Perspectives on Economic Flexible Operation (EFO)
December, 2017
Uniper is a global energy company

Our operations:
- Power Generation
- Commodity Trading
- Energy Storage
- Energy Sales
- Energy Services

Where we operate:
- 40+ countries around the world
- 4th largest generator in Europe

Employees: 13,000

Main activities:
- Gas fired plants 20.1 GW
- Coal fired plants 9 GW
- Energy storage Gas: 8.4 bn m³
- Gas fields
- Gas pipelines and infrastructure
- Regasification
- Nuclear plants 2.5 GW
- Hydroelectric plants 3.6 GW
- Trading
- Energy sales (small to large clients, electricity and gas)
- Services

Uniper has 100 year heritage serving 600 power sector, industrial clients in 40+ countries
Uniper’s portfolio and capabilities allows to offer technology services with global footprint

Global footprint and broad service offerings

- Innovation delivery
- Engineering services
- Maintenance and asset optimization
- Project management/development
- Nuclear services

Value proposition

- Leading one-stop-shop energy solutions provider with services across the value chain and life-cycle
- Optionality to tap into global new-build project opportunities

Business at a glance (UEG1)

- Expertise across multiple technologies
- Services to more than 600 customers
- Active in more than 40 countries

1. Uniper Engineering GmbH
2. Based on 2015
European market has changed significantly over 10 years

1. Reduction in Demand
   • Global recession has destroyed power demand across Europe

2. Global Commodity Prices
   • \( \text{CO}_2 \) prices have dramatically fallen caused by oversupply – attempts to reform have failed to date
   • US shale gas has increased US coal exports making coal generation cheaper than gas
   • However global gas prices have and oil prices putting coal at margin

3. Renewables Growth
   • Incentive schemes designed to deliver European 2020 targets have caused the strong and constant growth of Renewables

4. Political Intervention

Source: Eurostat (code: nrg_105a)
Conventional generation as base load needed on days of low yield of wind and solar

Key considerations

1. Significant renewables feed-in with direct impact on electricity production from conventional power plants
   - Very limited production by conventional power plants in times of high renewables feed-in

2. Conventional power plants required to address hours of limited renewables production

→ Change in operating regime for coal and gas power plants from base load to flexible
Higher renewable penetration on particular days can completely change the energy pattern

- Reduction in absolute MWh from coal and gas units
- Coal and gas switch on short run marginal costs (fuel)
- The future is uncertain with many more questions – what will electric cars mean?
Flexibility at Ratcliffe power station

Operating Hours and Starts Per year Since Commissioning

Monthly starts over time for a coal fired plant
Uniper’s Economic Flexible Operation (EFO)

- Uniper has developed a low cost commercial solution
- Unique and expert flexibility support in a single package
- A turnkey, holistic approach with optional components
- Immediate, mid, and long term issues
- A focus on economic operation, maximising income & reducing risk
- Developed & demonstrated over decades
- We can help you get the most from your existing assets
Potential Value of EFO

The potential real world value of EFO approach typically includes*:

- Shorten start-up times by 20-50%
- Improve ramp rate and load following by 50%
- Reduce major component replacement costs by 20-30%
- Increase max load by 5-10% of $P_{\text{max}}$
- Reduce minimum load to 10-20% of $P_{\text{max}}$
- Increase major outage intervals by 20-40%
- Reduce daily maintenance costs by 10-20%
- Reduce fuel oil and water consumption by 10-20%
- Extend economic plant life by 5-15 years

A significant increase in useful asset utilisation, life and profitability

*Achievable benefits are site specific
Our journey so far and learning from you…

- Government agencies
- State utilities
- Private companies
- Knowledge partners

Stakeholder management
Uniper & India Power have formed a strategic partnership to develop, service power sector

India Uniper Power Services (IUPS)

- 50:50 joint venture in power plant services
- A value-based service provider
- Offering a broad range of flexible and customised services
- Highly skilled talent pool of ~600 employees in India
- Supported by expertise from UK and Germany
Our experience as owner and operator allows us to offer services across the value chain.

