SPE-167331-MS

Real Time Online Energy Management at KNPC Refineries

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OUTLINE

• Introduction
  • KNPC refineries
  • Energy Management Cell
  • Real Time Energy Management System (RTEMS)

• Project implementation tasks

• RTEMS functionalities

• Optimization implementation procedures

• Cost savings and CO2 emissions reduction

• Conclusions
KNPC REFINERIES

- KNPC operates three refineries in Kuwait:
  - Mina Al Ahmadi refinery
    - Refining capacity: 466,000 bpd
    - Main units: Crude distillation, Fluid Catalytic Cracking, Atmospheric Residue Desulphurization, Vacuum Rerun and Sulphur Recovery. It also includes a Gas Liquefaction Plant
  - Mina Abdullah refinery
    - Refining capacity: 270,000 bpd
    - Main units: Crude distillation, Atmospheric Residue Desulfurization, Vacuum Rerun, Delayed coker, Sulphur Recovery, Hydrocracker, Hydrotreaters and Hydrogen plant
  - Shuaiba refinery
    - Refining capacity: 200,000 bpd
    - Main units: Crude distillation, Gas-Oil cracking, H-Oil, Catalytic Reforming, Unifiers, Sulphur Recovery and Hydrogen production
ENERGY MANAGEMENT CELL (EMC)

• Article 18 of Kuwait Petroleum Company (KPC) HSEMS requires that all KPC units develop an energy management policy. All operations must manage energy in accordance with the best engineering/environmental practices within regulatory compliance at all times.

• To comply with this requirement, a joint effort between Mina Abdulla, Mina Al-Ahmadi and Shuaiba refineries started to build and define the scope of Energy Management for the three refineries.
EMC: DUTIES AND RESPONSIBILITIES

- Daily energy rates monitoring for all process units
- Analyzing and troubleshooting Excess LP steam scenarios
- Identifying and leading energy savings related activities from process
- Adjusting operating parameter affecting unit energy consumption in view of refinery steam balance
- Reviewing and implementing technologies for energy improvements available from outside technology companies and consultancies
- Successful implementation of Real Time Optimizer, Visual Mesa for KNPC MAB Refinery with vendor team (Jul-2011 to Jun-2012)
ENERGY MANAGEMENT CELL

Mina Abdulla Refinery:

• Visual Mesa was implemented on Jun-2012

• Main objective was to analyze and troubleshoot Excess LP steam scenarios using Visual Mesa on daily basis

• Case studies were built using Visual Mesa stand alone

• In case of upset in steam system, Big Change report was used to identify the bad actors
ENLIGHTEN MANAGEMENT CELL

Savings = 116-35.49
= 80.51 $/ HR
Annual Savings = 0.64 Million USD
Estimated CO₂ reduction = 11820 Tons/year

AVG = 116

AVG = 35.49
ENERGY MANAGEMENT CELL

EXCESS LP STEAM VENTING TO ATM. KLB/HR

Date

LP steam Venting flow, KLB/Hr

16/03/13  18/03/13  20/03/13  22/03/13  24/03/13  26/03/13  28/03/13  30/03/13

Lp venting flow
KLB/HR

Average Year 2010
30 KLB/HR

Average Year 2011
7.5 KLB/HR
ENERGY MANAGEMENT CELL

EXCESS LP STEAM TO CONDENSOR, KLB/HR

Date

16/03/13 18/03/13 20/03/13 22/03/13 24/03/13 26/03/13 28/03/13 30/03/13

Excess LP to Condensor.
KLB/HR

- excess LP to cond
- Excess LP to cond Target
REAL TIME ENERGY MANAGEMENT SYSTEM (RTEMS)

REAL TIME ENERGY MANAGEMENT SYSTEM (RTEMS)

