Introduction

The project being described in this paper is one of the first of its' kind in the world and is made necessary for the future operations of the pipeline based on continuing deregulation. The effects of deregulation in countries around the world are driving pipeline companies on a global basis to re-think the way they operate and do business. The emphasis of this project is on the integration of the business and operational worlds to come into a more realistic perspective of how the physical world can impact the commercial world.

The implementation of pipeline modeling systems and business systems is a part of a project to provide a comprehensive real time pipeline monitoring, leak detection, and Nomination, Allocation and Billing System for the SembGas Gas receiving and distribution pipeline system in Singapore.

The system that has been provided on this project is based on Energy Solution's, gas on-line modeling and leak detection system called LICLDS and the Nomination, Allocation and Billing System called NABS. Both LICLDS and NABS are implemented on a single PC server based on an Intel processor running Microsoft Windows NT 4.0.

LICLDS is an enhancement to the functions provided by the SCADA system. LICLDS includes a graphical user interface, which provides access to all major modeling functions. SCADA makes field data available to the operator at designated consoles. The LICLDS system provides additional information about real time and/or future pipeline conditions, thereby enabling safe and efficient operation of the pipeline. Certain data at various measurement locations along the pipeline is passed from the SCADA system to the LICLDS model via the use of an OPC server/client interface. The real time model uses this data to generate detailed information on the pressures, flows and other values along the pipeline system. The application software detects and alarms for leaks and uncommon operating conditions. The Predictive Model provides a projection of current pipeline operation to forewarn the operator of possible minimum pressure violations. Results from the different modules can be viewed through the Graphical User Interface (GUI) including certain trends and graphical profiles of selected pipeline values.

NABS is a system for managing the business transactions between the Gas Supplier and End Users connected to the pipeline system. The End Users will submit nomination requests via a NABS client installed at each End User site to the NABS host system. The NABS host system consolidates these requests and submits nomination requests to the Gas Supplier. NABS passes the nomination forecast to the LICLDS Predictive Model for further analysis as described above.

The **Buyer's Facility** begins at the seller's delivery point. Once in the buyer's facility the gas passes through three sections:

- Filters
- Heaters, and
- Metering section.

The gas is normally delivered dry and free of liquids and particulates at 21^0C. and between 550 and 600 psig (37.93 – 41.38 Barg). Once in the facility the gas splits into two 24" trains that pass through a filter or heater or flow meter. Initially the trains will operate with one on stream and the other on standby. Each train is designed for a maximum capacity of 430 MMSCFD. Each stream passes through its own Cyclone type inlet filter and a cartridge type metering inlet filter, followed by their respective heater/breathers to ensure that a sufficient dew point margin is maintained. In the metering section the two streams pass through flow meters, gas chromatographs and dew point analyzers.

The metering section will return one flow, pressure and temperature measurement to SCADA from the Buyer's facility.

The **Distributions System** starts downstream of the analyzers. The 30" main header is split into three main pipelines:

- 16" pipeline to SembCogen
- 28" pipeline to Tuas Power with pipeline branch to Exxon,
- 24" pipeline to Seraya/Bassel

Each pipeline is equipped with an ESD valve at the inlet of each distribution line in order to isolate it from the other distribution lines. However since they originate from the same manifold they have the same upstream pressure and temperature. At designated locations, condensate traps are provided to collect any condensate produced during transportation.

Each **End-User inlet metering facility** comprises of a filtration system, a metering system and a flow limiter. The system is identical for all end-users, except for SembCogen, which is provided with an overpressure protection system and not a flow limiter. Each End-User returns flow, pressure and temperature information to SCADA.

NOTE: Currently the Pressures and temperatures are supplied from inside the metering section. The client has been informed that a pressure measurement upstream of the inlet valve would be required for the correct modeling of the pipeline for leak detection.