<table>
<thead>
<tr>
<th>Project Development</th>
<th>Construction and Implementation</th>
<th>Asset Operation</th>
<th>Energy Trading</th>
<th>Decom-missioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Project Development Participation</td>
<td>Owners Engineering Activity</td>
<td>Asset Strategy &amp; Management</td>
<td>Fuel Supply</td>
<td>Plant Decommissioning</td>
</tr>
<tr>
<td>Owners Engineer</td>
<td>Construction Management</td>
<td>Business Planning</td>
<td>Coal</td>
<td>Residual Waste Treatment Centre</td>
</tr>
<tr>
<td>EPC Tendering</td>
<td>Commercial Management</td>
<td>O&amp;M Strategy and Execution</td>
<td>LNG</td>
<td>Plant Demolition</td>
</tr>
<tr>
<td>Planning, permitting and Impact Assessment</td>
<td>Site Management &amp; Inspections</td>
<td>Asset Improvement</td>
<td>Natural Gas</td>
<td></td>
</tr>
<tr>
<td>Conceptual and Basic Design</td>
<td>Planning &amp; Execution</td>
<td>Performance Management</td>
<td>Market Access</td>
<td></td>
</tr>
<tr>
<td>External Stakeholder Management</td>
<td>Commissioning</td>
<td>Risk Management</td>
<td>Offtakes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Training, Learning and Development</td>
<td>Market Analysis</td>
<td></td>
</tr>
</tbody>
</table>

HSSE

Renewables | CCGT | Full Technology Coverage | Coal | Hydro

uniper
Coal: reliable partner for fluctuating solar and wind production …
# Power Plant Heyden – technical data

<table>
<thead>
<tr>
<th>General:</th>
<th>1987 start operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed Capacity</td>
<td>800 MW(_\text{el})</td>
</tr>
<tr>
<td>Todays capacity</td>
<td>875 MW(_\text{el})</td>
</tr>
<tr>
<td>Efficiency Full load</td>
<td>41 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Steam</th>
<th>2700 t/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supercritical pressure</td>
<td>215 bar</td>
</tr>
<tr>
<td>Supercritical temperature</td>
<td>544 °C</td>
</tr>
<tr>
<td>Intermediate pressuer / Temp</td>
<td>46bar / 545 °C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flexibility</th>
<th>20% / 180MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min load</td>
<td>11% / 100MW</td>
</tr>
<tr>
<td>Since 01.06.2017</td>
<td>15…20MW/Min</td>
</tr>
<tr>
<td>Ramp rate</td>
<td>1 hour</td>
</tr>
<tr>
<td>Hot start time to grid</td>
<td>3 hours</td>
</tr>
<tr>
<td>Hot start time to full load</td>
<td></td>
</tr>
</tbody>
</table>
One Mill operation for ~10% min load

- 2015: planning and checking technical feasibility
- 2016: testing
- 2017: optimizing, as normal operation since 01.06.2017
Increase of max Capacity

1987 Start operation 800 MW brutto
1993 Increase output 880 MW brutto
1998 Increase output 910 MW brutto
2005 Increase output 920 MW brutto
2015 Optimize output Back to 920 MW brutto
Production@Ratcliffe:

Increasing Ratcliffe’s flexibility and commercial offer to meet current and future energy market demands

December 2017
Production@Ratcliffe: More competitive in every aspect

- Faster to grid
- Faster to full load
- Cheaper to run
- Faster off the bars
- Warmer longer for the next start

Cheaper to start
Production@Ratcliffe: 
Taking Responsibility

- Pond Fines and Fuel Mix
- Hot Warm & Cold Starts
- Faster to Grid (improved NDZ)
- Access to market if NDZ within 90 minutes – more attractive for hot standby
- Fast Shutdown from SEL
- Super SEL
- Loading Rates / Hold Points
- NDZ/MZT/MNZT - Parameters
- On-load Oil Use
- 3 Mill Loading
- Boiler pressure raising with coal prior to sync
Production@Ratcliffe: Faster to full load

- Objective
  - Increase loading rates and reduced hold points
- Benefit
  - Supports reduced oil burn
  - ‘Extrinsic’ commercial value
- Status
  - Hold points removed from all starts
  - Aspiration to return to 5min hot turbine run-up to speed
  - Aspiration to achieve 50MW block load after synch (hot start)
  - 2MW/min load rate to 50MW trialled (cold start) [currently 0.5MW/min]

<table>
<thead>
<tr>
<th>State</th>
<th>Then (mins)</th>
<th>Now (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot</td>
<td>86</td>
<td>57</td>
</tr>
<tr>
<td>Hot / Warm</td>
<td>67</td>
<td>67</td>
</tr>
<tr>
<td>Warm</td>
<td>109</td>
<td>80</td>
</tr>
<tr>
<td>Cold</td>
<td>190</td>
<td>190</td>
</tr>
</tbody>
</table>

Underpinned by work on start-ups
+ Improved reliability of sequences (e.g. FGD)
+ Improved familiarity with soft desk
Startup  Hot & Hot/Warm

