombay
Load Profile of Commercial Sector (Urban Area) - IIT Bombay

IITB total load (kW)
Off-grid electricity generation with renewable energy technologies in India: An application of HOMER

Rohit Sen a, Subhes C. Bhattacharyya
Load Profile - Palari Village in Chhattisgarh State

Loads including community centre, shops, local business and small manufacturing units

Off-grid electricity generation with renewable energy technologies in India: An application of HOMER. Rohit Sen, a, Subhes C. Bhattacharyya
Residential Microgrid

- DG Set
- Community AC loads 40kW
- AC/DC Converter
- AC Bus
- DC/DC
- Community DC loads 10kW
- Energy Storage
- Renewable Sources (PV+wind) 40kW
- Plug in EV
- Three phase transformer
- Three phase transformer
Urban Residential Load Profile
kW profile for 3 residential buildings at IIT B Campus

Distributed 1 MW Solar power plant@IIT Bombay
Load Profile of a Remote Residential Region (Rajmachi Village, Maharashtra (data as on 14th April 2008))

Analysis of isolated power systems for village electrification; M.V. Manoj Kumar, Rangan Banerjee
Seasonal variation of load profile-Rural Residential Area

Ranikhet, Almora Kumaon region of Uttarakhand

Development of IREOM model based on seasonally varying load profile for hilly remote areas of Uttarakhand state in India
A.B. Kanase-Patil*, R.P. Saini, M.P. Sharma
Seasonal variation of load profile-Urban Residential Area

Residential Sector of Gujarat State

An assessment of household electricity load curves and corresponding CO2 marginal abatement cost curves for Gujarat state, India
Amit Garg a,n, P.R. Shukla b, Jyoti Maheshwari c, Jigeesha Upadhyay
Strategies

- Optimal Sizing
- Integration of DSM and Supply, Demand Response
- Hybridisation of Supply
- Demand Response
- Intelligent Microgrids - Smart Grids
- Advanced Storage – Hybridisation
- Innovation
- Learning Curve - Public Domain Information
Sizing methodology for a PV-battery system employing DSM

**Inputs for load model**
- Number of households
- Appliances and their technical characteristics
- Share of appliances
- Agricultural pump sets and ratings
- Commercial loads and technical characteristics
- Usage pattern (Time of use) (Daily and seasonal variation)

**Load model**
- Residential electricity consumption (kWh) (2)
- Agricultural electricity consumption (kWh) (4)
- Commercial electricity consumption (kWh) (6)
- Total electricity consumption (kWh) of the area (7)

**Inputs for supply side model**
- Solar radiation data
- Ambient temperature data
- Technical specifications of PV modules
- Technical specifications of battery

**Solar PV and battery model**
- Increment number of PV panels and battery capacity
- Calculation of Reliability (LOLE) for number of PV panels and capacity of battery. (15)

**DSM options input**
- DSM options for end use loads from literature. DSM_i, i=1, 2, 3, ..
- CSE_i ≤ MCOE
  - NO
  - YES
    - Available Demand side option
      - NO
      - YES
        - All DSM options integrated?
          - NO
          - YES
            - Optimum configuration of PV-battery ALCC CGE

**Calculation of ALCC and CGE for different ratings of PV, and battery. (16) - (18)**
<table>
<thead>
<tr>
<th>Sector</th>
<th>Load</th>
<th>% contribution to total load</th>
<th>EE option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Lighting</td>
<td>41.1</td>
<td>60W incandescent to 15W CFL</td>
</tr>
<tr>
<td></td>
<td>Fan load</td>
<td>12.7</td>
<td>Ceiling Fan of 65W replaced by BLDC fan</td>
</tr>
<tr>
<td></td>
<td>TV load</td>
<td>2.1</td>
<td>19 inch CRT TV replaced with 22W LCD</td>
</tr>
<tr>
<td>Agricultural</td>
<td>Motor &amp; pump loads</td>
<td>29.55</td>
<td>Energy efficient motor-56%</td>
</tr>
<tr>
<td>Community</td>
<td>Street lighting</td>
<td>8.45</td>
<td>HPSV lamps by LED lighting</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Annual energy savings(kWh/year)</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>25610</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Load</th>
<th>EE option</th>
<th>Demand savings(kWh/year)</th>
<th>Hours of operation/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lighting load</strong></td>
<td>Replacing Incandescent with 15W CFL</td>
<td>13140</td>
<td>1460</td>
</tr>
<tr>
<td></td>
<td>Replacing CFL with LED</td>
<td>2044</td>
<td>1460</td>
</tr>
<tr>
<td></td>
<td>Replacing with 8W LED</td>
<td>15184</td>
<td>1460</td>
</tr>
<tr>
<td><strong>FAN load</strong></td>
<td>Replacing with 35 W BLDC motor</td>
<td>3240</td>
<td>1460</td>
</tr>
<tr>
<td></td>
<td>Replacing with energy efficient blades(60W)</td>
<td>540</td>
<td>1460</td>
</tr>
<tr>
<td></td>
<td>Improved AC induction motor(50W)</td>
<td>1620</td>
<td>1460</td>
</tr>
<tr>
<td><strong>TV</strong></td>
<td>Replacing with 19 inch LCD TV</td>
<td>635</td>
<td>1095</td>
</tr>
<tr>
<td><strong>Agriculture</strong></td>
<td>Energy efficient motor-56%</td>
<td>5748</td>
<td>2008</td>
</tr>
<tr>
<td><strong>Street lighting</strong></td>
<td>HPSV lamps by LED lighting(40W)</td>
<td>2847</td>
<td>4745</td>
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</table>
Storage Options

UK & India Partnership in Smart Energy Grids and Energy Storage Technologies: IMASE- IITB – Univ Nottingham
End-Note

http://dilbert.com/
Acknowledgment

Thank you

Jani Das
Ammu Susanna Jacob
K. Aravind
Prof. Prakash Ghosh
Amit Parihar
Balkrishna Surve
References


- Renewable Energy in India: Progress, Vision and Strategy, MNRE, Govt. Of India


- SELCO, 2011


