Gas Pipeline Simulation Software
State-of-art and Future Outlook

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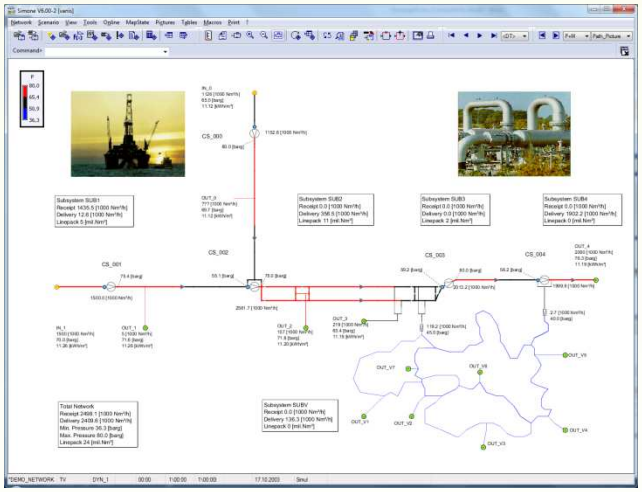
Technical presentation, IGU WOC3 Meeting
October 6-9, 2014, Prague

Outline

- Introduction
  - History
  - Background
- Basic applications
  - Technical view
  - System integration
  - Benefits
- New requirements
  - TSO/DSO environment
  - Technical advances
- Case study
- Outlook & Vendor's Mission



Gas Pipeline Simulation

- History
  - Research, Spin-off companies
  - In-house software
  - Standardized industrial solutions
- Complex background
  - Flow physics
    - Pipe flow, non-pipe equipment
  - Mathematics
    - Numerical methods, Optimization
    - Dynamic systems
  - IT

$$\frac{\partial m}{\partial x} + S\frac{\partial \rho}{\partial t} = 0$$

$$\frac{1}{S}\frac{\partial m}{\partial t} - 2w\frac{\partial \rho}{\partial t} + w^2\frac{\partial \rho}{\partial x} + \frac{\partial P}{\partial x} + g\rho\frac{dh}{dx} + f_R = 0$$

$$S\rho c_P\left(\frac{\partial T}{\partial t} + w\frac{\partial T}{\partial x}\right) - S\left(1 + \frac{T}{z}\left(\frac{\partial z}{\partial T}\right)_p\right)\frac{\partial p}{\partial t} - Sw\frac{T}{z}\left(\frac{\partial z}{\partial T}\right)_p\frac{\partial p}{\partial x} + Swg\rho\frac{dh}{dx} + Q_E = 0$$

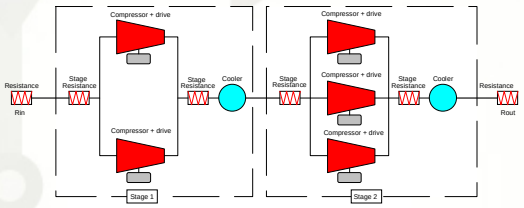
$$\lambda = \frac{1}{\left(2\log\left(\frac{4.518}{\mathrm{Re}}\log\left(\frac{\mathrm{Re}}{7}\right) + \frac{k}{3.71D}\right)\right)^2}$$