**REAL TIME ENERGY MANAGEMENT SYSTEM (RTEMS)**

**VISUAL MESA**

Energy Management System

**CLOSED-LOOP**
signals to
control systems

**OPEN-LOOP**
advise reports to
operators

**Measurements**

**Optimum Set Points**

**Industrial Site**

**Utilities Systems**

- Hydrogen
- Fuel
- Steam
- Water
- Electricity

**Process**

**Emissions Regulations**

**External Utilities Contracts**

**Optimum Operations Report**

**Energy and Emissions KPIs Monitoring**
PROJECT IMPLEMENTATION TASKS

- Define and Installation Stage
  - Data collection
  - Control system review
  - Software installation
  - Detailed model scope definition

- Model Building and Configuration Stage
  - Detailed model of the steam, fuels, electricity, emissions, boiler feed water and condensates systems

- Training Stage
  - Users training
  - Review and fine tuning

- Site Acceptance Stage

- Commissioning Stage
PROJECT IMPLEMENTATION TASKS: MODEL BUILDING

Graphical User Interface – KNPC MAB model
PROJECT IMPLEMENTATION TASKS: CONFIGURATION

- Main optimization handles configured are:
  - Fired boilers steam production balancing (taking into account also the on-line calculated efficiencies)
  - Steam letdowns
  - Steam vents
  - Pump swaps (steam turbine and electrical motor optional drivers)
  - Fuels to fired boilers
  - Makeup fuel to Fuel Gas network (Natural Gas)
  - Electricity importation

- Main constraints to be met are the following:
  - Processes energy demand
  - Burners capacity
  - Emissions limits (NOx / SO2)
  - Contractual constraints
  - Maximum and minimum operating limits for boilers
**PROJECT IMPLEMENTATION TASKS: CONFIGURATION**

### Actionable Items

<table>
<thead>
<tr>
<th>Boilers Production (kib/hr)</th>
<th>Actual</th>
<th>Optimized</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-31-101A</td>
<td>124.3</td>
<td>100.0</td>
<td>-24.3</td>
</tr>
<tr>
<td>B-31-101B</td>
<td>137.9</td>
<td>100.0</td>
<td>-37.9</td>
</tr>
<tr>
<td>B-31-101C</td>
<td>111.3</td>
<td>100.0</td>
<td>-11.3</td>
</tr>
<tr>
<td>B-31-102A</td>
<td>146.4</td>
<td>146.2</td>
<td>-0.2</td>
</tr>
<tr>
<td>B-31-102B</td>
<td>146.2</td>
<td>146.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Total Boilers 900# Steam</td>
<td>666.1</td>
<td>629.5</td>
<td>-36.6</td>
</tr>
<tr>
<td>B-06-101 (150# Steam)</td>
<td>56.7</td>
<td>56.7</td>
<td>0.0</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>U18 Letdowns (%opening)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>U-18 TR1 - 900# to 450# LD</td>
<td>10.0</td>
<td>5.0</td>
<td>-5.0</td>
</tr>
<tr>
<td>U-18 TR2 - 900# to 450# LD</td>
<td>17.0</td>
<td>5.0</td>
<td>-12.0</td>
</tr>
<tr>
<td>U-18 TR3 - 900# to 450# LD</td>
<td>6.0</td>
<td>5.0</td>
<td>-1.0</td>
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</table>

### Turbines and Motors Swaps

<table>
<thead>
<tr>
<th>Unit</th>
<th>Driver</th>
<th>Name</th>
<th>Power (HP)</th>
<th>Steam cons. (meas.)</th>
<th>Actual Status</th>
<th>Optimized Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-31 (Utilities)</td>
<td>Turbine</td>
<td>P-31-101B-ST</td>
<td>286</td>
<td>0.00</td>
<td>Stopped</td>
<td>Running</td>
</tr>
<tr>
<td>U-31 (Utilities)</td>
<td>Motor</td>
<td>P-31-101B-M</td>
<td>286</td>
<td>0.00</td>
<td>Running</td>
<td>Stopped</td>
</tr>
<tr>
<td>U-37</td>
<td>Turbine</td>
<td>P-37-101B-ST</td>
<td>292</td>
<td>0.00</td>
<td>Stopped</td>
<td>Running</td>
</tr>
<tr>
<td>U-37</td>
<td>Motor</td>
<td>P-37-101B-M</td>
<td>292</td>
<td>0.00</td>
<td>Running</td>
<td>Stopped</td>
</tr>
<tr>
<td>U-37</td>
<td>Turbine</td>
<td>P-37-102B-ST</td>
<td>86</td>
<td>7.42</td>
<td>Running</td>
<td>Slow Roll</td>
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<tr>
<td>U-37</td>
<td>Motor</td>
<td>P-37-102C-M</td>
<td>86</td>
<td></td>
<td>Stopped</td>
<td>Running</td>
</tr>
</tbody>
</table>

