Facilitating RE Integration: Impact of RE on Electricity Networks

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AUE/MEDELEC/Dii Workshop hosted by STEG
TUNIS, 16.04.2014
Our Member States
The first native Arab index dedicated to monitoring and analyzing sustainable energy competitiveness in the Arab region.
AFEX Renewable Energy Final Scores

Colors show range for overall score:
- 0-20
- 20-40
- 40-60
- 60-80
- 80-100

Morocco: 71
Jordan: 59
Egypt: 53
Palestine: 47
Tunisia: 47
Algeria: 45
Lebanon: 33
Syria: 29
Bahrain: 28
Sudan: 25
Yemen: 25
Libya: 20
Iraq: 13
RE Share in Electricity

Figure 6: RE sources as a share of electricity generation for RCREEE countries (2012)

Source: AUE (2012), RCREEE focal points
### RE Share in Electricity (non-hydro)

#### Table 9: RE installed capacity in MW and percentages (2012)

<table>
<thead>
<tr>
<th>Country</th>
<th>Wind MW</th>
<th>Wind %</th>
<th>PV MW</th>
<th>PV %</th>
<th>CSP MW</th>
<th>CSP %</th>
<th>Other RE MW</th>
<th>Other RE %</th>
<th>Total RE MW</th>
<th>Total RE %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>25</td>
<td>0.22</td>
<td>0</td>
<td>0</td>
<td>25</td>
<td>0.22</td>
</tr>
<tr>
<td>Bahrain</td>
<td>0.5</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.06</td>
<td>0</td>
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<td>0.01</td>
</tr>
<tr>
<td>Egypt</td>
<td>550</td>
<td>1.77</td>
<td>15</td>
<td>0.05</td>
<td>20</td>
<td>0.06</td>
<td>0</td>
<td>0</td>
<td>585</td>
<td>1.88</td>
</tr>
<tr>
<td>Iraq</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Jordan</td>
<td>1.45</td>
<td>0.05</td>
<td>1.6</td>
<td>0.05</td>
<td>0</td>
<td>0</td>
<td>3.5</td>
<td>-</td>
<td>6.55</td>
<td>0.10</td>
</tr>
<tr>
<td>Lebanon</td>
<td>0.5</td>
<td>0.02</td>
<td>0.6</td>
<td>0.03</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.1</td>
<td>0.05</td>
</tr>
<tr>
<td>Libya</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0.06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0.06</td>
</tr>
<tr>
<td>Morocco</td>
<td>290</td>
<td>4.50</td>
<td>15</td>
<td>0.23</td>
<td>20</td>
<td>0.31</td>
<td>3,000 m³</td>
<td>-</td>
<td>325</td>
<td>5.08</td>
</tr>
<tr>
<td>Palestine</td>
<td>0</td>
<td>0</td>
<td>1.5</td>
<td>1.06</td>
<td>0</td>
<td>0</td>
<td>0.023</td>
<td>0.02</td>
<td>1.523</td>
<td>1.06</td>
</tr>
<tr>
<td>Sudan</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Syria</td>
<td>0.15</td>
<td>0</td>
<td>2</td>
<td>0.02</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2.15</td>
<td>0.02</td>
</tr>
<tr>
<td>Tunisia</td>
<td>154</td>
<td>3.81</td>
<td>4</td>
<td>0.10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>158</td>
<td>3.91</td>
</tr>
<tr>
<td>Yemen</td>
<td>0</td>
<td>0</td>
<td>1.5</td>
<td>0.10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.5</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Source: RCREEE focal points
### Grid Access