$$p = \rho RTz$$

$$Q_E = \pi Dk\left(T - T_{soil}\right)$$

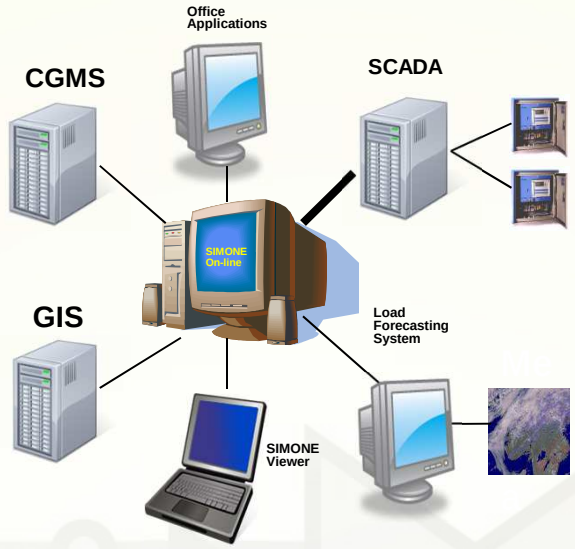
$$\dot{x} = Ax + b$$

$$F(x) = 0$$



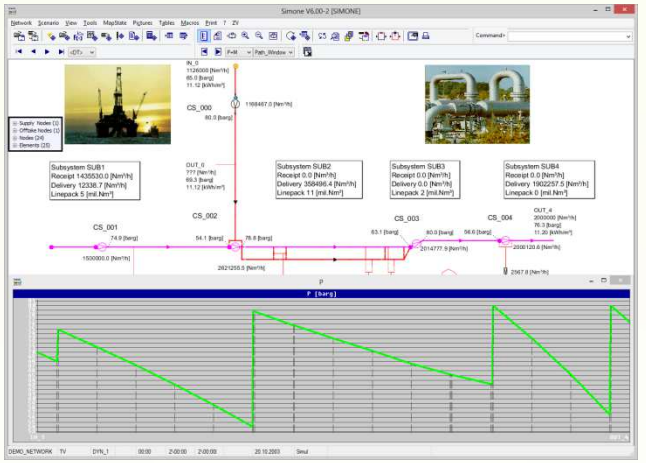
Basic Applications

- Offline simulator
- Online simulator
- Leak detection
- Training system
- Gas quality reconstruction



- Simulation | Real-time simulation | Optimization

Computational Tasks

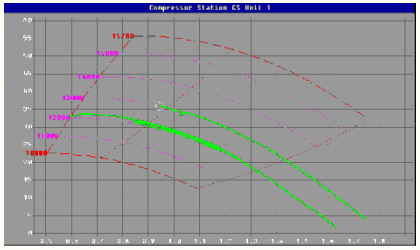


- "What-if?"
  - Steady-state simulation
  - Transient simulation
  - Real-time simulation
- "What to do?"
  - … to minimize fuel gas
    - Steady-state optimization
    - Compressor control, number of units running
    - Transient optimization
  - … to plan transport routes
  - … to plan network extensions

Offline Simulator

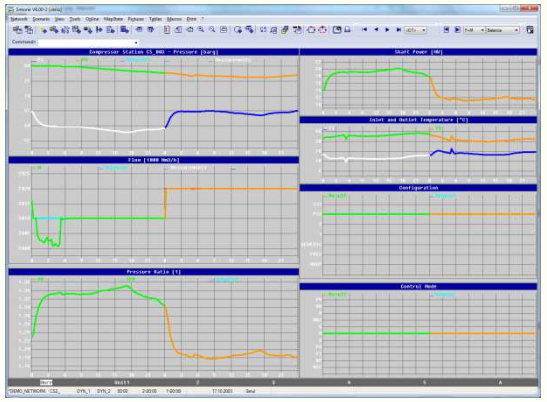
- Standalone desktop application
- Expert use
- Integrated features
  - Network topology & equipment data handling
  - GUI
  - Steady-state & transient simulation
  - Optimization
- System interactions
  - On request
  - Network model – GIS
  - Load data - CGMS, SCADA archives…

Offline Simulator - Use & Benefits



- Asset management of TSO/DSO
  - Pipeline design, extensions & changes
  - Equipment verification
  - Capacity verification
  - Operational planning (mid-term)
    - Outages handling
    - Suggested procedures
- Operational planning
  - Live process data???

