Boosting Capacity of Electric Generation through the use of Turbo-Expanders in Natural Gas Network

8 May 2014
Main Objective

Investigation the possibility of increasing the generation capacity through the use of Turbo-Expanders in Natural Gas Networks.
Basic Concept

Additional Electricity with No Fuel

High Pressure Level

Throttling Valve

Large amount of energy of high pressure gas is wasted during the pressure reduction process.

Low Pressure Level

Gas Preheater

Turbo-Expander

Extracting electric generation capacity from wasted energy in natural gas pressure reduction stations at electricity power plants.
Natural Gas Network in Egypt

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
Today, NG is transmitted and distributed through the NGG, which extends from Matrouh in the northwest and the Western Desert to the Sinai in the east with high density in the Nile Delta and Suez areas.
Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
The Recommended Pressure Reduction Levels for Turbo-Expander Installation

Supply: 70 barg
Main Distribution: 42 barg
Gas Turbine Power Plant: 13 barg
Distribution Pressure for Industrial and Residential Districts: 7 barg
Distribution Pressure within Facilities: 4 barg
Working Pressure: 20 mbarg

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
The Recommended Pressure Reduction Levels for Turbo-Expander Installation

**Up Stream Reduction Stations**

- Are the most attractive sites to install Turbo-expander units.
- These stations enjoy steady, high pressure ratio as well as high flow rate.
- Most of them are supplying large industrial companies as well as electric power plants.
- They are close to the electricity grid.

**Down Stream Reduction Stations**

- are not attractive sites.
- They are highly dispersed and consequently supplying limited number of equipment.
- They suffer from low diversity factor, which makes the gas flow less steady.
- They have limited flow rates as well as low pressure ratios.

All these factors limit the potential of power per site as well as reduce the unit loading ratio.
A Turbo-Expander is basically a radial or axial gas turbine which produces power due to gas expansion from high pressure at its upstream to a low downstream pressure.

Expansion Process → Temperature Decrease

- Cooling of the gas
- Condensation of the gas composition
- Erosion of expander blades

Therefore, gas preheating is used.
Turbo-Expander Mechanism

• **Gas Preheating:**
  - boosts the power of the Turbo-expander due to the increase in the enthalpy of the upstream gas.
  - prevents hydrate forming in natural gas stream.

• When the Turbo-Expander is installed parallel to the throttling valve in a pressure reduction station, the pressure reduction is primary achieved by the Turbo-Expander while the throttling valve is only used during maintenance time of the expander.
Evaluating the Potential of Electricity Generation from NG Pressure Reduction

<table>
<thead>
<tr>
<th>NG Flow (Standard m³/hr)</th>
<th>Incoming Gas Pressure (bar g)</th>
<th>Outlet Gas Pressure (bar g)</th>
<th>Pressure Reduction Ratio</th>
<th>Power Generated (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
<td>60</td>
<td>2</td>
<td>30:1</td>
<td>700</td>
</tr>
<tr>
<td>45,000</td>
<td>37</td>
<td>15</td>
<td>2.45:1</td>
<td>1500</td>
</tr>
<tr>
<td>6,500</td>
<td>55</td>
<td>9</td>
<td>6.1:1</td>
<td>750</td>
</tr>
<tr>
<td>9,000</td>
<td>40</td>
<td>7</td>
<td>5.6:1</td>
<td>470</td>
</tr>
<tr>
<td>16,000</td>
<td>18</td>
<td>6</td>
<td>3:1</td>
<td>850</td>
</tr>
<tr>
<td>5,500</td>
<td>50</td>
<td>3</td>
<td>16.7:1</td>
<td>570</td>
</tr>
</tbody>
</table>

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
Additional Power Generation of Cairo Electricity Production Company

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
Additional Energy Generation of Cairo Electricity Production Company

Annual Energy Generated (GWh)

<table>
<thead>
<tr>
<th>Site</th>
<th>Annual Energy Generated (GWh)</th>
<th>Additional Annual Energy Generated (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoubra El-Kheima (St)</td>
<td>5,168.4</td>
<td>36.84</td>
</tr>
<tr>
<td>Cairo West (St)</td>
<td>6,803.7</td>
<td>625</td>
</tr>
<tr>
<td>Cairo West Ext. (St)</td>
<td>4,010.05</td>
<td>42.65</td>
</tr>
<tr>
<td>Tebbin (St)</td>
<td>2,630.83</td>
<td>23.47</td>
</tr>
<tr>
<td>Cairo South I (CC)</td>
<td>709.21</td>
<td>17.13</td>
</tr>
<tr>
<td>Cairo South II (CC)</td>
<td>46.41</td>
<td>6.94</td>
</tr>
<tr>
<td>Cairo North (CC)</td>
<td>126.2</td>
<td>1.36</td>
</tr>
<tr>
<td>Wadi Hof (G)</td>
<td>625.34</td>
<td>4.1</td>
</tr>
<tr>
<td>6 October (G)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network

