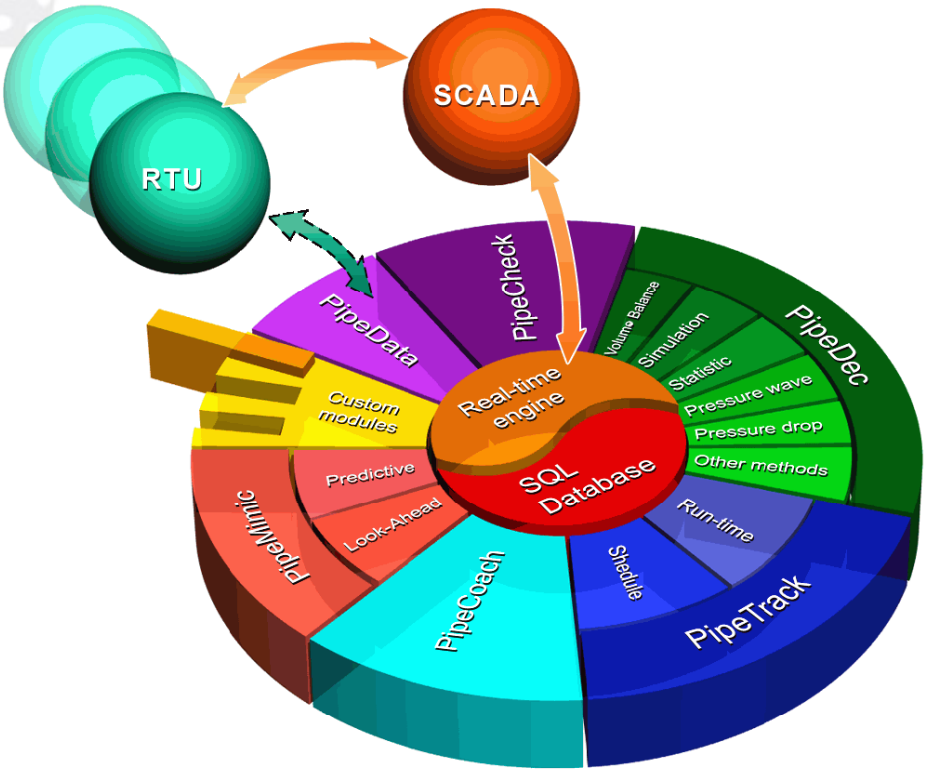
PipeMan
pipeline management system
System overview

PipeMan solution

Pipeline application software PipeMan is internationally industry proven system providing support for safe and cost effective operation of liquid pipelines.



PipeMan offers a full range products for liquids pipelines, it consists of industry standard online and offline modules including following:

- **Leak detection and location**
- **Over/under pressure protection**
- **Parcel/Batch tracking**
- **Pig tracking**
- **Custody transfer**
- **Batch scheduler**
- **Offline training simulator**
- **Offline pipeline simulator**
- **Historical data collection**
- **Content management system**

All PipeMan modules are based on industry standards and they cover complete range of operating conditions with various parameters.

Latest PipeMan version was built to provide also high flexibility and adaptability. It can be easily extended with a new custom built module and easily integrated with any SCADA system.

Online modules

PipeMan online modules (Batch tracking, LDS, etc.) preform calculations based on real-time data. The data source can be SCADA system, OPC server or directly PLCs/RTUs.

PipeMan platform supports fully duty/stand-by operation with automatic failover in case of hardware or network failure.

The latest PipeMan system was developed respecting SCADA engineer thinking. It means that its configuration and tuning are as close as possible to SCADA. For this reason the most common solution is PipeMan integration with SCADA system. SCADA system acquires data from RTUs/PLCs at regular intervals. Our system accesses information from SCADA system using the provided data interface (native API, OPC or ODBC).

Depending on deployed modules and methods following data are important for PipeMan:

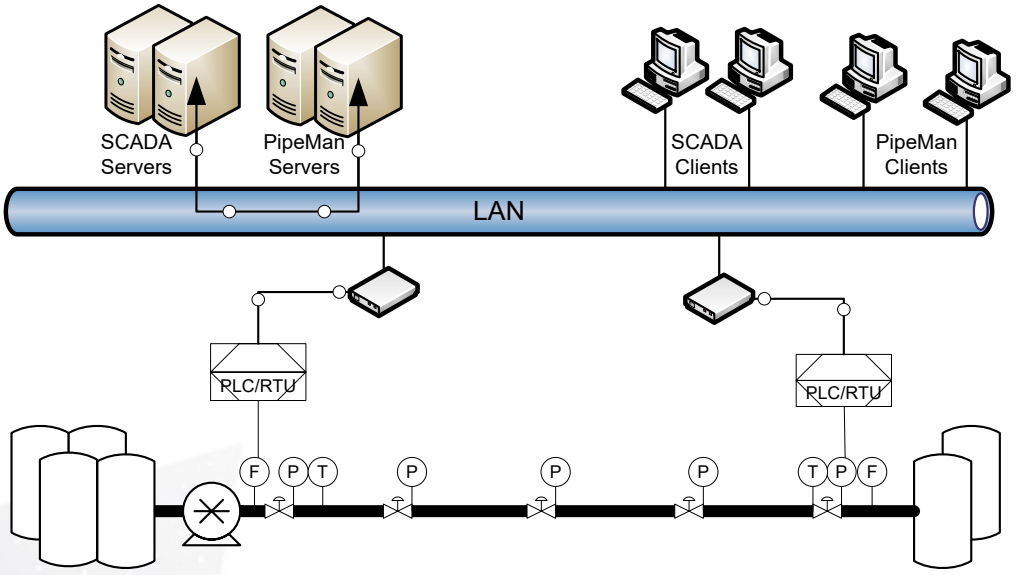
- Pressures
- Flow rates, volume totals
- Temperatures
- Densities
- Valve states (isolating or control valve position)
- Pump states (and pump rpm if available)
- Tank levels (if required)

Any information resulting from the PipeMan calculations can be fed back to SCADA using the same interface. By default, only critical alarms and events are transferred to SCADA system and processed in SCADA's own standard manner.

PipeMan provides web based user interface accessible from any web browser supporting HTML 5 standard. This allows to integrate the client to SCADA mimics and at the same access it from any workstation or even mobile devices with the web browser.

PipeMan can be even fully integrated into SCADA system, with use of SCADA mimics for presentation of PipeMan calculation results.

PipeMan is already prepared for integration with various SCADA systems offered by the industry known SCADA vendors and SCADA systems supporting OPC standard.



PipeMan online architecture with redundant servers

PipeDec - Leak detection and location module

Example of PipeMan starting screen - PipeDesk

PipeMan leak detection and location module called PipeDec was built with experiences acquired on many projects and from hundreds of testing leaks in the real world conditions. All these experiences make PipeMan not only more sensitive, accurate, but also very reliable and stable without losing a flexibility

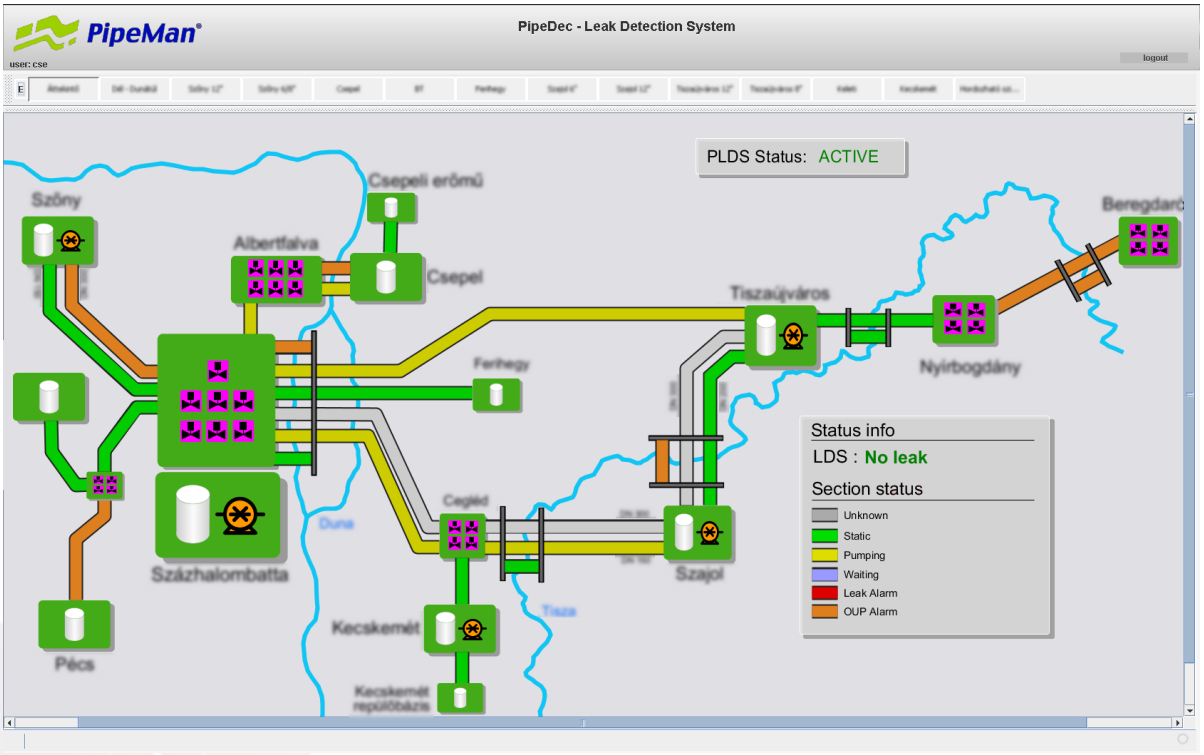
The module relies on several leak detection techniques suitable for different conditions and using different instruments. The following methods can be plugged into PipeMan server:

- Pressure wave method
- Dynamic simulation method
- Volume balance method
- Pressure drop method

The system has its own UI running on the web or as a desktop application and it supports all main operating systems because it is Java based. If preferred, leak detection can easily be integrated with SCADA and use only its mimics.

Alarm, event viewer and various reports are included by default. If pipeline coordinates are available, PipeDec can display the leak location on the map.