Custom report example with RTEMS optimization recommendations
RTEMS FUNCTIONALITIES

• Real Time Optimization
  • Objective function:
    • Total energy cost = Fuels cost + Power costs + Other costs (water)
    • Mixed Integer Non Linear optimization technique
    • Automatic run at a given frequency (30 minutes)

• What-if planning
  • Evaluation of potential capital or operating changes to the complex and assess the economics and operability of the changes, by using the model in stand-alone mode

• Auditing and Monitoring
  • Follow-up of key parameters such as equipment efficiencies and energy cost savings
  • Data validation and imbalances identification
RTEMS FUNCTIONALITIES: RTO – EXAMPLE 1

- Example of Delta views (differences optimum – actual) for KNPC SHU refinery model

- Optimization recommendations:
  - Steam production ratio among boilers
  - Pump swaps
Delta view for KNPC MAB refinery model (differences between optimum and actual)
• Pump swaps as main optimization actions
• Significant reduction in steam letdowns
• Reduction in the excess of low pressure steam
RTEMS FUNCTIONALITIES: RTO – EXAMPLE 2 (CONT.)

Delta view for KNPC MAB refinery model (differences between optimum and actual)

• Group of turbines and motors giving the same service where the start of steam turbine and shutdown of an electrical motor was recommended
РTEMS FUNCTIONALITIES: WHAT-IF PLANNING EXAMPLE

• Evaluation of the impact on utilities system of reducing the Medium Pressure steam to the reformers at KNPC MAB refinery

• In this case, 16 kph less (8 kph to each cell) is sent to the steam methane reformers so a reduction of 0.8 in the Steam to Hydrocarbon ratio (S/HC ratio) is obtained

• It was observed a decrease of 900 psi steam to the network from the unit (in this case 12.5 kph) and a decrease of Fuel gas consumed

• The corresponding effect on the power plant is a decrease in steam letdowns and low pressure steam vent and/or steam to condensing

• The Delta View from RTEMS graphical user interface show the differences between actual and comparison cases highlighted
Delta view for KNPC MAB refinery model corresponding to the evaluation of the impact of reducing medium pressure steam to reformers.