13/05/2014
## Additional Power Generation of East Delta Electricity Production Company

<table>
<thead>
<tr>
<th>Plant</th>
<th>Installed Capacity (MW)</th>
<th>Additional Power Generation (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ataka (G)</td>
<td>900</td>
<td>3.44</td>
</tr>
<tr>
<td>Abu Sultan (St)</td>
<td>600</td>
<td>3.02</td>
</tr>
<tr>
<td>Shabab (G)</td>
<td>100</td>
<td>0.12</td>
</tr>
<tr>
<td>Port Said (G)</td>
<td>73</td>
<td>0.07</td>
</tr>
<tr>
<td>EL-Arish (St)</td>
<td>66</td>
<td>0.3</td>
</tr>
<tr>
<td>Oyun Mousa (St)</td>
<td>640</td>
<td>3.51</td>
</tr>
<tr>
<td>Damietta (CC)</td>
<td>1,200</td>
<td>4.59</td>
</tr>
<tr>
<td>New Gas Damietta (G)</td>
<td>500</td>
<td>2.42</td>
</tr>
<tr>
<td>New Gas Shabab (G)</td>
<td>1,000</td>
<td>5.23</td>
</tr>
</tbody>
</table>

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
Additional Energy Generation of East Delta Electricity Production Company

Annual Energy Generated (GWh)

Additional Annual Energy Generated (GWh)

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
Additional Estimated Power Generation of Middle Delta Electricity Production Company

Boasting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network

<table>
<thead>
<tr>
<th>Location</th>
<th>Installed Capacity (MW)</th>
<th>Additional Power Generation (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talkha (CC)</td>
<td>290</td>
<td>1.27</td>
</tr>
<tr>
<td>Talkha steam 210 (St)</td>
<td>420</td>
<td>1.69</td>
</tr>
<tr>
<td>Talkha 750 (CC)</td>
<td>750</td>
<td>1.82</td>
</tr>
<tr>
<td>Nubaria 1,2,3 (CC)</td>
<td>2,250</td>
<td>5.78</td>
</tr>
<tr>
<td>Mahmoudia (CC)</td>
<td>316</td>
<td>1.53</td>
</tr>
<tr>
<td>El-Atf (CC)</td>
<td>750</td>
<td>2.87</td>
</tr>
</tbody>
</table>
Additional Energy Generation of Middle Delta Electricity Production Company

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
Additional Power Generation of West Delta Electricity Production Company

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
## Additional Energy Generation of West Delta Electricity Production Company

<table>
<thead>
<tr>
<th>Location</th>
<th>Annual Energy Generated (GWh)</th>
<th>Additional Annual Energy Generated (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaff El-Dawar (St)</td>
<td>1,957.7</td>
<td>16.19</td>
</tr>
<tr>
<td>Damanhour Ext. 300..</td>
<td>522.53</td>
<td>3.76</td>
</tr>
<tr>
<td>Damanhour (St)</td>
<td>982.671</td>
<td>8.52</td>
</tr>
<tr>
<td>Damanhour (CC)</td>
<td>1,035.26</td>
<td>6.25</td>
</tr>
<tr>
<td>Abu Kir (St)</td>
<td>4,871.3</td>
<td>35.4</td>
</tr>
<tr>
<td>El-Seif (G)</td>
<td>209.141</td>
<td>23.47</td>
</tr>
<tr>
<td>Sidi Krir (St)</td>
<td>3,848.41</td>
<td>24.02</td>
</tr>
<tr>
<td>Sidi Krir (CC)</td>
<td>5,315.94</td>
<td>2.93</td>
</tr>
<tr>
<td>Matroh (St)</td>
<td>339.909</td>
<td></td>
</tr>
</tbody>
</table>

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
Additional Power Generation of Upper Egypt Electricity Production Company & BOOT