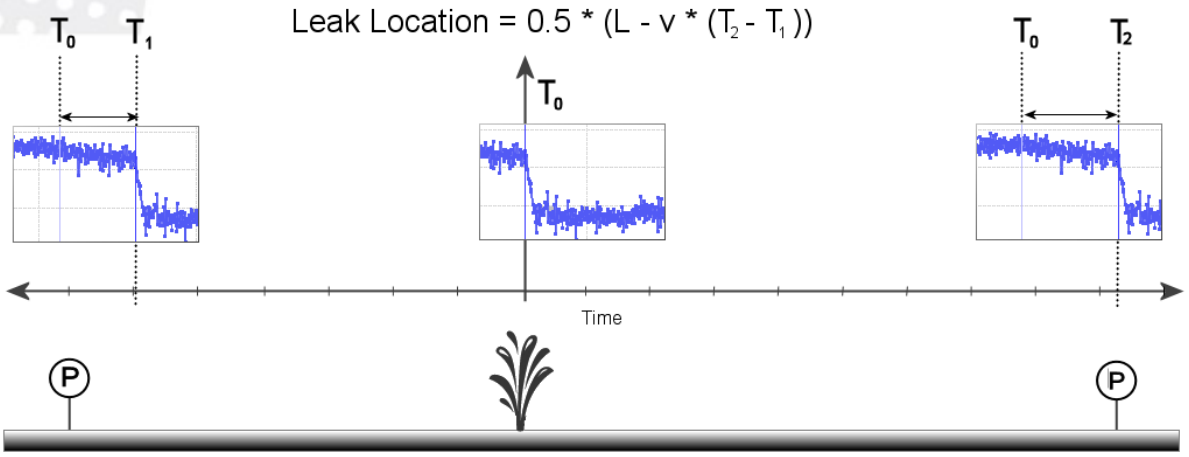
New method arbiter in PipeMan 5.0 collects results from all methods, analyses them and presents to the user processed data with statistical analysis of leak probability.



Example of UI - PipeDec overview mimic

Pressure wave detection (PWM)

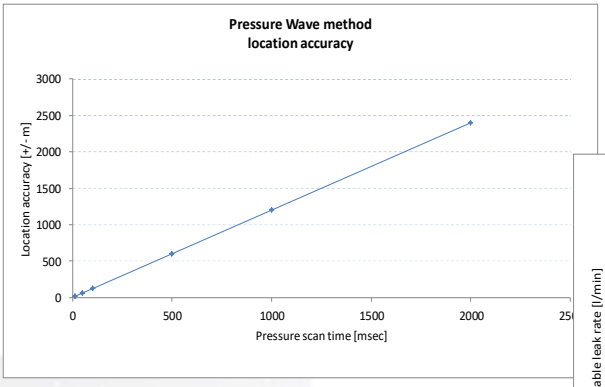
When the leak appears, the pressure wave propagates from its origin towards both ends of the pipeline branch. The application software detects this wave and analyses it.

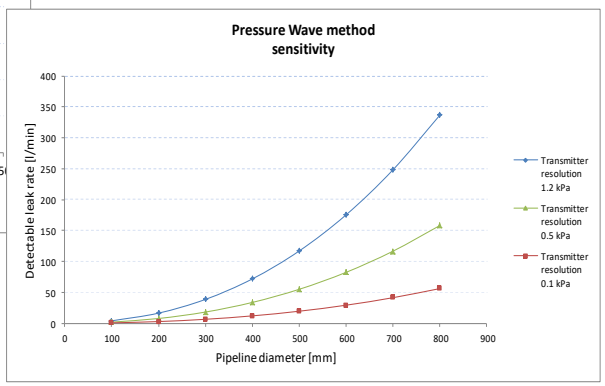


The method uses the principle of pressure wave propagation for leak detection. Rapid pressure changes are monitored on line pressure meters. Time differences in these pressure changes are evaluated and based on this information eventually an alarm is generated.

An alarm is generated in case, when the first pressure meter detects the rapid pressure change and this is confirmed by other pressure meters in the time interval that is specific for pressure wave propagation. Pressure meters to a predefined distance, typically 100 km from the pressure meter which initiated the algorithm, are taken into account for calculation.

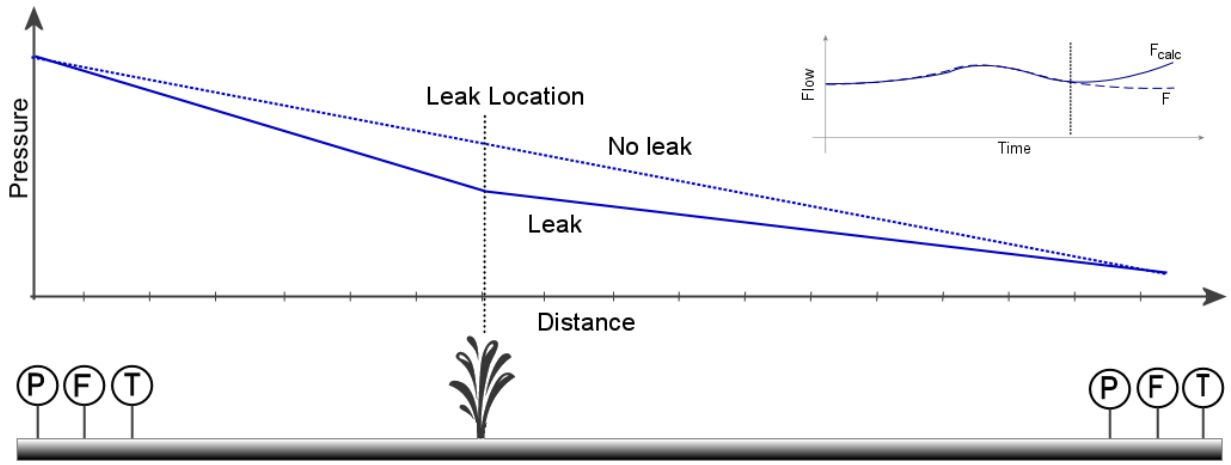
The evaluation of pressure trends on multiple transmitters allows distinguishing of the normal transients on pipeline from leaks. The time sequence of sudden pressure drops on multiple transmitters is evaluated, so that to unmask the pressure variations caused by changes in line valves position, or originated outside of supervised section (inside of the terminal or pump station).





Dynamic simulation of pipeline hydraulics (DSM)

This method is based on real-time model. The primary point of this model is to continuously produce a transient hydraulic estimate of the pipeline, including accurate roughness and thermal characteristics based on real time process data.



The module simulates the hydraulic system based on all known pipeline and liquid data, with boundary conditions supplied for real time. The mathematical model of a pipeline uses the numerical solution of differential equations, describing the liquid pipeline behaviour.

Information about the operation on the pipeline is essential to establish the correct design and functioning of the application software in both steady state and transient conditions.

Real-time model is used as the basis for this leak detection method. Comparison is made between modelled flow and pressure and real-time data. Discrepancies between calculated and measured values result in unexpected variations, which are then used for leak detection.

After longer research concentrated on data series analysis from the real leaks, PipeMan version 5.0 brought a new leak location algorithm which makes the method more accurate than ever.

Model-compensated volume balance

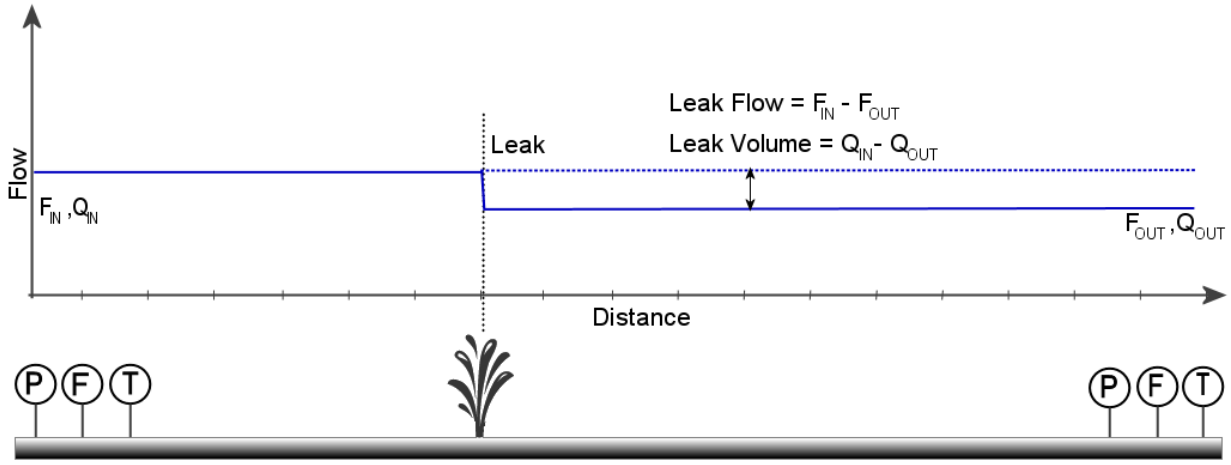
The model-compensated volume balance method calculates an inventory of volume in the pipeline through the accumulation of all inflows and outflows.

The method accounts for the inventory fluctuations with changing pressure and temperature. It is assumed that the temperature gradient between two measurement points will be linear.

The volume balance calculations run in three intervals

- Short term
- Medium term
- Long term

The evaluation logic is arranged in accordance with the user's needs, either to issue the alarms as soon as possible after exceeding the first limit, or waiting until confirmation of the leak, when the limit is exceeded on more intervals



Limits for each of the three intervals and each pipeline route are defined during the tuning period and may be changed by the end user's personnel. Those limits depend primarily on the accuracy of the measurement at inlets and outlets.