#### Table 5: Priority access and dispatch of RE to the grid

<table>
<thead>
<tr>
<th>Country</th>
<th>Priority Access and Dispatch of RE to the Grid Guaranteed by Law</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>Yes, Executive decree No. 06-428 of 26 November 2006, executive decree No. 06-429 of 26 November 2006, and the order of 21/02/2008</td>
</tr>
<tr>
<td>Bahrain</td>
<td>No</td>
</tr>
<tr>
<td>Egypt</td>
<td>No, but currently, Egyptian Electricity Transmission Company (EETC) purchases all existing RE</td>
</tr>
<tr>
<td>Iraq</td>
<td>No</td>
</tr>
<tr>
<td>Jordan</td>
<td>Yes, Law No 13 (2012) on Renewable Energy and Energy Efficiency, Article 8 C</td>
</tr>
<tr>
<td>Lebanon</td>
<td>No</td>
</tr>
<tr>
<td>Libya</td>
<td>No</td>
</tr>
<tr>
<td>Morocco</td>
<td>No</td>
</tr>
<tr>
<td>Palestine</td>
<td>No, but Palestinian electricity distribution companies are committed to purchase all produced electricity</td>
</tr>
<tr>
<td>Sudan</td>
<td>No</td>
</tr>
<tr>
<td>Syria</td>
<td>No</td>
</tr>
<tr>
<td>Tunisia</td>
<td>No</td>
</tr>
<tr>
<td>Yemen</td>
<td>No</td>
</tr>
</tbody>
</table>

## Supporting Policies (end 2012)

<table>
<thead>
<tr>
<th>Country</th>
<th>Public Competitive Bidding</th>
<th>Direct Proposal Submission</th>
<th>Feed-in Tariffs</th>
<th>Net Metering</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RE sites identified</td>
<td>Tenders announced</td>
<td>Contracts awarded</td>
<td></td>
</tr>
<tr>
<td>Algeria</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bahrain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Egypt</td>
<td>315</td>
<td>315</td>
<td></td>
<td>495</td>
</tr>
<tr>
<td>Iraq</td>
<td>70</td>
<td>60</td>
<td></td>
<td>170</td>
</tr>
<tr>
<td>Jordan</td>
<td>2000</td>
<td>100</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Lebanon</td>
<td>50+</td>
<td>50+</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Libya</td>
<td>170</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morocco</td>
<td></td>
<td></td>
<td></td>
<td>50+</td>
</tr>
<tr>
<td>Palestine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syria</td>
<td>60</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sudan</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tunisia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yemen</td>
<td>60</td>
<td>60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RE in Grids

Extra and High Voltage
- Large Hydro
- CSP
- Large Wind

Medium Voltage
- Commercial Rooftop PV
- Large PV
- Medium Wind
- Residential Rooftop PV
- Small Wind

Low Voltage

Source: Marwa Mostafa, EgyptERA, 2013, LAS/RCREEE Workshop on RE Grid Integration, Bahrain
Connection & Infrastructure Challenges

• System constraints
• Lack of grid access
• Limited grid capacity and coverage
• Lack of technical standards
Example for Variation of PV output due to clouds

PV systems can experience variations in output of +/- 50% in a 30 to 90 seconds, and +/- 70% in a five to ten minute time frame.
System operation

High levels of penetration of RE power have significant impact on the planning and operation of the grid.
Reserves and frequency behavior of power system as a function of time when a large power plant is disconnected from the power system.
Balancing Capacities

Site, grid and market dependent

At 20% capacity penetration, typically 7% of additional capacity is needed for balancing.

Assuming a perfect forecast, it is estimated that only 2% additional capacity would be needed at this penetration level.

Source: Marwa Mostafa, EgyptERA, 2013, LAS/RCREEE Workshop on RE grid Integration, Bahrain
Congestion Management

Implementation of power flow controlling devices in conventional or Flexible Alternative Current Transmission System (FACTS) technology,

Construction of new lines and substations

Access Priority, Curtailment

Avoiding Curtailment

Storage (Hydro Pump-Storage, others)

Cross-boarder Interconnection
460MW STEP D’AFOURER, Morocco
Grid connection

Load flow and dynamic studies to identify:

a. How RE plants will respond to events and faults in the grid?
b. How RE plants will affect the stability of the grid?