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**RTEMS FUNCTIONALITIES: MONITORING REPORT EXAMPLE**

<table>
<thead>
<tr>
<th>Heater</th>
<th>Current Efficiency (LHV %)</th>
<th>Target Efficiency (LHV %)</th>
<th>Current O2 %</th>
<th>Target (Design) O2 %</th>
<th>Current FG Flow (KSCF/h)</th>
<th>Current FG Duty (MMBTU/h)</th>
<th>At Target Efficiency FG Flow (KSCF/h)</th>
<th>At Target Efficiency FG Duty (MMBTU/h)</th>
<th>At Target Efficiency FG Duty Savings (MMBTU/h)</th>
<th>At Target Efficiency $ Savings per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-14-101</td>
<td>89.0</td>
<td>89.2</td>
<td>2.2</td>
<td>2.0</td>
<td>39.7</td>
<td>49.6</td>
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<td>49.5</td>
<td>0.1</td>
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<tr>
<td>H-14-102</td>
<td>88.9</td>
<td>88.8</td>
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<td>2.0</td>
<td>36.2</td>
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<td>36.2</td>
<td>45.2</td>
<td>0.1</td>
<td>8.2</td>
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<tr>
<td>H-14-103</td>
<td>91.4</td>
<td>91.2</td>
<td>1.5</td>
<td>2.0</td>
<td>163.5</td>
<td>204.4</td>
<td>163.5</td>
<td>204.4</td>
<td>0.1</td>
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<tr>
<td>H-18-101A</td>
<td>82.4</td>
<td>82.1</td>
<td>1.7</td>
<td>2.0</td>
<td>135.1</td>
<td>168.9</td>
<td>135.1</td>
<td>168.9</td>
<td>0.1</td>
<td>8.2</td>
</tr>
<tr>
<td>H-18-101B</td>
<td>82.7</td>
<td>82.4</td>
<td>1.7</td>
<td>2.0</td>
<td>132.3</td>
<td>165.4</td>
<td>132.3</td>
<td>165.4</td>
<td>0.1</td>
<td>8.2</td>
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<td>82.6</td>
<td>1.9</td>
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<tr>
<td>H-18-301A</td>
<td>83.1</td>
<td>82.6</td>
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<td>169.8</td>
<td>135.9</td>
<td>169.8</td>
<td>0.1</td>
<td>8.2</td>
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<tr>
<td>H-18-301B</td>
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<td>81.9</td>
<td>1.4</td>
<td>2.0</td>
<td>132.1</td>
<td>165.1</td>
<td>132.1</td>
<td>165.1</td>
<td>0.1</td>
<td>8.2</td>
</tr>
</tbody>
</table>

- The model calculates the incremental cost for the fuel burnt
- This report allows prioritizing the actions to improve combustion based on economic impact
RTEMS FUNCTIONALITIES: IMBALANCES FOLLOW-UP EXAMPLE

• Big imbalances are visually identifiable
  • The size of the balloon increases and/or the color dynamically changes
• Either visually or in a report, the RTEMS will flag these large imbalances to the user who can then focus maintenance attention on the meters associated to that balance
• If a particularly important sensor fails in the validation test, the RTEMS could automatically shut down optimizers
OPTIMIZATION IMPLEMENTATION PROCEDURES

RTEMS gathers the sensors data from DCS/Plant Information System through OPC server

New process condition will occur and the results shown in DCS/Plant Information System after implementation

RTEMS processes the online data values and it is automatically executed for the recommendation

Energy Management Cell (EMC) evaluates the recommendations and passes them to Operations for implementation

The Recommendation are automatically generated every half an hour and shown in the web based report
COST SAVINGS AND CO2 EMISSIONS REDUCTION

The base case was established when the model was completed on May ’12 with energy cost savings opportunity of about 680 $/hr.

By the end of December ’12 the energy cost savings potential were reduced to about 180 $/hr reflecting obtained savings of about 500 $/hr (4.4 MM$/year).

Captured savings because of the optimization actions implementation resulted in reduced firing in the boilers and less power purchase.

(Results corresponding to KNPC MAA refinery)

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COST SAVINGS AND CO2 EMISSIONS REDUCTION

The cost savings and CO2 emission reductions came from two main sources:

- Excess steam vent / condensing reduction (i.e., less fuel gas used for UHP steam production because of the steam waste reduction)
- Letdown reduction (i.e., less power purchase for driving the pumps and compressors because of the use of turbines instead of motors)

Note: KNPC MAA Energy Management Cell was awarded with the KNPC President HSE Silver Award because of reducing Carbon footprint
CONCLUSIONS

• Implementation of RTEMS to help with the three KNPC refineries energy cost minimization and energy management has been described
• It allows to clearly identify the different economic trade-offs that challenges the operation of the site wide energy systems at minimum cost while reducing the energy waste and, therefore, CO2 footprint
• Recommendations given by the RTEMS are taken into account by operations on a daily basis
• It has been also observed that having a model of the whole refinery energy system validated with real time data, in one environment that everyone has access to, also to understand all the decision variables and the associated constraints, which sometimes are hidden or ignored, helps in the coordination among plant areas in order to increase energy efficiency and reduce total energy costs
Thank You!

Questions?