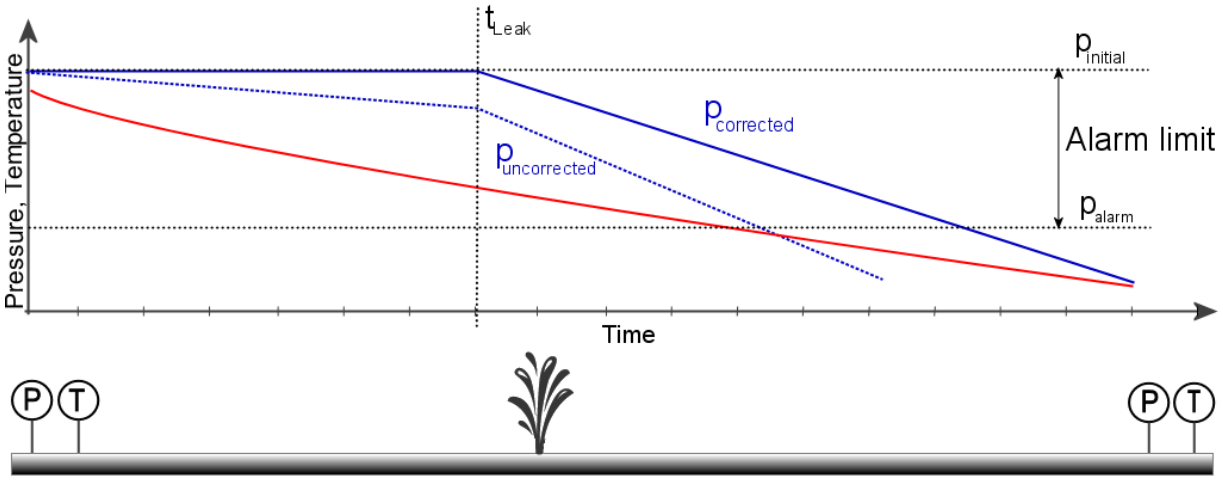
Volume balances are automatically adjusted to the measurement differences from the flow meters and the method handles moderate transients by auto adjusting detection limits to avoid false alarms. However, this behaviour can be changed on customer demand.

On the longer time frames Volume balance detects very small leaks, but it does not provide leak position.

Pressure drop detection

This method monitors all the pressure meters located on a isolated section. When the recalculated pressure values drop under a specified limit alarm is issued.

The alarm limits are configurable in either pressure (kPa) or flow/volume measures (litres, litres/hr, whichever applicable for particular limit. The cross-calculation between pressure change and corresponding flow/volume of leak is provided automatically by applying a particular pipeline and liquid properties.



By examining the pressure drop and gradients, the system evaluates if the changes likely to be caused by a leak or by natural physical processes (e.g. temperature change). The algorithm consists of following calculations:

- *Uncorrected absolute differential*: After start-up of the method (expiration of settling period), the uncorrected (natural) pressures on each sensor is stored. Each new pressure value is then compared with the stored one. An alarm is issued if the pressure drops to a lower value than the stored one, minus the threshold.

- *Corrected absolute differential*: The same algorithm is used as above but with corrected pressures. The pressure is corrected to standard temperature in accord with relevant API calculations. The linear temperature fall between both ends of the section is expected.

- *Corrected gradient*: After start-up of the method on a given section and expiration of the settling delay, the method calculates pressure / time gradient and compares this value to a limit value. If the drop is higher, an alarm is issued.

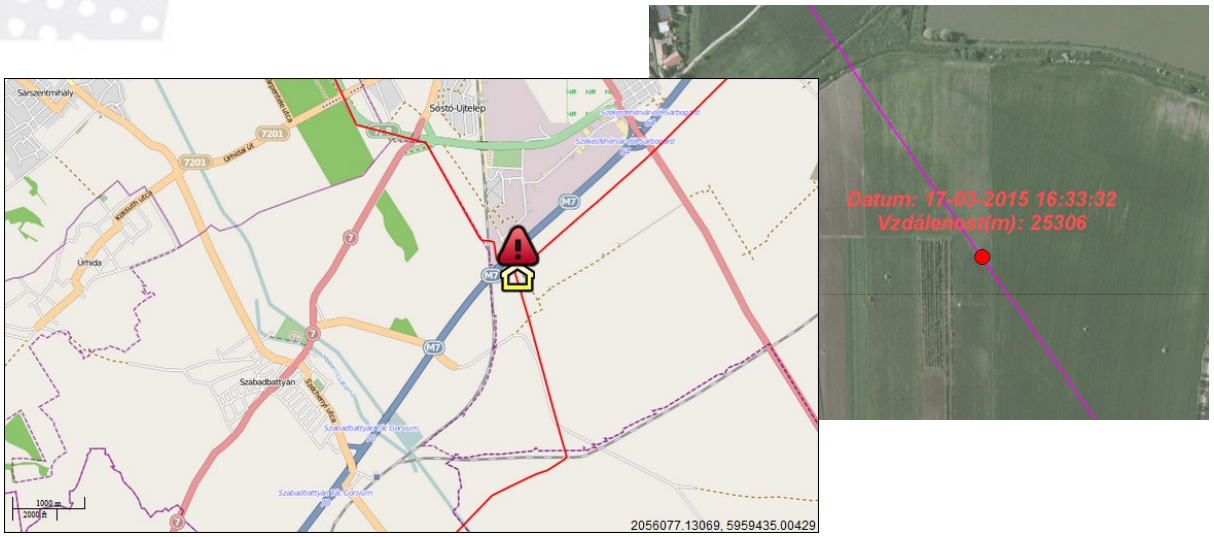
- *Dynamic gradient*: Pressure/time gradient on 2 separate time frames: current and historical is calculated. The gradients of these 2 intervals are compared to a limit value. If the pressure gradient difference exceeds the limit, an alarm is issued.

Comparison of LDS methods

Method	Advantages	Limitations
Pressure wave detection method The calculation of the leak position is based on the time of detection the pressure wave generated by the leak.	Very accurate leak location Very high sensitivity Very fast response	Requires accurate time stamped pressure data scanned with higher frequency Preferable spacing of pressure points is 20 km. Recommend longest section without an intermediate pressure point 100 km
Dynamic simulation of hydraulic system Numerical method for simulation of the hydraulic behaviour of pipeline in real time.	Sensitivity is not compromised under transient conditions	Demanding on the amount of information needed for the method configuration
Volume balance method Volume balance is processed for separate sections of pipeline. Balance is calculated from the total of all inlets and outlets and it can be compensated for pressure and temperature.	Provides high reliability and reasonable sensitivity in spite of its simplicity.	Does not provide the leak location
Pressure drop leak detection Used for shut-in leak detection. The method detects pressure drops in any isolated section or the whole pipeline system when pumping has stopped. System evaluates if the pressure changes were likely to be caused by a leak or by natural physical processes (e.g. temperature change).	Several evaluation algorithms ensure high sensitivity for continuous leaks in static conditions.	Does not provide the leak location

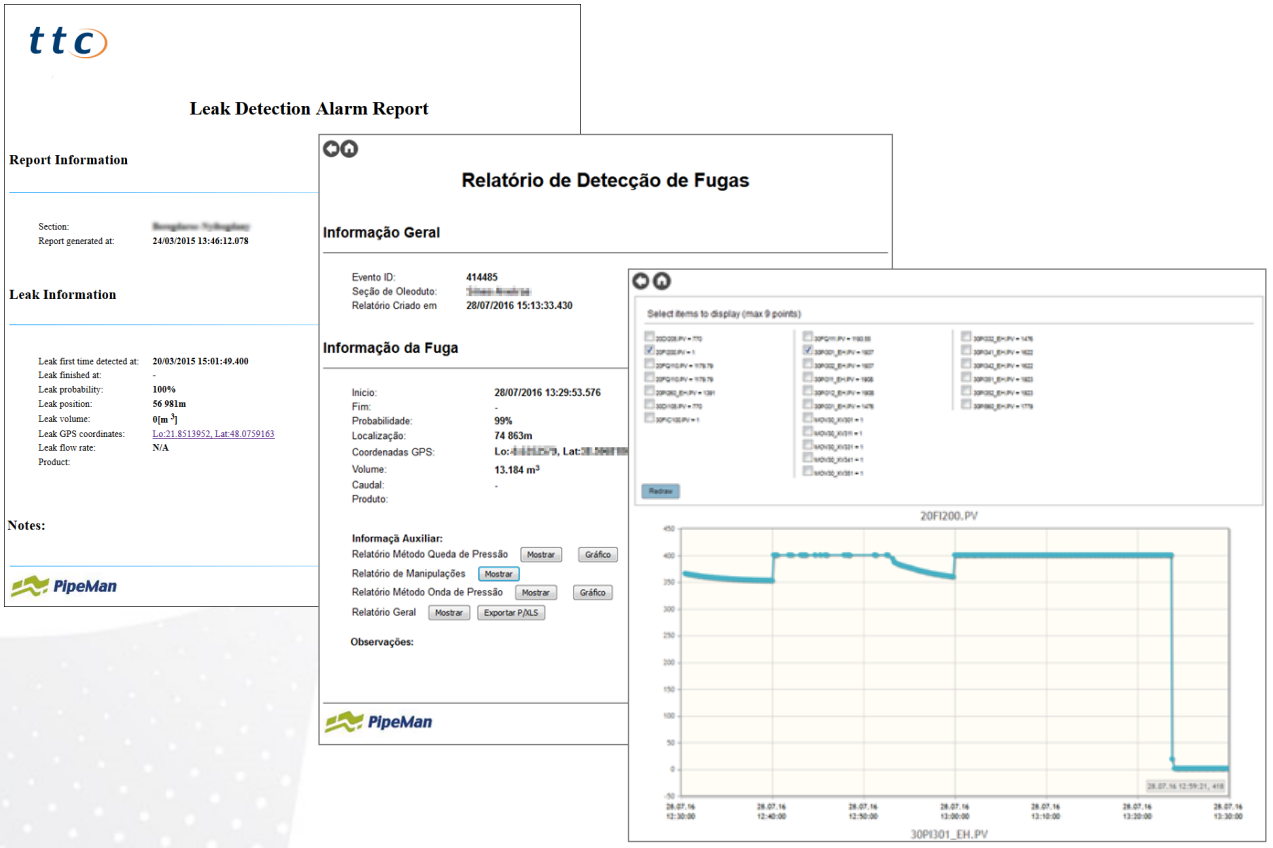
PipeMan LDS method arbiter

Method arbiter collects information from all running LDS methods and evaluates their results. By comparing the results from various methods it calculates the probability of the leak and its location. Arbiter also provides geographical information necessary for coupling with maps system (e.g. google maps) or GIS.