The SembGas system consists of the following broad categories:

- ***LICLDS*** System
  - Real Time model
  - Leak Detection Module
  - Predictive Model
  - Pig Tracking Module
  - Instrument Analysis Module
  - Interface to SCADA
  - Sammi Graphical User Interface

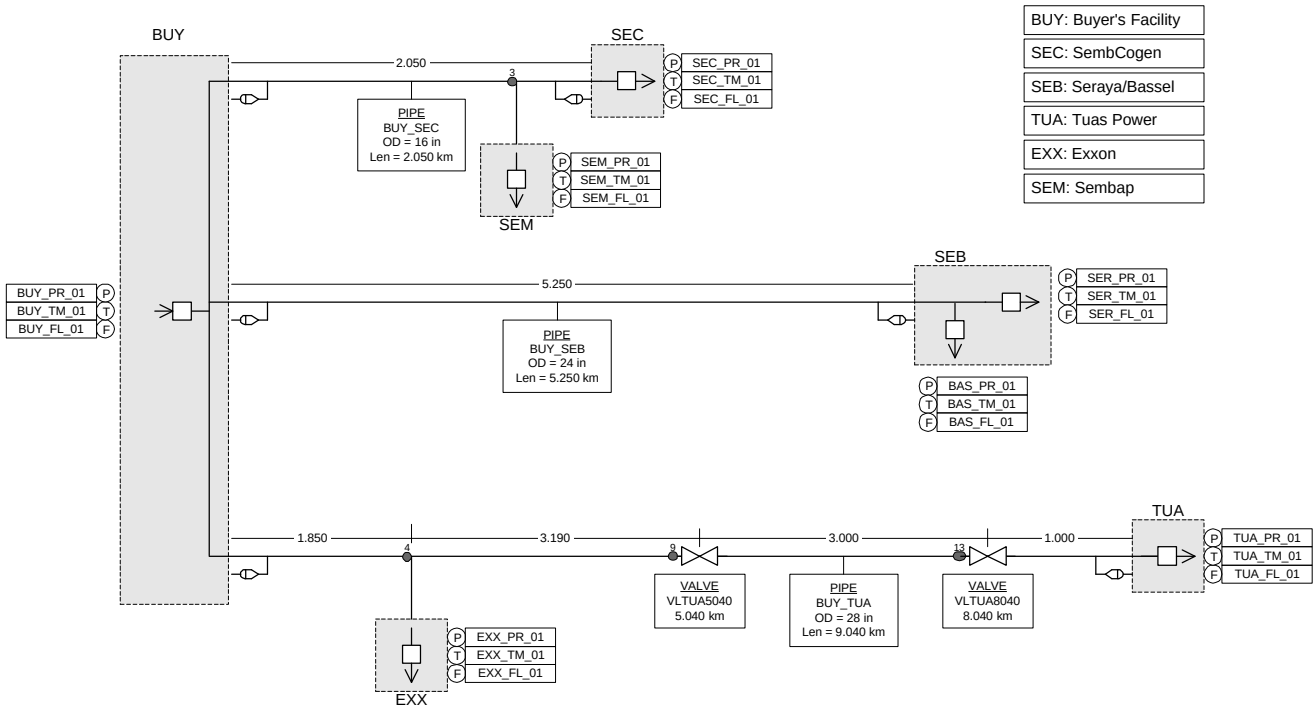
- ***NABS*** System
  - Gas Supplier and End User Agreement Model
  - End User Client Applications
  - Telex Service to Gas Supplier
  - Interface to SCADA
  - Interface to LICLDS Predictive Model

- **Energy Solutions** Implementation Services

- Documentation

- Project Control & Execution

- Operator and End User Training



REFERENCES

REMOTE VALVE
MANUAL VALVE
DELIVERY
RECEIPT
JOINT BOUNDARY
COMPRESSOR STATION
PRESSURE MEASUREMENT
TEMPERATURE MEASUREMENT
FLOW MEASUREMENT
SCRAPER LAUNCHER
SRAPER RECEIVER

SembGas

PF model to initiate actual model

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1.1 THE PIPELINE MODELING SYSTEM-*LICLDS* (OVERVIEW)

The supply of real-time application software is based on a set of existing basic standard modules, which are configured to suit specific applications. The approach ensures that project related software development is kept at a minimum and that subsequent changes in the pipeline system or in the mode of operation can be accounted for without a major re-writing of the software. The basic software modules described in the following section constitute the frame for the specific applications.