Grid codes are developed based on such studies.

Integrating RE projects into power systems is manageable, but not costless. For wind integration: costs rise with higher levels of wind penetration, but are below $10/MWh – and often below $5/MWh – for wind capacity penetrations of as much as 30% of the peak load of the system*.

Highlights from RCREEE Countries

E.g. Egypt’s Wind Code

Egypt Electricity Code:
• Section 1: Data Code
• Section 2: Connection Code
• Section 3: Testing Code
• Section 4: Protection Code
• Section 5: Performance Code
• Section 6: Planning Code
• Section 7: Operation Code
• Section 8: Metering Code
• Section 9: Scheduling and Dispatch Code

• Wind Code

Main Requirements
• Fault ride through (FRT) requirements.
• Transmission system voltage and reactive power capability requirements
• System frequency and frequency response requirements; (Active Power Control)
• Wind power forecasts requirements
• Power Quality
• Secondary equipment, monitoring at the point of common coupling and remote operation requirements
Highlights from RCREEE Countries

E.g. Egypt’s Wind Code

- **Conditions for connection**
  
  Frequency: $48 \text{ Hz} \leq f \leq 50.2 \text{ Hz}$  
  Voltage: $0.95 \text{ per unit} \leq U \leq 1.05 \text{ per unit}$

- **Start-up of the Wind Farm**
  
  The increase in the active power shall not exceed 10 % of the Rated Power of the Wind Farm per minute.

- **Disconnection from the Grid**
  
  - **Voltage ranges**
  
  - **Frequency ranges**

<table>
<thead>
<tr>
<th>Voltage range</th>
<th>Time period for operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.85 per unit – 0.90 per unit</td>
<td>Unlimited</td>
</tr>
<tr>
<td>0.90 per unit – 1.10 per unit</td>
<td>Unlimited</td>
</tr>
<tr>
<td>1.10 per unit – 1.15 per unit</td>
<td>30 minutes</td>
</tr>
</tbody>
</table>

![Voltage and Frequency Chart]

![Voltage and Frequency Table]
E.g. Egypt’s Wind Code

**Active power control**
- Active power output
- Active power reduction due to over frequency

\[ \Delta P = 0.4 \times PM \times \frac{\Delta f}{Hz} \]

PM: actual output power before the grid frequency exceeds 50.2 Hz
\( \Delta f \): actual grid frequency minus 50.2 Hz

**Reactive power control**

**Fault Ride Through (FRT)**

**Power Quality**
- Harmonics (IEEE – 519)
- Flicker (IEC61000-3-7)
- Voltage unbalance (up to 2%)
- Voltage fluctuations (up to 5%)
- Voltage change (± 5%)

Source: Marwa Mostafa, EgyptERA, 2013, LAS/RCREEE Workshop on RE Grid Integration, Bahrain
Draft Egypt’s PV Code (Low Voltage Connections)

- Voltage range of operation (+ 10%)
- Frequency range of operation (48.5Hz - 51Hz)
- Flicker (Distribution Code)
- Harmonics (IEC 61727)
- Power factor (0.9)
- D.C. Injection (up to 0.5% - IEC 61727)
- Synchronization (inverter)
- Disconnection due to over and under frequency (47.5 Hz and 52 Hz)
- Earthing
Highlights from RCREEE Countries

Jordan Case

- Establishing a Renewable Energy & Energy Efficiency Fund JREEF
- Obligation to purchase renewable energy
- All Energy Output from RE projects must be purchased pursuant to Power Purchase Agreements (PPA).
- Interconnection Cost: NEPCO – Transmission Company ------- To interconnect and cover the costs of interconnection line between the project and the nearest substation.