Example of LDS integration with various maps

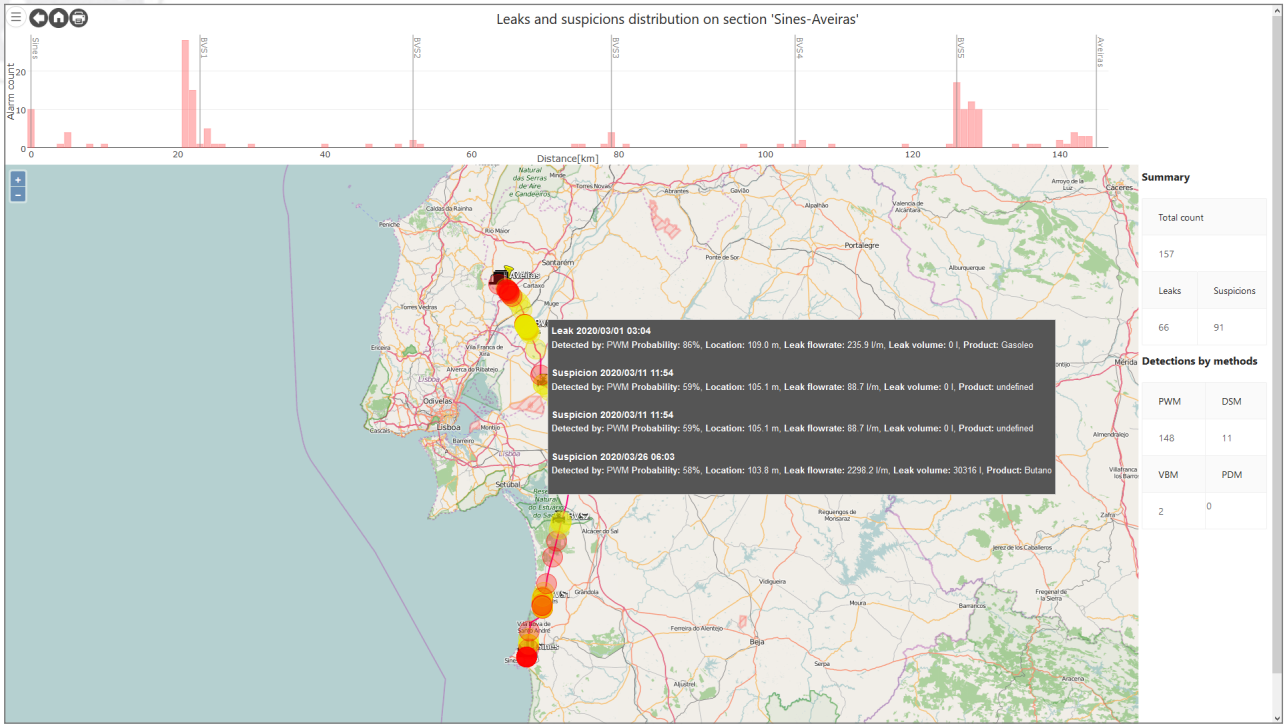
The summary report produced by the arbiter contains all available information related to the leak: leak probability, location (including GPS coordinates), flow rate, volume and product. Additionally it provides data snapshot and technology manipulation report from the time of the leak which simplifies the evaluation of the LDS event.



LDS Report examples

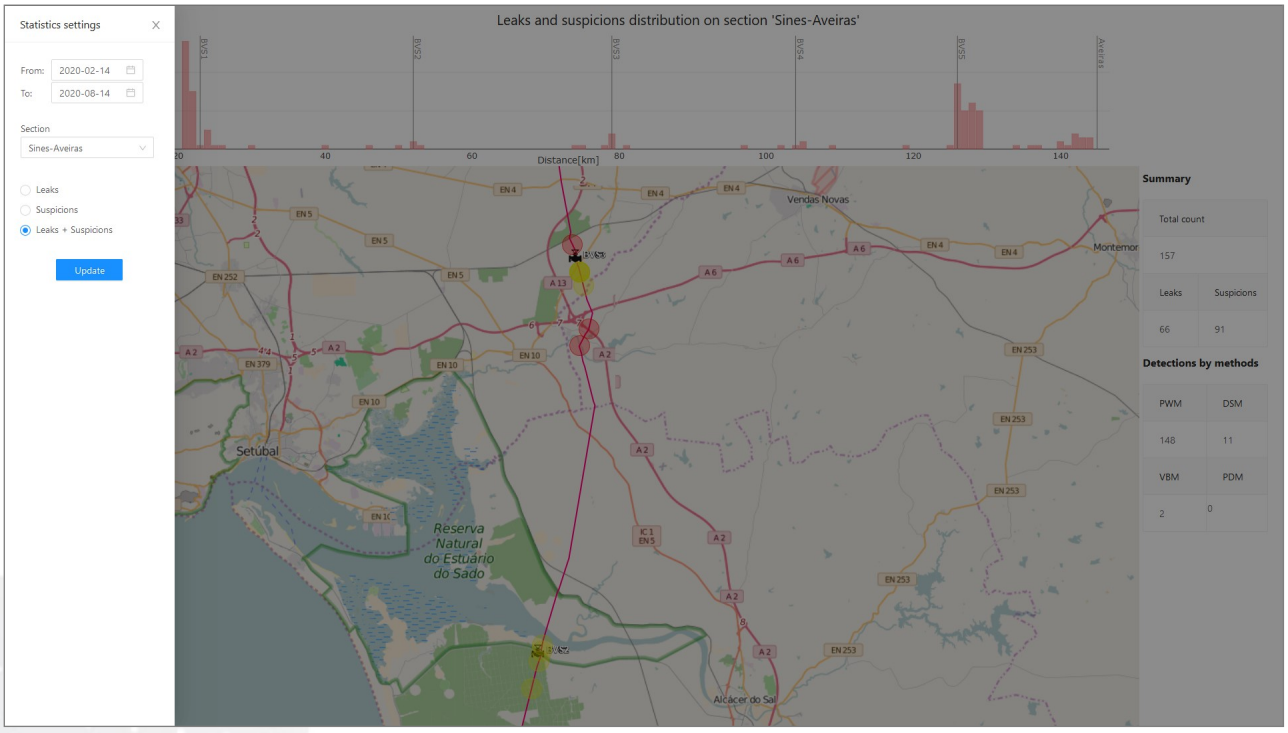
PipeMan Leak statistics module

PipeMan collects leak related data, including detected leaks and leak suspicions in its database. Leak statistics module allows analysis of leak distribution and its visualization on the map.



Example of PipeMan leak statistics module

The settings of the leak statistics can be adjusted including an interval of analysis, pipeline section and type of the leak.



Settings of PipeMan leak statistics module

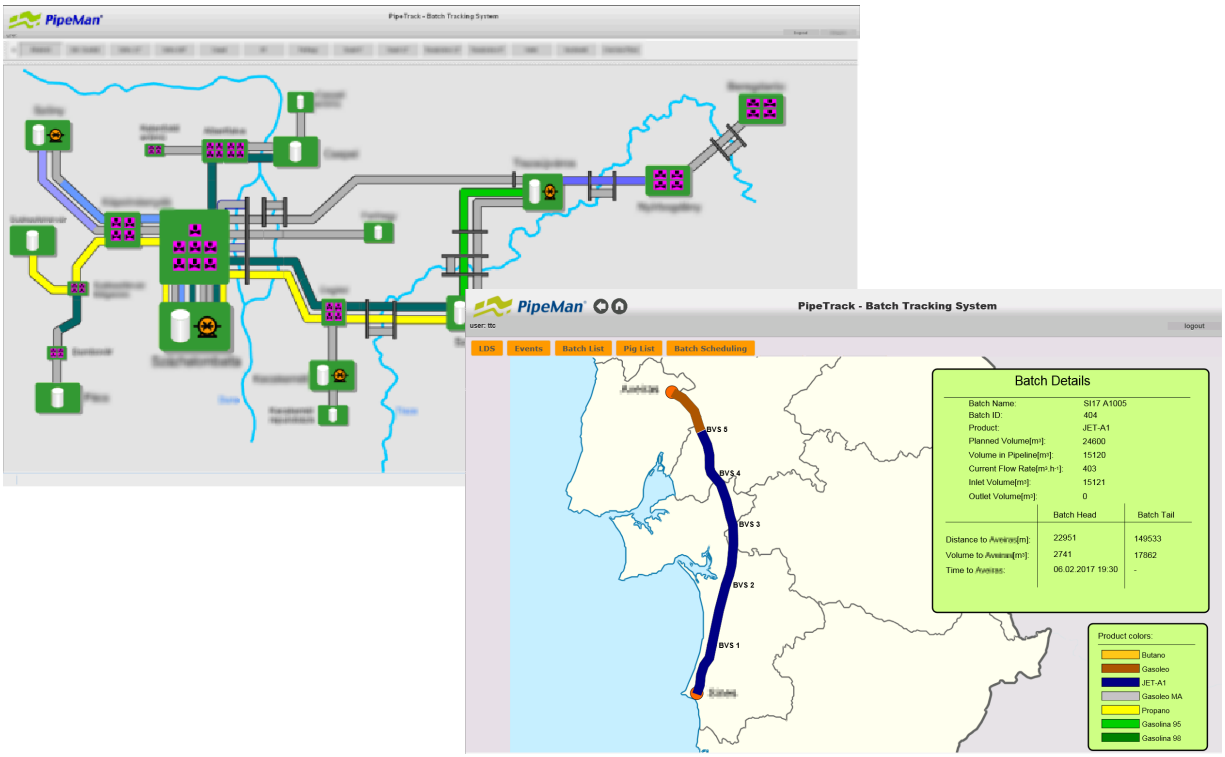
Batch tracking module – PipeTrack

The PipeTrack module is part of the PipeMan package. It calculates the movement and position of individual batches based on monitored technological data from the pipeline network (flow rates, opening/closing of valves) and on data from a transaction table.