LICLDS consists of a set of software modules providing the following real-time applications:

- Data Reception and Transmission
- Data Pre-processing and filtering
- Dynamic Pipeline Models (Real Time Model)
- Leak detection and location
- Look Ahead Model
- Pig Tracking

- Instrument Analysis

A key element underlying several of the functions is a real-time computer modeling of the pressure, flow, temperature and variations in product properties along the pipelines. In connection with LICLDS, the pipeline model acts as an 'intelligent' measurement filter with the unique capability of 'removing' pressure and flow variations caused by normal operation of the pipeline, leaving behind only the information caused by a possible leak.

LICLDS continuously collects process information from the SCADA system. Thus, at regular intervals measurements of valve states, flow, pressure and temperature are provided. After an extensive validation, which is comparable to an engineer's validation and interpretation of data before he makes an analysis or a decision, the process data are fed into the pipeline model.

Alarm and event indicators from the real-time application software as well as other key results are issued on a screen on the workstation for presentation to the operator. Results from all the system's main functions and system configuration data are available via the GUI.

1.1.1 DATA RECEPTION

The system receives real-time process data from SCADA at regular intervals. In order to support the transient hydraulic profile, it is recommended that all pressure and flow data should be updated every 3 seconds or better. The update rate for data send from the SCADA system to NABS is not that critical.

The basic cycling time of the system can be configured in multiples of one second and will be defined on the basis of the frequency by which the SCADA system provides a complete set of fresh pressure and flow data representing the true real-time data.

The system can use time stamps on the individual measurements in order to arrange the individual data in a common time frame. Assuming that the SCADA system includes routines, which collect data from the local stations so that all data normally are updated at regular intervals, there is only a marginal benefit from this facility.

1.1.2 DATA PRE-PROCESSING

The pre-processing of the real-time data is an essential feature. The objective is to evaluate the credibility of the incoming data through a series of validity checks specifically designed for real-time pipeline modelling.

If data cannot pass these checks, the system will seek to replace the faulty or missing data, but more importantly, the system automatically uses this information in the subsequent analysis. In practice, the extended use of data pre-processing ensures a minimum of false alarms of the system, which the operator otherwise would have to evaluate.

Hence, the output of the data pre-processing is a complete set of data values at a given instant in time to be used in the subsequent processing and all data are identified by a quality tag.

Further, the results of the pre-processing provide information on operational mode in terms of pipeline configuration, pumping status and flow distribution to take-off points.

1.1.3 PIPELINE MODEL

In terms of the pipeline model, the pipeline system can be subdivided into a number of sections. The division into sections depends on the location of measuring points - in particular flow measurements - but in practice the division is dynamic to allow for alternative operational modes.

The pipeline model uses data from end-points of each section for dynamic real-time simulation models, which give complete profiles along each pipeline section of pressure and flow at any time. The pipeline model is based on the solution of the governing equations by means of the method of characteristics.

- Conservation of Mass
- Conservation of Momentum
- Equation of Energy
- Equation of State

1.1.4 LEAK SIZE AND LOCATION

A LICLDS module called LLOC calculates the leak size and location. Leak size and location estimates will be provided. The leak size is calculated from the UF leak responses.

For a given leak size, different leak locations imply different responses of UP and UF. Leak location calculations based on pipeline models rely on this dependency.

In order to improve model accuracy during operational changes (i.e., expected variations), the leak location is calculated by integrating the dynamic pipeline model equations rather than calculating the location from the steady state expressions for UP/UF.

1.1.5 PREDICTIVE MODEL (LOOK AHEAD)

The Predictive Model provides the operator of a transmission system with the ability of analyzing the effect of a predefined set of operational conditions, which can be customized for different scenarios.

It requires an integrated, real-time mathematical model of the process to provide a detailed, realistic picture of the current flow status in the pipeline to be used as a starting point.

Based on this status, the current operational conditions (set points, batch distributions, valve positions, supply and take-off) a forced flow analysis ahead of real-time is performed. The flow analysis runs in the same flow model as above, but in a 'faster than real-time' mode.

The PM is invoked by operator request and supports regular alarm and reporting facilities. The PM runs using the nominations forecast from the NABS system, thereby providing a realistic impression of future response of the real process.