• Objective
  • Reduce oil burn, reduce firing time & target oil burners out by 100MW
  • Extend Hot status window into Hot/Warm
  • Reduce Notice to reach BOA market (85 mins on Hot now with trading)

• Benefit
  • Oil burn saving £750k – £1.25m
  • Normalise UO workload & avoid ‘peaks’
  • Increased value from more runs

• Status
  • Stage 1 testing completed (oil burners O/O/S by 160MW), New Ops procedure written & rolled out to all shifts.
  • Stage 2 testing in progress - oil burners O/O/S by 100MW, aim for ~60 mins first fire to unit sync
Startup - Warm

• Objective
  • Similar principle to Hot & Hot/Warm (faster & cheaper!)

• Benefit
  • Oil burn saving £200k - £400k

• Status
  • To start following Hot & Hot/Warm trials

Now seeing benefits from other areas will influence ability to deliver
Data shows learning points from other states are already being embedded
Startup - Cold

• Objective
  • Reduce total cold start time by ~3hrs (7 hrs down to 4 hrs)
  • Reduce time from Sync to SEL.

• Benefit
  • Unit in the money faster after sync
  • Oil burn saving £250k - £500k
  • Reduce cold NDZ to <300Mins (if boiler N2 capped) or <479 (if boiler ‘wet stored’)

• Status
  • 2 Cold start trials carried out – U3 30/07/2017 & U2 04/09/2017
  • Initial trials successful.– 27.4T of oil saved, total time from first burner to sync 4hrs, and then Sync to 230MW 1hr.
  • Area’s identified where further improvements can be made – Aim to target oil usage of <50t for cold start.
Production@Ratcliffe: Faster off the bars

- **Objective**
  - Reduce shut down time and oil burn
  - Retain more heat in turbine to facilitate faster return and extended warmth states (stay hotter for longer)

- **Benefit**
  - Oil burn saving ~ £250k

- **Status**
  - Plant Sim for 140MW shutdown permissive & 80MW de-load rate implemented for testing on all available units.
  - Shut down time reduced from 17mins to 9mins for 230MW so – 0MW.
  - 9 mins shut down now being achieved consistently.
  - Ready to be rolled out
Production@Ratcliffe: Cheaper to Run

Focus on actual fuel mix to bunkers. Increasing pond fines and USHS proportions

Improved ash & gypsum sales

Integrated work with trading to reflect actual costs in dispatch
On-Load Oil Use

• Objective
  • Reduce on-load oil usage
    • No oil burners for 5th/ 6th /7th mills In/Out of service

• Benefit
  • Supports reduced oil burn (£300k - £600k)

• Status
  • Test procedure written and circulated for comment
  • Testing planned to start in October
3 Mill Loading

4 Mills I/S @ 230MW
- Nox emissions close to monthly limit c.440mg

3 Mills I/S @ 230MW
- Nox emissions very good c.350mg.

In both Cases
- No supporting ignition fuel required for stable flame
- Fire was clean and stable
- No impingement of burner flame on furnace rear wall
  - PF flame ‘well rooted’ to the ignition tube
  - No pulsating of the flame
- Furnace pressure stable and maintaining ~-0.5 mbar
Startup Oil

Startup Oil Performance

Reduced Consumption
Reduced Variation
Future Targets
Start Oil Reductions – achieved and target
Production@Ratcliffe: More Competitive

Faster to grid
- 50% reduction NDZ for Hot Starts

Faster to full load
- 30% reduction in Hot Start time to full load

Cheaper to run
- 12% reduction in £/MWhr

Faster off the bars
- 50% reduction in time to shut down

Warmer longer for the next start

Cheaper to start
- 25% fuel cost reduction per Hot Start

Ratcliffe Generating – The Uniper Way
Disclaimer

This document is provided to you by Uniper solely for discussion purposes and does not create any legally binding obligation. This document is for your exclusive reference only and neither it nor any of its content may be disclosed, summarised or otherwise referred to except as agreed in writing with Uniper. The distribution of this document and the availability of any products referred to in it may be restricted by law in certain jurisdictions.

This document is not intended to form the basis of any decision to enter into a transaction or investment activity. The products, services, deliverables mentioned in the document are solely for the purpose of illustration and does not constitute as an offer or commitment, a solicitation of an offer or a commitment to deliver or any recommendation to do so. The binding terms and conditions will be set forth in a separate document. To the extent applicable, Uniper does not accept any liability for any direct, consequential or other loss arising from reliance on this document or any other information provided.