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- PC system based on artificial intelligence for data mining and numerical/analytical simulators used for on-line optimization and predictions.

- Day-to-day optimization and short/long term planning with on-line connection to dynamic data – SCADA, numerical forecast of UGS performance with respect to conditions on the market specified by dispatching center and financial management.

- Optimization of UGS and enhanced control of gas production/injection with respect to reservoir and well properties, conditions of surface technologies and distribution pipelines leads to realization of full storage potential and reducing operational costs and future investments.

- ES started by RWE-Transgas with Schlumberger and ESK in 2004.
Smart UGS Concept

An instrumented and controlled underground gas storage that utilizes Information Technology to bring together people, technology, processes and information in a dynamic, secure and global system to reduce risk, lower cost and enhance rates and active capacities. Expert system is intended for day-to-day optimization of UGS operation.
Integration Platform

Level 3
- Dispatch Environment
- Expert system

Level 2
- Numerical models

Level 1
- Dynamic data: SCADA system
- Static data: well, reservoir and technology descriptions

Reservoir - Wells - Gathering system - Facilities

Model Coupling and Automated Execution
- Eliminate divide between up- and downstream
- Understand facility constraints on reservoir
- Identify system optimization opportunities

Model Management
- Existing models: ensure that they are well-behaved e.g. no significant convergence issues when run stand-alone

Data Preparation and Pre-Processing
- Data QC, Parameter Calculation,
  Data Distribution, Event Detection
ES UGS – basic chart

UGS SCADA System

Core of ES

Control Module Short-Term

Surveillance and Reporting Modules

Workflow Design and Automation

Data Buffer

Network Modelling

Database

Simulation

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seconds

minutes – hours

1 hour - 1 day

1 month – 1 year (cycle)
ES UGS-Workflow

UGS Online Workflow

Well Performance

- **Well Status**
  - (Shut-In, Downtime)
  - Production Constraints
  - BHP Calculation
  - Gas Volumetric

Reservoir Performance

- **Reservoir Simulation**
  - History Match Verification
  - Weekly Potential
  - Cycle Potential

Facility Performance

- **Facility Simulation**
  - (Injection Production)
  - Evaluation of Facility Status
  - Flowmeter Restrictions
  - Capacity Constraints
  - Delivery Request

**System Optimisation**

- (Key Performance Indicator Calculations, Smart Alarming and Visualisation, Forecasting)

**Data Pre-Processing**

- (Filtering, Outlier Removal, QC, Availability)

**Data Preparation**

- (Data Generation, Parameter Calculation)

**Automated Data Distribution and Model Execution**

Flow of Input Data
Flow of Performance Data
Flow of Simulation Data
Model Control Processes

Model Integration and Control

Material Balance
Simulation Blackoil
Function of Influence
Proxy Model
Well Simulator
Network Simulator

Design Workflow
Core of Expert System
Monitoring and Data QC
Event Detection and Performance Monitoring
Automated Data Transfer and Model Execution

Operational Workflow
Neural Networks Training & Architecture

- Neural Networks “learn” during iterations
- Continuous iteration through all training data
- Weights are adjusted to minimize error (RMS)

Calculate RMS Error
\[ \Delta = S_i - O_i \]

Calculate all patterns Input Pattern again

if \( \Delta > \varepsilon \) then adjust weights

Input Layer
- THP
- BHP
- Watercut

Hidden Layer

Output Layer
- Gas Production

Output Pattern after calculating all patterns

Diagram: Neural Network Architecture
- Neural network structure with input, hidden, and output layers.
- Equations for calculating input and output:
  \[ a = \sum_i w_i \cdot o_i \]
  \[ o = f(a) \]
- Adjust weights for minimizing error.
Reservoir/Well Performance Surveillance

- Real-time surveillance data is forwarded to the dynamic model to update the pressure and water influx prediction.
- Together with updated rate data, the Neural Network calculates a bottom hole flowing pressure which is then compared with the actual measurement.
- Changes in the well’s PI due to increased sand production could be determined very early.

Investigate the performance of your gas storage reservoir
- use colours to identify your time cycles (e.g. yearly)
- use online data queries
- identify trends
- identify storage volumes

ALARM! Measured bottomhole flowing pressure deviates from expected pressure behavior! Well PI changed!
Surface – Reservoir Coupling Optimisation and Prediction

Vertical Flow Performance Tables

- DECIDE! HUB SERVER
- DECIDE! DESKTOP
- CENTRAL DISPATCHING AND MANAGEMENT
- NUMERICAL MODELS: ECLIPSE, PORTEC, MBI, PIPESIM

UGS Desktop Modules
- UGS LOBODICE
- UGS TVRDONICE
- UGS STRAMBERK
- UGS DOLNI DUNAJOVICE
- UGS TRANOVICE

UGS SCADA

UGS LOBODICE
UGS TVRDONICE
UGS STRAMBERK
UGS DOLNI DUNAJOVICE
UGS TRANOVICE
Dispatchers environment and operational tool – automated update and forecast
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Conclusions:

- The challenge of ES development lies in direct remote analyses and objective unbiased operation.

- Cost savings are related to a high level of automation and continuous optimization of reservoir and surface network management of UGS operation.

- By the end of 2007- ES application on all UGS facilities of RWE-Transgas, a.s.