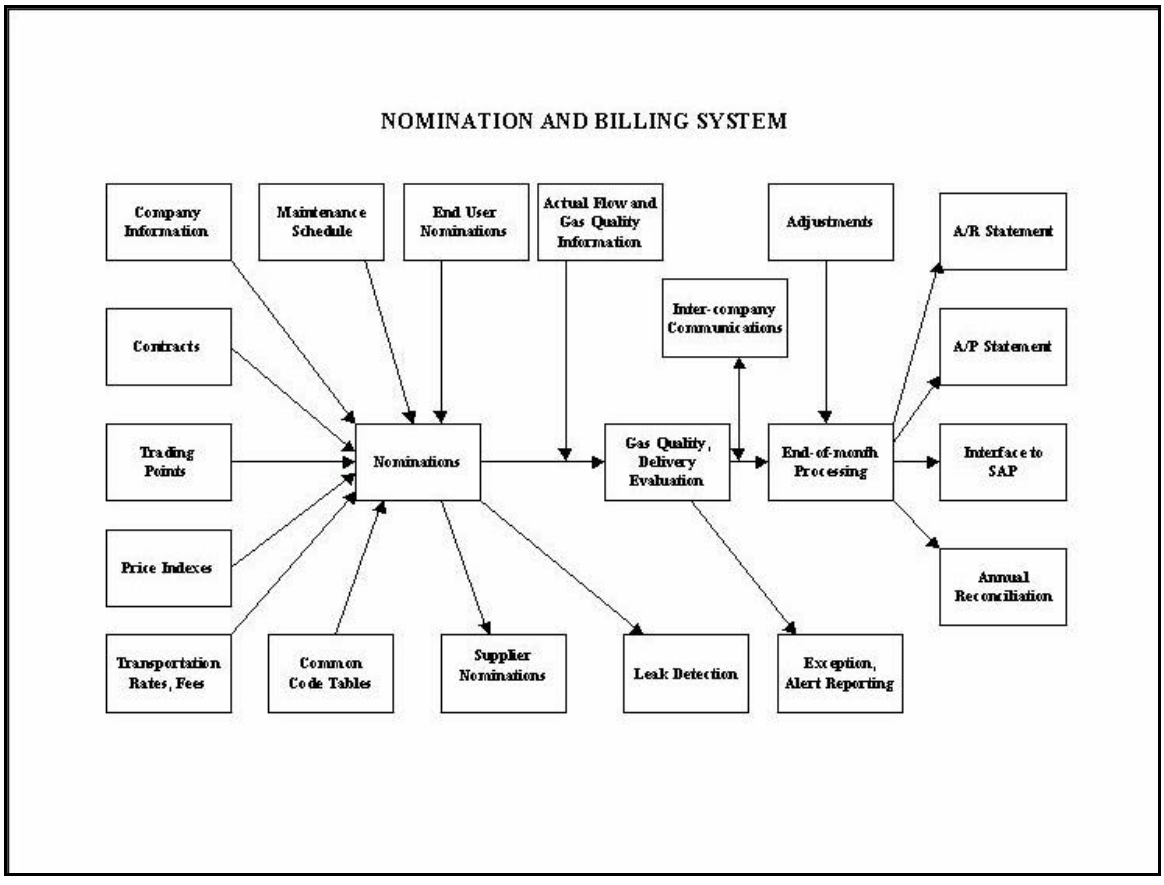
The results of the PM can be subject to standard alarm facilities and can be utilised in crises management to estimate the remaining operating time and to evaluate possible actions.

1.2 THE *NABS* SYSTEM (OVERVIEW)

1.2.1 OVERVIEW

The "Nomination and Billing System" is designed to meet legal, commercial, and operational objectives for SembCorp Gas Pte Ltd. It is used in conjunction with a SCADA system that monitors continuous flow and gas quality information and a leak detection and flow simulation package.

To meet the contractual requirements of the business, the "Nomination and Billing System" must capture actual flow and gas quality information from the SCADA system. The system must provide a mechanism to capture and submit daily gas nominations, monitor gas flow versus nominations, and bill for actual deliveries at the end of the month. The following diagram represents an overview of the "Nomination and Billing System".