Online Simulator



- Interfacing SCADA → live process data
- Real-time simulator
  - Cyclic state reconstruction
- Look-ahead simulation
  - Starts from last estimated state
  - Forecast of load used
  - What happens if no control action takes place
- Interactive “what-if” simulations
  - Derived from look-ahead, or from archive data
- Administration
  - Cyclic tasks, network model, data links, manual entries
- Integration
  - SCADA MMI  GUI of simulator

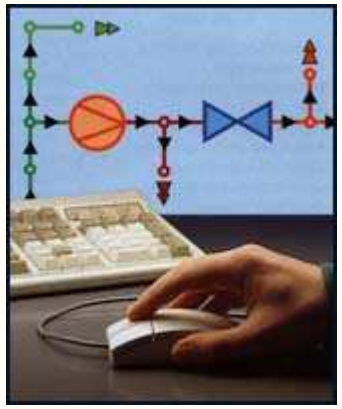
Online Simulator – Benefits, Experience

- Interdisciplinary implementation project
- Follow the user roles!
- Continuous surveillance needed
  - More apparently than e.g. SCADA
  - → Improving process data overview
- Routine results improve dispatcher's overview
- Analytical features for expert users

Simulation-based Leak Detection

- Real-time model
  - Cyclic state reconstruction
- Leak detection
  - Balance method
  - Signal analysis over real-time model results
  - Location methods (area → position)
  - Network state augmented by leak size and location
- Performance
  - Limits exist
  - Location no better than $10^{0 \div 1}$ km
  - Continuous surveillance needed!
- To be considered in conjunction with other approaches

Training System



- Prepare dispatching staff
  - Emergency and/or non-standard situations
- Simulation loop
  - Lecturer's scenario
  - Trainee's input
- Trainee's environment ~ SCADA MMI
- Defining lecturer's scenarios
  - Link to archived process data beneficial

Gas Quality Reconstruction

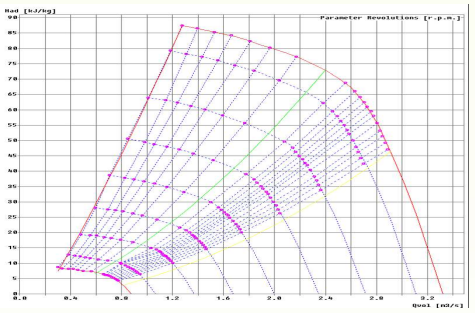
- Gas quality known at supplies (entries)
- Gas quality at off-take points?
- State reconstruction on ex-post data
  - 1 month back, data completed & corrected
- Use for energy-based billing
  - Legal issues - metrological approval
  - Virtual metering device
  - Verified by test operation

New Requirements – User Environment

- Unsteady environment for TSO/DSO
  - Regulatory changes
  - New transport routes
- Flexible operation planning
  - Short-term, under varying inputs
  - Improve expert use of online simulator
- Flexible capacity verification
- New challenges for asset management
- Staff preparation
- Risk management

New Requirements - Technical

- Compressor technology advances
- Controlled gas mixing
- Gas properties description
- Flow physics
- Solution methods development
- Computer science & technology
- IT



$$p = \rho RTz$$

Case Study

- **TSO: NET4GAS, SW: SIMONE**
  - **Offline instances – asset management, capacities**
  - **Online simulator**
    - Linked with SCADA (IDS)
  - **NSM – integrated solution for short-term operation planning**
    - Linked with online simulator
    - Nominations from CGMS (Trygas)
    - Prepare & evaluate next gas day plan
  - **Training system**
    - Training loop integrated into SCADA-like environment (UniControls)

Vendor's Mission (SIMONE)

- SIMONE – one of standard industrial solutions
  - SIMONE Research Group + LIWACOM Informationstechnik
  - 350 installations incl. 36 online systems at 78 pipeline operators in 35 countries
- Ready-to-use general package
  - GUI – comfort & power
  - Defined system perimeter for integration
  - Easy implementation
  - Defined ways for customization
  - Uniform environment for all tasks
- Computational kernel
- Balance general functionality & user requirements

Conclusion

- Particular but mission-critical part of gas industry
- Live & developing field
  - Theoretical background
  - Technical view
  - Process view
  - IT & system integration
- Thank you!