The transaction table contains scheduled quantities of pipeline products required for transportation by the multi-product pipeline over a certain period. After completion of the transaction, the actual quantity supplied and actual time of completion is recorded.

PipeTrack module provides the operator with estimated time of arrival (ETA) of the head of the batch/parcel to a pump station/terminal. This information is displayed on the user interface and the related events and alarms are transferred to SCADA.

The PipeTrack can track multiple batches in multiple pipeline sections simultaneously. The batch movement is calculated automatically according to actual pumping routes .



The system can be configured to launch the parcel/batch:

- *Automatically* on any digital or analogue signal (or its combination)
- *Manually* by an operator/supervisor from the user interface

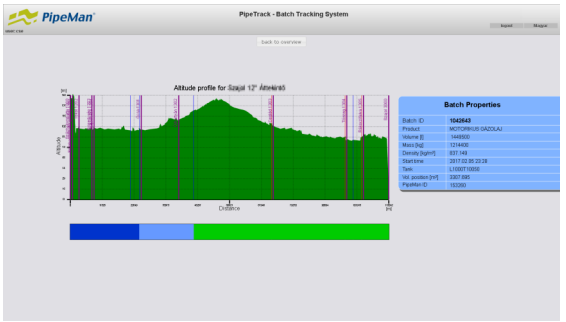
The position of running parcel/batch is then recalculated using actual flow rates (measured by flow-meters along the pumping route).

When a batch arrives to an outlet station, the meter ticket report is generated automatically, listing the batch name, product, start time and actual time of arrival and other information.

Position, motion and volume of batches will be corrected with regard to correction factor for each flow meter.

The PipeTrack module includes also interface detection. This module tracks the interface between different types of products of different density and calculates the volume of the interface. Different mechanisms of interface handling can be configured in the system.

The PipeTrack graphical output displays position of batch interfaces, pigs (scrapers) and batch data on the operator screen. Estimated arrival time to the egress points (terminals) determined in advance, is indicated for each batch.



PipeTrack allows batch/parcel manipulation:

- position movement (of interface or whole batch)
- split
- merge
- remove

Automatic position adjustment is by default included in the module. Position can be adjusted by density-meter or colorimeter.

Batch tracking module provides following main outputs:

Reports

- Meter tickets
- Batch tracking report

Alarms:

- Preliminary alarm (batch about arrive)
- Batch launched alarm, along with product id code
- Batch received alarm, along with product id code

Summary reports:

- Weekly / monthly pumping summary

Scraper/pig tracking module

The scraper/pig tracking is a part of PipeTrack and it can be used also separately. This module monitors the position of the pigs (scrapers) in the pipeline and computes estimated arrival time (ETA) of each pig to the pig chamber.

Scraper position can be adjusted automatically by scraper signallers along the pumping route. Additionally individual slide factor for each scraper type can be set.

Scraper/pig tracking module provides following outputs:

Alarms

- Preliminary alarm (scraper reaching end of route)
- Scraper launched alarm, along with pig id code
- Scraper received alarm, along with pig id code

Reports:

- Scraper arrival report

Custody Transfer Module

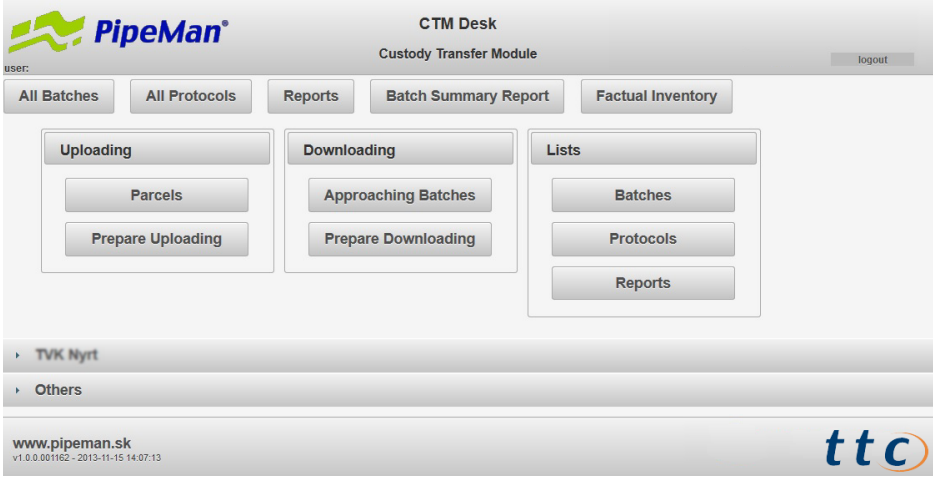
Custody transfer module extends PipeMan package and offers functions to support whole process from scheduling through monitoring of pumping process to an analysis of pumping history:

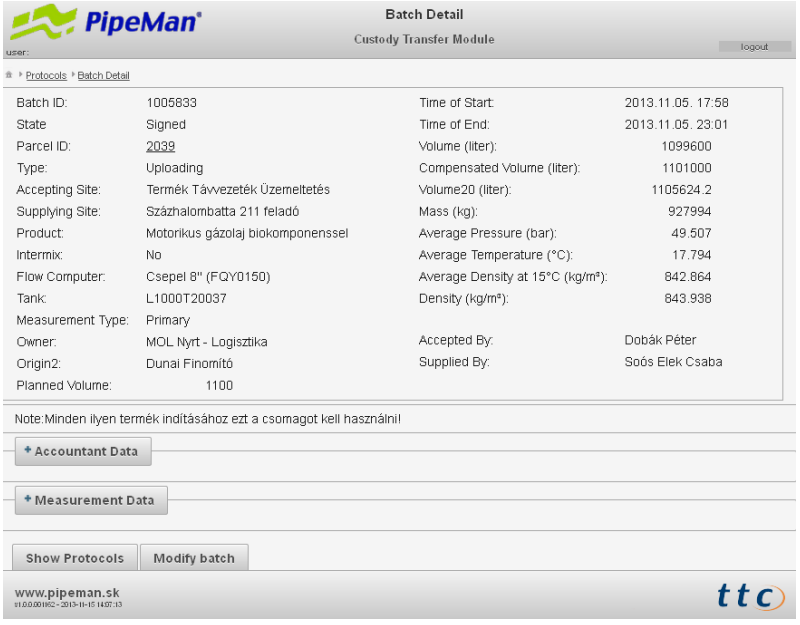
- Advanced batch scheduling
- Batch ticketing
- Pumping history analysis
- Pipeline Inventory
- Flow metering functions
- Reporting

The module provides a wide range of functionality out of the box but it is also expected to be customised to meet the customer's specific needs.

The custody transfer module can cooperate with third party systems the customer currently uses.

The module provides integrated web based user interface for each group of users such as operators, dispatchers, accountants or managers. Each group has its own duties in the pipe-line logistics and the module also provides a dedicated user interface to each of them.



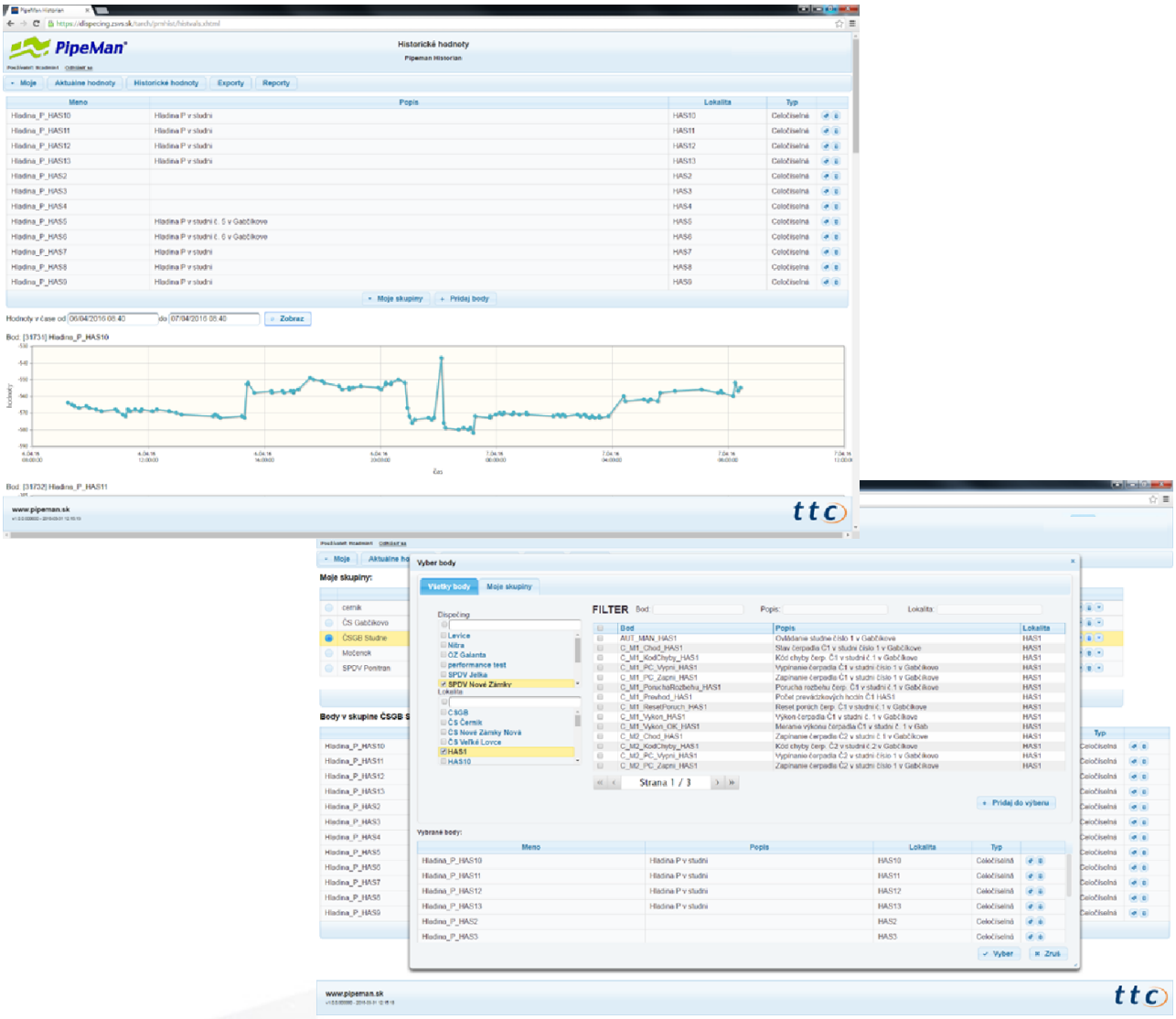


PipeMan Historian

PipeMan Historian provides complex solution for collection, processing and presentation of historical field data.