Key regulations are issued or being finalized:
- Guideline for Connection of RE Systems – Under Net Metering System
- Cost of Connecting RE Facility to Distribution Grid (Network Upgrading)
- Draft Electric Power Wheeling Services Charge Directive
- ....
Highlights from RCREEE Countries

Jordan Case

Under Net-metering

- The maximum of the overall installed and connected capacity of Renewable Energy Systems to
  - Low Voltage side: shall not exceed (1%) of the Peak load of each Distributor.
  - Medium Voltage side: shall not exceed (1.5%) of the Peak load of each Distributor.
  - A 1-ø & 3-ø (Low Voltage) & 3-ø (Medium Voltage): Customers may install and use Renewable Energy Systems with a capacity not exceeding the average monthly consumption.


Figure 5.43 NEPCO LVRT requirement of Wind Power Plant

Fault Ride Through optimization
Highlights from RCREEE Countries

Jordan Case

Technical Impact

✓ For horizon year 2020 the unexpected generation drop of wind Farms can be tolerated only in interconnected mode.

✓ The trip of wind farms in isolated mode of operation can be mitigated increasing the primary control reserve up to 10% of total generation otherwise blackout.

Incremental Requirements for Operational Reserve

<table>
<thead>
<tr>
<th>Year</th>
<th>Reserve no-wind</th>
<th>Reserve with wind</th>
<th>Incremental reserve</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>110</td>
<td>111</td>
<td>1%</td>
</tr>
<tr>
<td>2015</td>
<td>126</td>
<td>131</td>
<td>4%</td>
</tr>
<tr>
<td>2020</td>
<td>172</td>
<td>204</td>
<td>19%</td>
</tr>
</tbody>
</table>

# Highlights from RCREEE Countries

## Lebanon Case

### Net-Metering

<table>
<thead>
<tr>
<th>Specifications and Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Connection Voltage Match</strong></td>
</tr>
<tr>
<td>Feedback less than meter capacity</td>
</tr>
<tr>
<td><strong>Power Factor: 90-100%</strong></td>
</tr>
<tr>
<td>Voltage Surge Protection</td>
</tr>
<tr>
<td><strong>External Safety Switch</strong></td>
</tr>
<tr>
<td>Earthing system ~30 Ohms</td>
</tr>
<tr>
<td><strong>Specify if generator is self excited type</strong></td>
</tr>
<tr>
<td>P&lt;60 kW</td>
</tr>
<tr>
<td><strong>Voltage 230/400 V</strong></td>
</tr>
<tr>
<td>Monophase: Max 60A</td>
</tr>
<tr>
<td><strong>Tri-Phase: 3x100A</strong></td>
</tr>
<tr>
<td>Inverter: Islanding, UL1741, High freq. transformer</td>
</tr>
<tr>
<td><strong>Specifications for inverter</strong></td>
</tr>
<tr>
<td>IEC/VDE</td>
</tr>
</tbody>
</table>

Source: LCEC presentation, 2013, LAS/RCREEE Workshop on RE Grid Integration, Bahrain
Arab Guideline for Renewables Grid Connection Requirements

Scope: Wind and solar energies for generating electricity.

Expected Contents:
• Major technical challenges and proposed solutions
• Regulatory translation of the technical requirements
  • Regulations
  • Contracts
• Codes:
  • Generic codes for large scale wind farms being connected on high voltage grids
  • Generic codes for small scale PV connected to low voltage
• Compliance with Grid codes
• Basic and complementary studies for connecting RE plants and Forecast of RE
• Survey for the current status of grids and RE and the expected plans, and associated analysis with examples of necessary documents in different Arab countries

Coming Soon
Conclusion

• Access to the grid is crucial for the viability of RE projects.

• Priority dispatch and grid access is important to increasing competitiveness of RE and for guaranteeing transmission and distribution of RE electricity at time of production.

• Governments should establish clear and consistent conditions for grid access and operation requirements.

• Specifying the grid access details in national-level regulations is an effective approach.

• Integration of RE is manageable but not costless!!
Project: *Wind farms in Zafarana*
Capacity: *545 MW*
Developer: *Public (NREA)*
In operation since: *2001-2010*