1.3 OVERVIEW OF SYSTEM INTERFACES

The interfaces between NABS-LICLDS, NABS–Fast/Tools and LICLDS-Fast/Tools use a standard communication protocol called OPC. The communication between CONOCO and NABS will use a program called Wintelex. The OPC protocol uses COM and DCOM Technology, which are based on Client-Server architecture (Refer to Figure 2-1 for an Overview of the entire data communication path).

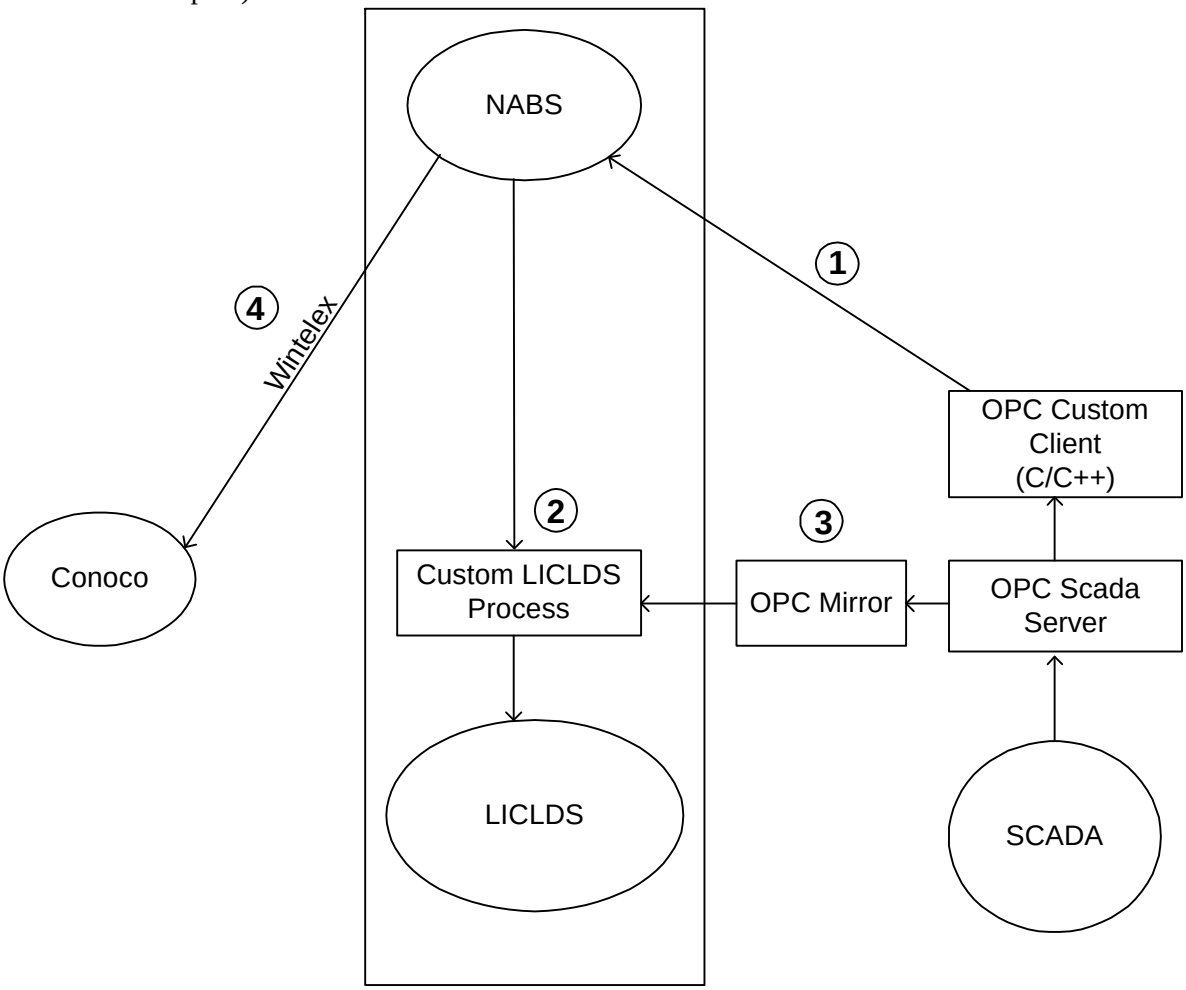


Figure 2-1: The NABS/LICLDS System Communication Overview