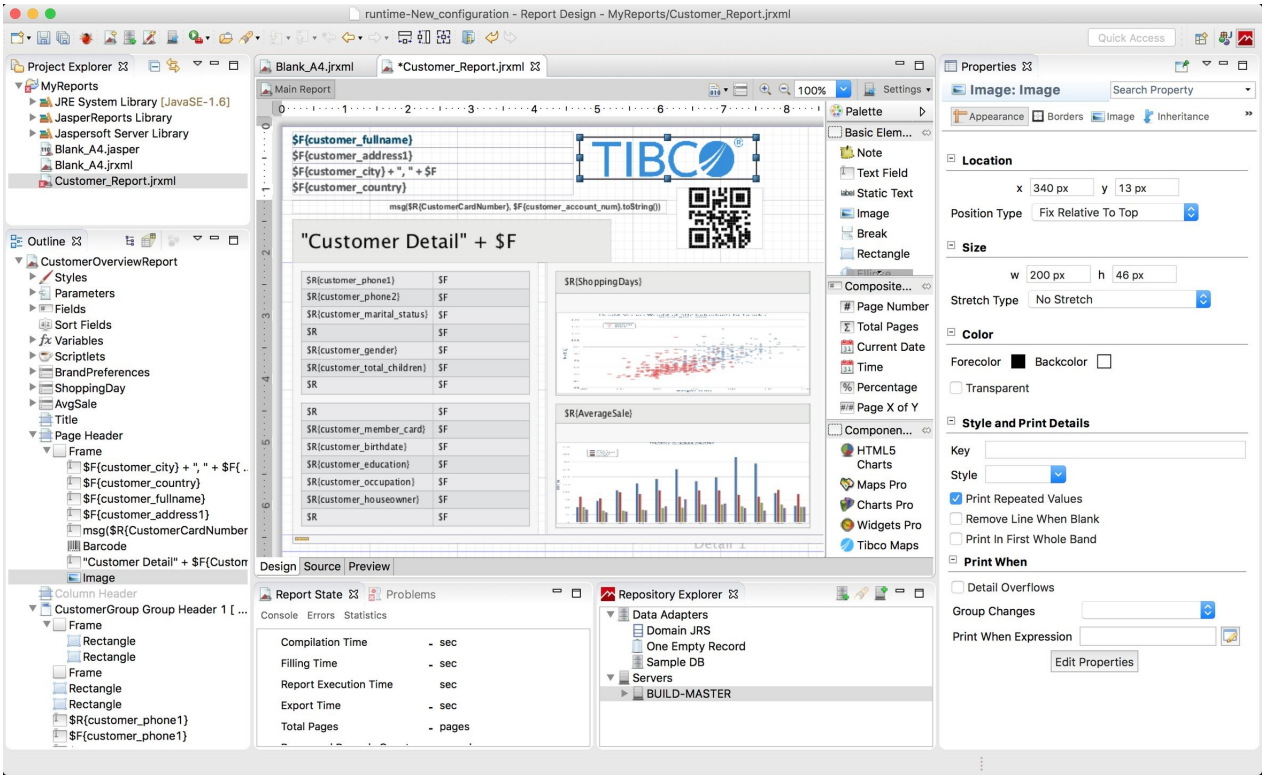
Robust data collecting mechanism uses remote logger applications feeding the data from multiple data sources (OPC, DDE, ODBC, etc) into single database. This mechanism can cope with network outages without losing the data. Once the connection is restored, the logger application will feed data to the server. Moreover the robustness of the system can be improved by using distributed database design.

Intuitive and easy to use user interface can be adjusted to customer needs providing data exports to common file formats (csv, xls), reports or advanced data analysis.



PipeMan Historian can be delivered with JasperReports. The JasperReports is the world's most popular open source reporting engine. It is entirely written in Java and it is able to use data coming from any kind of data source and produce pixel-perfect documents that can be viewed, printed or exported in a variety of document formats including HTML, PDF, Excel, OpenOffice and Word.

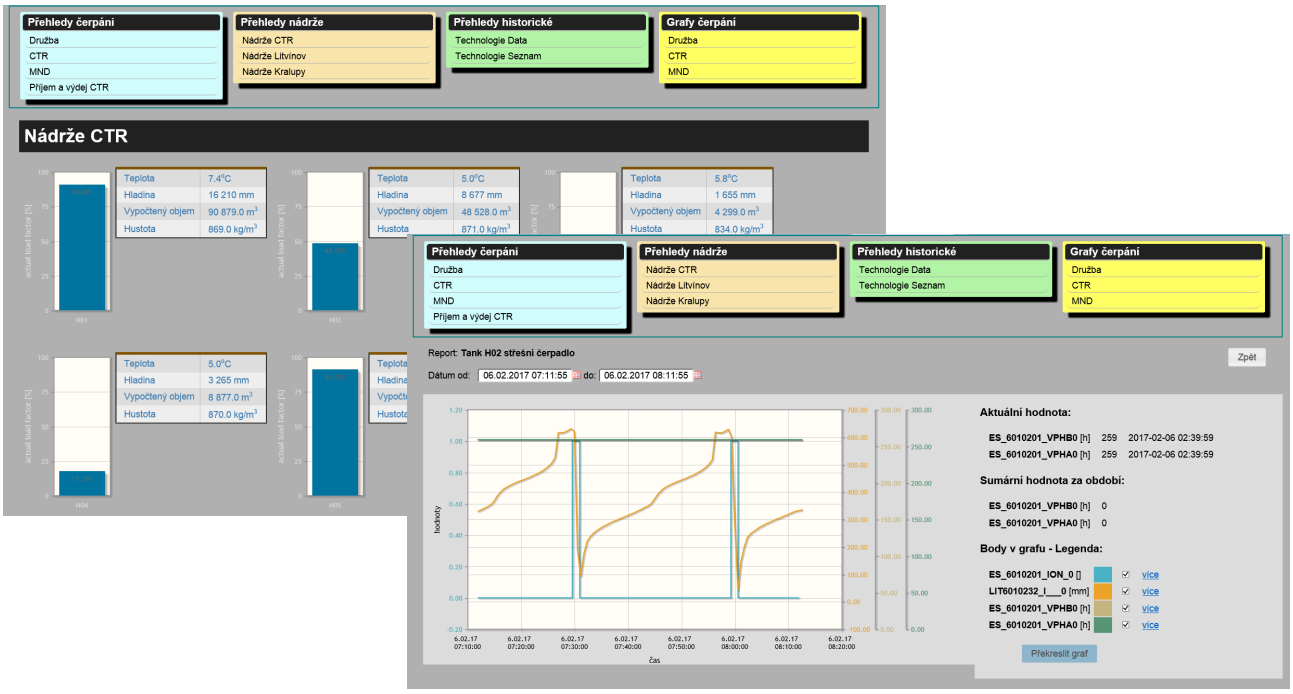
The iReport Designer for Eclipse allows development of new advance reports and speeds up the report change process by allowing quick editing of existing reports.

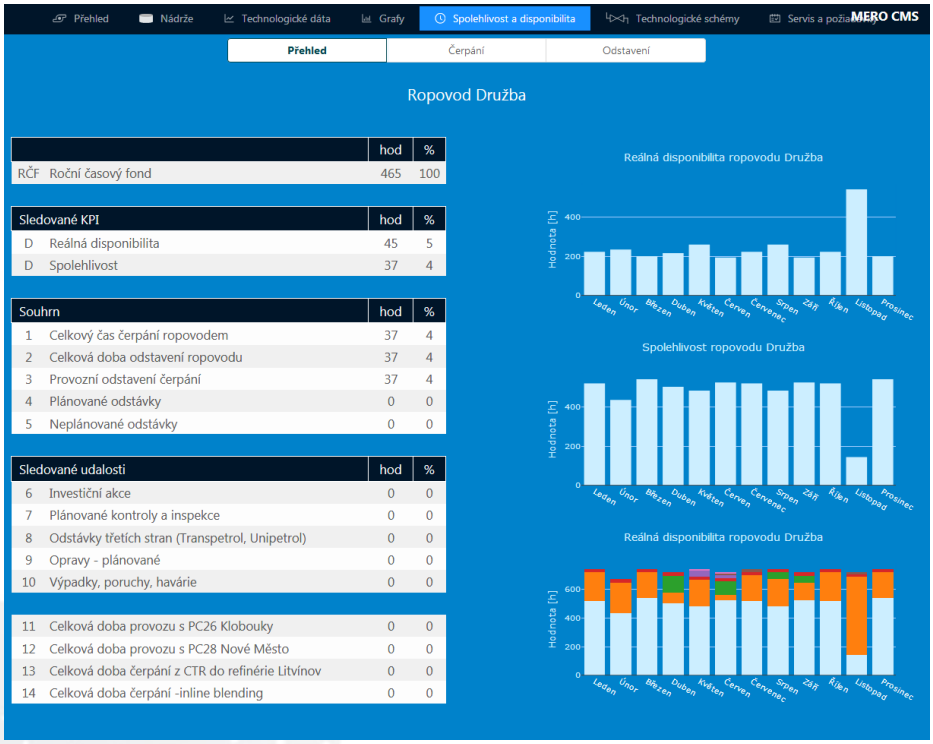


Content Management System

Content Management System (CMS) is web based application that allows the user to monitor and analyse operating status of the technology without the need of direct usage of SCADA system.