- Kuriemat (St): Installed Capacity 1,254 MW, Additional Power Generation 5.13 MW
- Kuriemat 1 (CC): Installed Capacity 750 MW, Additional Power Generation 2.5 MW
- Kuriemat 2 (CC): Installed Capacity 750 MW, Additional Power Generation 2.44 MW
- Sidi Krir 3,4 (St): Installed Capacity 2,754 MW, Additional Power Generation 2.89 MW
- Suez Gulf North (St): Installed Capacity 2,754 MW, Additional Power Generation 2.68 MW
- Port Said East (St): Installed Capacity 2,754 MW, Additional Power Generation 2.79 MW

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
<table>
<thead>
<tr>
<th>Location</th>
<th>Annual Energy Generated (GWh)</th>
<th>Additional Annual Energy Generated (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuriemat (St)</td>
<td>7,397.7</td>
<td>44.97</td>
</tr>
<tr>
<td>Kuriemat 1 (CC)</td>
<td>4,986.38</td>
<td>21.89</td>
</tr>
<tr>
<td>Kuriemat 2 (CC)</td>
<td>4,348.29</td>
<td>21.34</td>
</tr>
<tr>
<td>Sidi Krir 3,4 (St)</td>
<td>4,614</td>
<td>25.32</td>
</tr>
<tr>
<td>Suez Gulf North (St)</td>
<td>3,994</td>
<td>23.44</td>
</tr>
<tr>
<td>Port Said East (St)</td>
<td>4,247</td>
<td>24.44</td>
</tr>
</tbody>
</table>

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
• The turbo-expander additional electricity is generated without affecting the natural gas consumption by power plant. Hence, a certain amount of natural gas is avoided.
• This amount will result in carbon dioxide release avoidance.

<table>
<thead>
<tr>
<th></th>
<th>Annual NG Avoided</th>
<th>Annual Co2 Avoided</th>
<th>Annual NG Avoided Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ktoe</td>
<td>Ton CO2</td>
<td>Subsidized NG</td>
</tr>
<tr>
<td>Total</td>
<td>129.85</td>
<td>44,753</td>
<td>8,656,038</td>
</tr>
</tbody>
</table>
Final Results

Total additional power generation = 91.25 (MW)

Total additional annual electricity generated = 799.39 (GWh)

Annual NG Avoided = 129.85 (ktoe)
Impact of Inlet Temperature Variation on Power Generation

If the inlet temperature changes by 10 degrees Celsius reduction, then the capacity will fall by 2.8% and vice versa.

- Tin=70°C: Total Power = 88.67 MW
- Tin=80°C: Total Power = 91.26 MW
- Tin=90°C: Total Power = 93.84 MW
## Potential Profit Margin

<table>
<thead>
<tr>
<th>Owner</th>
<th>Capital Cost (Mio EGP)</th>
<th>Profit (Thousand EGP)</th>
<th>Payback Period (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Subsidized)</td>
<td>1,450</td>
<td>60,652</td>
<td>27</td>
</tr>
<tr>
<td>(Unsubsidized)</td>
<td>1,450</td>
<td>228,382</td>
<td>6</td>
</tr>
</tbody>
</table>
Ownership and Operational Responsibility

High Pressure Gas

Meter

Pressure Reduction Station

Throttling Valve

Meter

Boiler

Turbine

Generator

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
Ownership and Operational Responsibility

High Pressure Gas

Pressure Reduction Station

Throttling Valve  Turbo-Expander

Boiler  Turbine  Generator

Meter  Meter  Meter  Generator

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
Ownership and Operational Responsibility

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
Ownership and Operational Responsibility

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
Transmission and distribution networks

Bilateral agreement

Payment through escrow account

Generation Co.

IPP expansion

Electricity users

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network
ITT expansion

Generation Co.(s)

Trans Co(s)

Dis Co(s)

MV & LV Customers

Exports & Imports

Private Distributor

MOEE/EEHC

Gov. PP

BOOT(s)

UHV Customers

HV Customers

MV Customers

LV customers

ISP

Target Market

Phase one

Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network

13/05/2014
Target Market
Proposed phase two
Ministry of Electricity and Energy

- IPP expansion
- Generation Co.(s)
- TSO
- Dis Co(s)
- MV & LV Customers
- BOOT(s)
- UHV Customers
- HV Customers
- MV Customers
- Exports & Imports
- ISP(s)

Independent Merchant Transmission & Distribution

Target market proposed phase three

EEUCPRA
Boosting Capacity of Electric Generation through the use of Turbo-Expanders in NG Network

13/05/2014
Possible demo implementations

• At plants with large/steady flow rate of NG, and with high pressure reduction
  – In power plants
  – At current power plants in the industrial sector
  – At large scale industrial sector
THANK YOU