CMS can provide various views on the pipeline network operation including pumping status, tank farm status, etc. In connection with the Historian can provide advanced historical data analysis as well as future prognosis.





		hod	%
RČF	Roční časový fond	465	100

Sledované KPI		hod	%
D	Reálná disponibilita	45	5
D	Spolehlivost	37	4

Souhrn		hod	%
1	Celkový čas čerpání ropovodem	37	4
2	Celková doba odstavení ropovodu	37	4
3	Provozní odstavení čerpání	37	4
4	Plánované odstávky	0	0
5	Neplánované odstávky	0	0

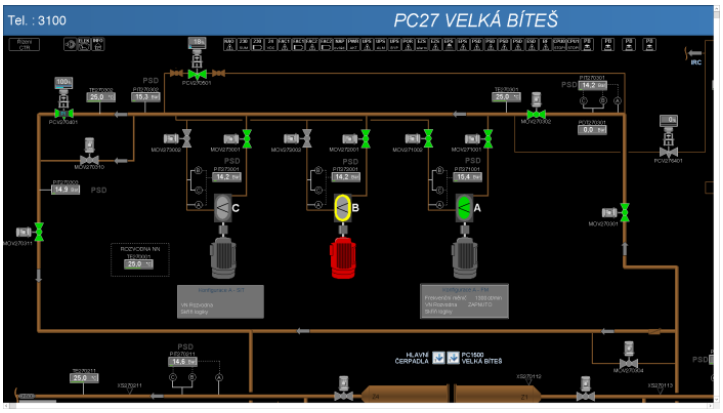
Sledované udalosti		hod	%
6	Investiční akce	0	0
7	Plánované kontroly a inspekce	0	0
8	Odstávky třetích stran (Transpetrol, Unipetrol)	0	0
9	Opravy - plánované	0	0
10	Výpadky, poruchy, havárie	0	0

11	Celková doba provozu s PC26 Klobouky	0	0
12	Celková doba provozu s PC28 Nové Město	0	0
13	Celková doba čerpání z CTR do refinérie Litvínov	0	0
14	Celková doba čerpání -inline blending	0	0

Training simulator

The training simulator is the application that facilitates the operator's training of actions in both standard and exceptional situations, like an unexpected pump trip or leak.

Training simulator is used for training of pipeline operators on the system that behaves as real pipeline operation and has the same SCADA user interface as a live system. This is done by using a copy of SCADA system operated by a customer and simulator of technology and pipeline hydraulic behaviour.



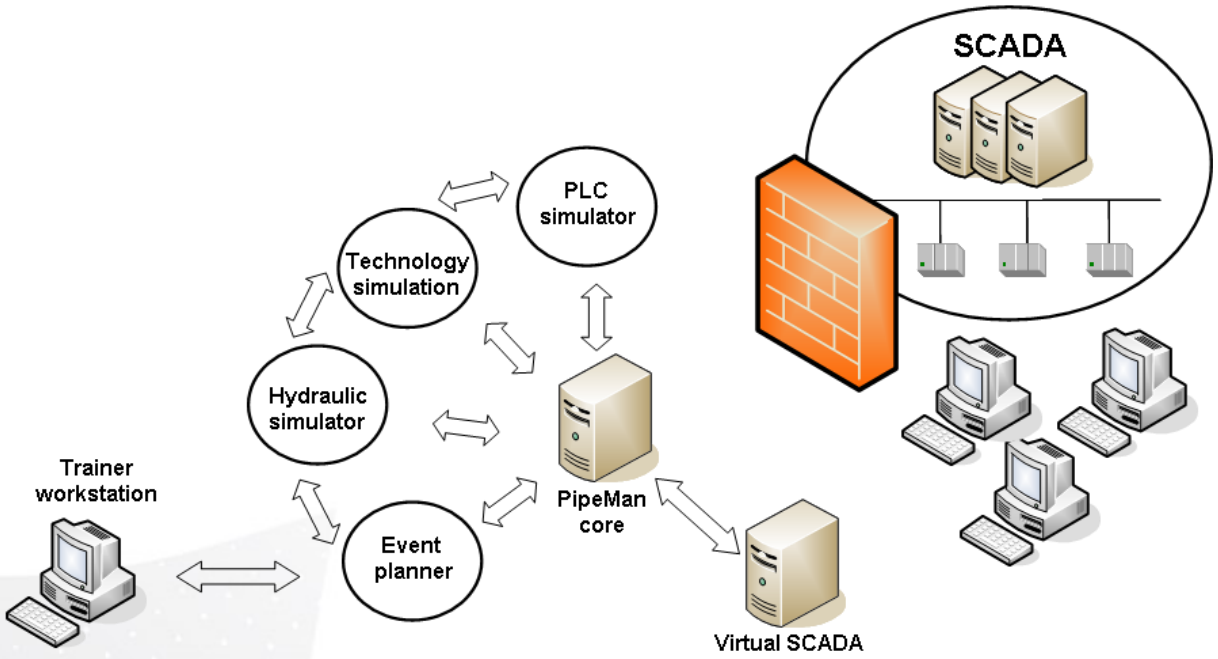
The system has two defined levels – trainer and trainee access. The trainer is able to run scenarios and make changes to examine the behaviour of the trainee.

The training simulator consists of three principal components:

- SCADA package with all its features, running offline from the real-time system
- Technology and PLC/RTU logic simulator
- Hydraulic model and simulator – Training Simulator Package, which models the scenario and responds to operator's actions in terms of variations in pressure and flow in the pipeline system

The Pipeline Simulator simulates but is not limited to elements like:

- Single pipeline branch
- Pipeline junction
- Pump (Booster and Main Line Pumps)
- Valve, regulation valve

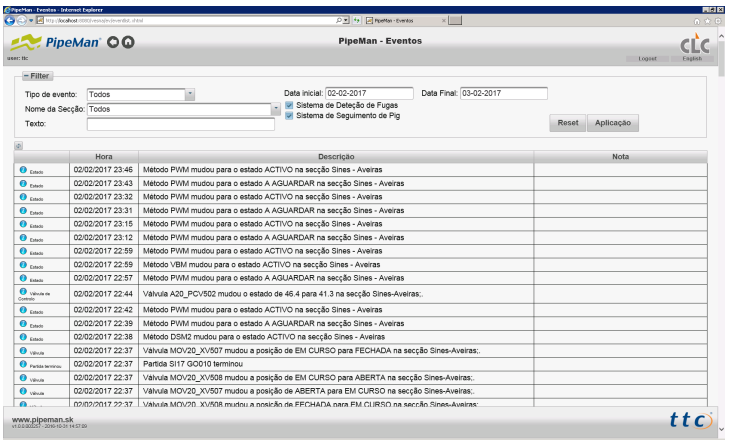


Architecture of Training Simulator

Events and alarms

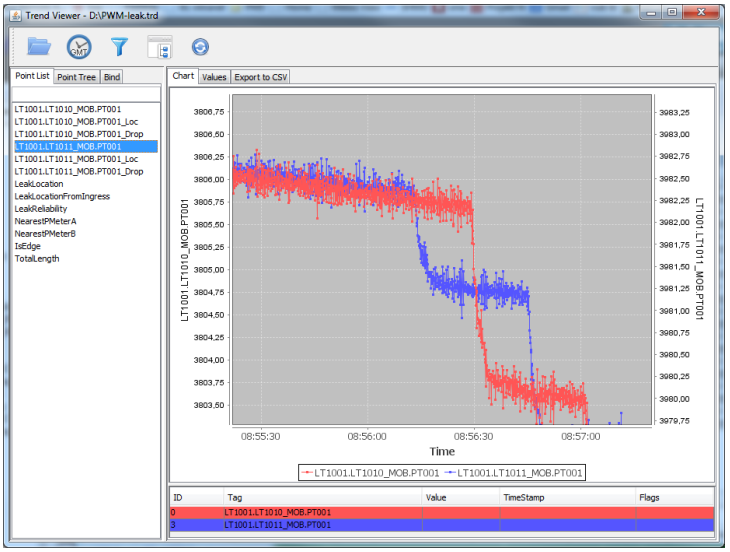
PipeMan package uses alarms and events log similar to SCADA systems. All PipeMan online modules can use it to log important messages for the user. Additionally the report with all related information for selected alarms can be generated and attached to the event.

User interface provides view with wide sorting and filtering functions.



Trend archiving functionality

Beside the Historian, PipeMan package provides out of the box basic historization functionality. Any data point (input or internal) can be stored in trend files on the server. The trend files can be later automatically compressed to reduce the storage requirements.



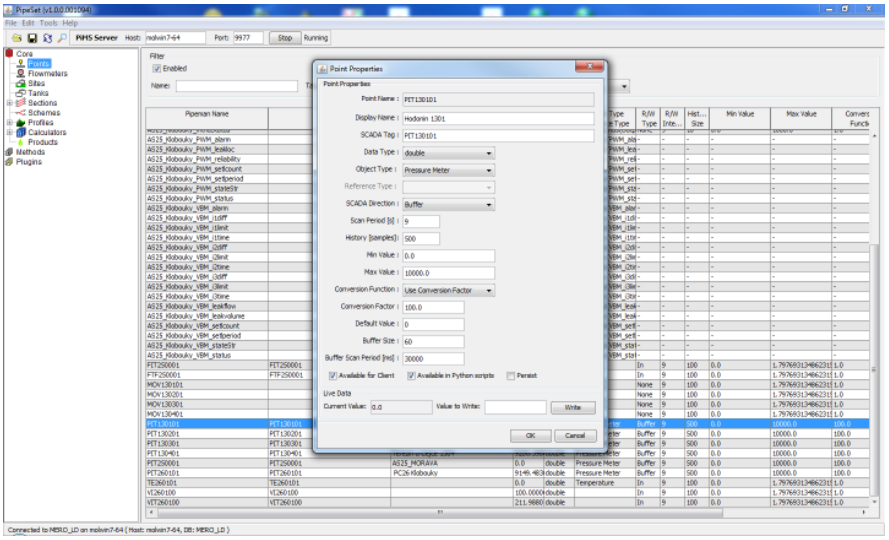
Archived data can be viewed and analysed using trend viewer tool. The export to CSV file format is available as well.

Moreover the trend files can be replayed with offline system to analyse behaviour of the system in various scenarios or can be used to debug eventual issues.

Configuration tool – PipeSet

The PipeSet is the pipeline configuration utility, which allows the configuration of the system including points, sections, methods and calculators as well as custom scripts.

The configuration is fully graphical and the most common options are preset to simplify and speed up configuration process. Its point oriented philosophy provide a good starting point for user skilled in SCADA configuration (SCADA engineers).

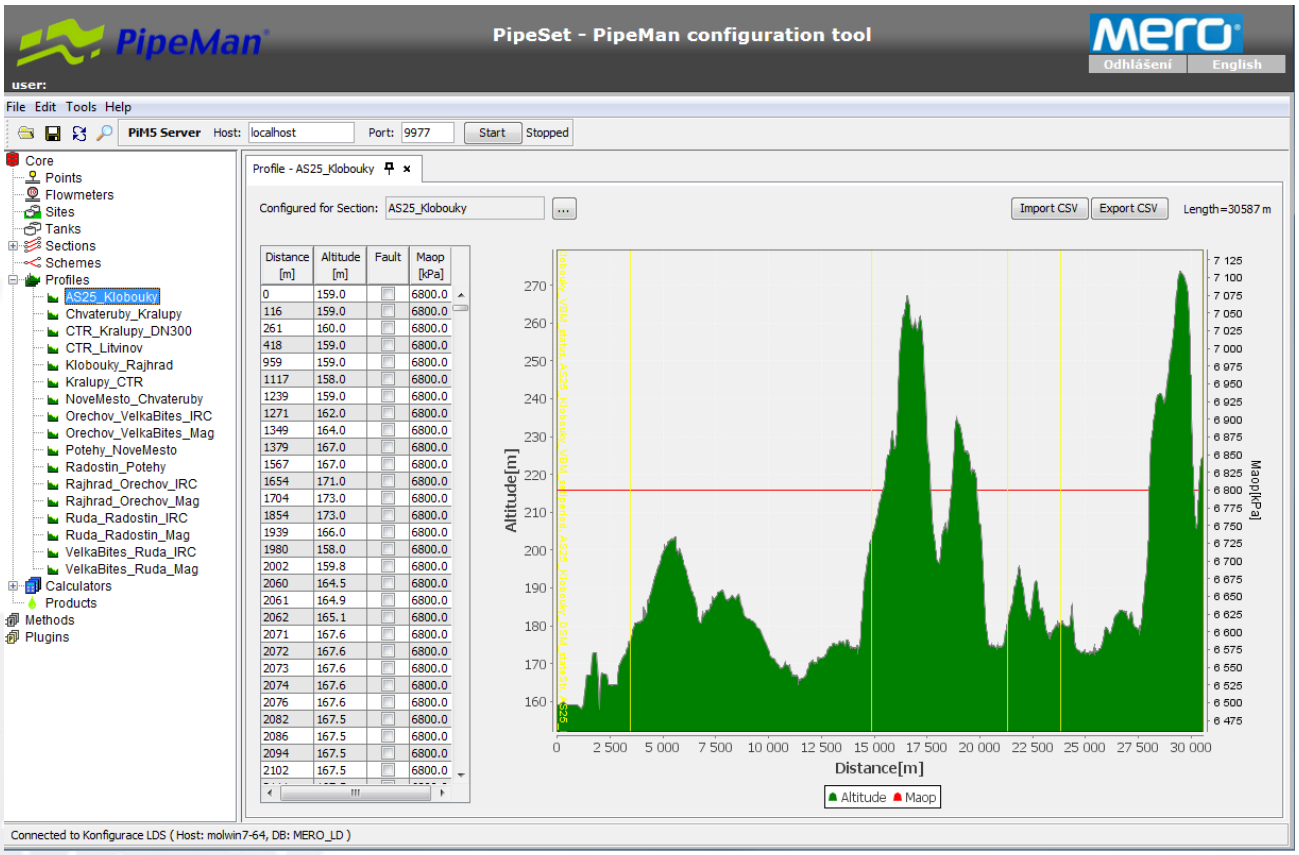


The application can be extended with additional plug-ins for new calculators, new methods or other tools. PipeSet allows also to change parameters for the already configured system. The helpful feature is also a facility for monitoring live data values .

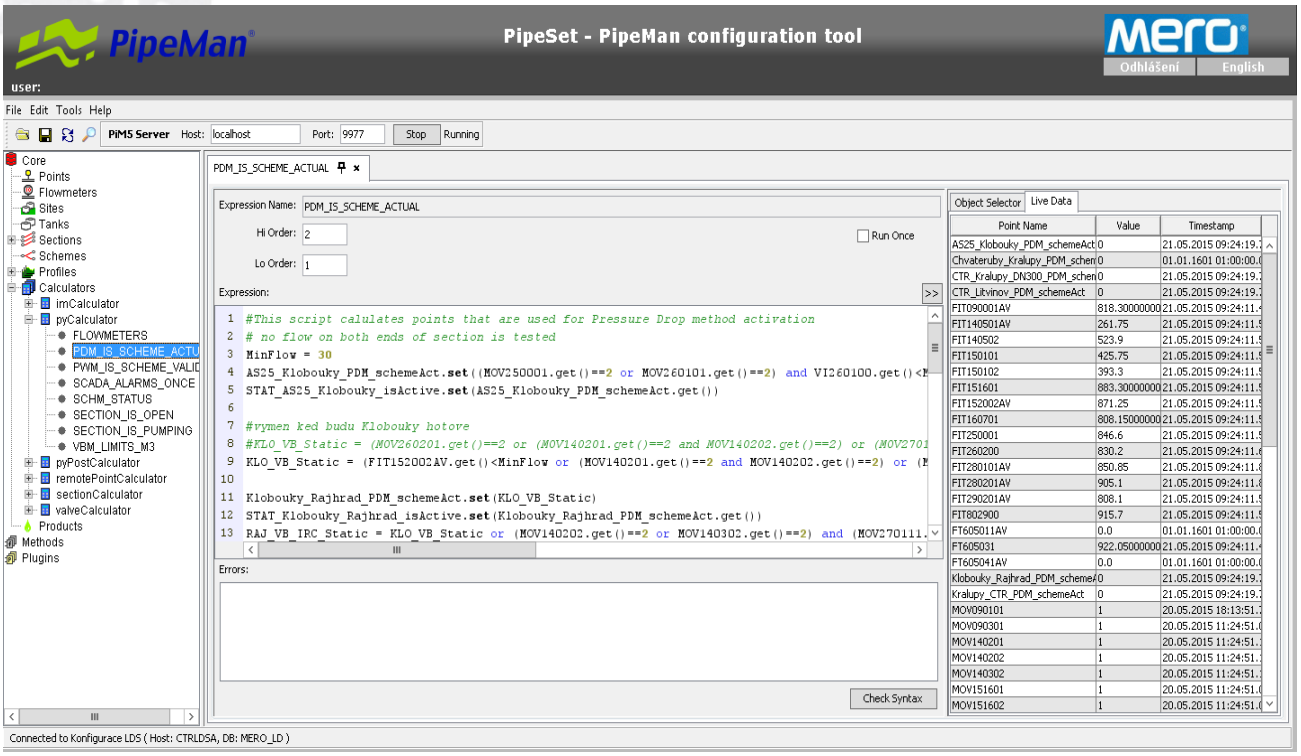
Configuration data are stored in the configuration database and it is shared with other PipeMan modules.

PipeSet includes also diagnostic functions to tune the parameters of methods and calculators, e.g. the point viewer or script tuning functions.

PipeSet can be run as a standalone application or as a web application.

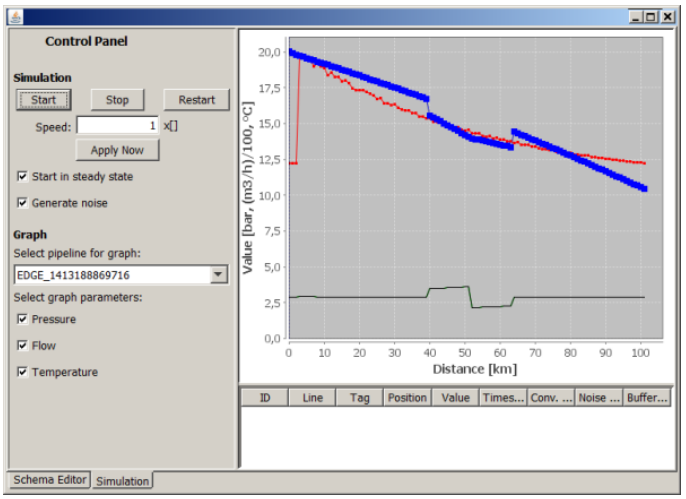


The Python scripting engine is a standard part of PipeMan server. The PipeSet configuration tool comes with editor for creation of python scripts and for their tuning. The editor provides syntax highlighter and syntax checker



Pipeline simulator

Pipeline simulator application allows to configure complete pipeline network with pumps, valves and tanks for hydraulic simulation. It allows to simulate various operational scenarios in real time to observe the transient states in the pipeline or use the accelerated time function to verify the steady state operation.



The simulated data can be observed on line, can be written to OPC server or logged to a trend file for further analysis.

In connection with OPC server the simulator is a powerful testing tool for the PipeMan platform. It can be used to simulate various technology operational states, including product leaks to test the configuration in the early stage of project implementation (FAT) prior the commissioning.

Selected support functions, modules and tools

- *PipeCheck* module checks availability of instrumentation and validates the instrument data used by other PipeMan modules.
- *Over/Under pressure method* monitors the pipeline for pressures outside the allowed operational range taking in account elevation profile and current products contained in the pipeline. It alarms the excess of maximum allowed pressure as well as possibility of “slack line” conditions.
- *Pipeline efficiency* function can provide information about the efficiency of transportation by analysing of pipeline friction losses
- *Pig stuck detection* application works in online or offline mode. It detects stuck pig/scraper and located its position using the data from pressure transmitters
- *Redundancy and data replication* option makes from PipeMan server a robust solution
- *Client server architecture,* web based or stand alone UI and multiple user levels with customizable accesses. Operator and supervisor roles are by default configured in PipeMan
- *Possibility of total integration with SCADA* including the use of SCADA UI
- *Comprehensive, configurable log system* for troubleshooting