energysolutions®

World leaders in pipeline management.

An Example of Business and Operational Integration for a Gas Pipeline

David Reed, Energy Solutions International
Olga Narvaez, Energy Solutions International
Alexandre Tepedino, Transpetro
Caetano Frisoli, Transpetro
2006

ABSTRACT

The purpose of this paper is to show how a pipeline company can integrate its operational and commercial practices into a real-time environment that will allow safe, efficient, and profitable operations. Operational pipeline modeling/management, SCADA, and commercial transaction systems can be combined to provide hydraulic validations of business transactions and provide a real-time and forward look at pipeline expectations. This helps pipeline companies better manage oil and gas shipments on a real-time basis and to comply with issues of restructuring and regulations to avoid unnecessary costs and build revenue.

Transpetro in Brazil has automated and integrated many of its processes. This paper will define the issues encountered by Transpetro and the steps it took to integrate both its operational and commercial business systems into a real-time environment. The paper will also document the integration of systems to merge the commercial business transactions and operational parameters to provide forward looking models necessary to utilize the entire pipeline system effectively. The solutions developed by Transpetro could be applied to many other pipeline companies.

ABOUT TRANSPETRO

Transpetro is a full subsidiary of Petroleo Brasileiro S.A. – Petrobras and was incorporated on June 12, 1998. Its mission is bulk transport and storage of petroleum and its byproducts and of natural gas through pipelines and ships, and to operate terminals. There are two big networks (Northeast and Southeast), each one with a number of pipelines: The Northeast Network runs along seven states in Brazil (Bahia, Sergipe, Alagoas, Pernambuco, Paraíba, Rio Grande do Norte e Ceará) and moves approximately 9 Million m^3/day. The entire network includes three (3) compressor stations. This network is composed mainly of five pipelines: GASFOR, NORDESTÃO, GASALP, GASEB, and a Sub-Network.

The Southeast Network runs along three states (Rio de Janeiro, São Paulo e Minas Gerais) and moves 20 Million m^3/day. The entire network includes five (5) compressor stations and it has the following pipelines: GASBEL, GASVOL, GASPAL, GASAN, Merluza, GASDUC I, GASDUC II, and G1, G2, G4, Namoradao, Enchovao (G3), GASCAB I (G5) and GASCAB II. The last seven are essentially gas gathering lines that bring gas from offshore.

Among other business TRANSPETRO sells gas transportation capacity to a number of companies interested in moving gas from the producing site to the consumption points. TRANSPETRO's client companies called "shippers" request on a daily and monthly basis a certain amount of gas to be transported by TRANSPETRO from a supply point to a given delivery point.

TRANSPETRO also provides operational, maintenance, and administration services to other transporters. TRANSPETRO must maximize the amount of transported volume while maintaining the operating limits of the pipeline.

TRANSPETRO SYSTEM

The Transpetro system consists of a pipeline hydraulic simulator with both real-time and predictive models, and a nominations system. Operations use the real-time model to monitor the state of the pipeline networks for purposes of operational analysis, linepack/pressure management, etc. There is also an integrated interface with the nominations system to receive (and return) nomination volumes for all supplies and deliveries from the business environment. The real-time model in turn converts these volumes into expected daily loads for the current and next gas day. Dedicated predictive models utilize these flow patterns to validate the nominations in the operational environment, determining if any operational limits are exceeded. The nominations or the pipeline operation may be changed based on the results of these validation exercises.

Real world examples and experiences will be used to demonstrate that pipeline simulation tools can be merged with commercial transactions to maximize physical and financial opportunities for all parties involved. In addition, cases will be shown that point out how business transactions and real-time operational factors need to be considered simultaneously to provide for the most efficient and profitable operations of a pipeline.

BUSINESS PROCESSES AND NOMINATIONS

Pipeline companies often must manage transactions from a number of third party customers. In many cases, the pipeline company sells transportation capacity to parties who need assurance that natural gas will be available to be delivered to certain facilities on a consistent basis. These third parties will often pay a premium for the right to have preferential rights through the pipeline system. Other companies are content to utilize the pipeline on an as needed, or “space available” basis. These companies may pay a lesser amount for transportation services, but run the risk of not having space available at all times. These determinations are made by individual customers based on their operational, contractual, and commercial needs and requirements. Those companies who have the need for such assurance of availability will be considered “firm” or highest priority customers. With that designation comes a requirement to pay additional fees – and in many cases the stipulation to pay for space whether it is utilized or not. Additionally, with this comes the expectation that nothing short of an unexpected operational upset or force majeure even will prevent their transactions from being fully realized. Finally, pipeline companies look to maximize throughput, and therefore revenue, by making sure that as many transactions as possible are accommodated without infringing on the guaranteed rights of their firm shipper customers. This is where pipeline models can come into play.

Nomination business applications will configure a pipeline so that business transactions can take into account each of the specific positions of customers utilizing a pipeline system. These applications are normally web-based and allow third party customers to provide nominations or “orders” via a secured website. The pipeline then has the responsibility to manage these nominations, taking into account the priorities of each of the customers. Pipelines can manage these transactions in a number of different ways. In some cases, nominations can clearly be rejected or reduced because the quantities requested to be received and delivered are outside of set commercial or contractual boundaries. However, since pipeline operations can fluctuate due to environmental and business factors, running a predictive or simulation model maximizes a pipeline's efficiency. Once the nominations are received, they can be sent to a model for the running of a hydraulic validation.

In Brazil, the rules of the business are imposed by the Brazilian Regulatory Entity (ANP). These rules are reflected on the contracts that TRANSPETRO maintains with its shippers and transporters. These agreements are configured in the commercial application.

During the scheduling process the TRANSPETRO user verifies all the information gathered from the clients. Once the verification is done, the TRANSPETRO user (scheduler) has the option to validate this information or to send it to PipelineManager (PLM) team to get a hydraulic validation. If the option is to send the information to PLM to be hydraulically validated, the system sends the nominations or the re-nominations by delivery point, PLM runs a predictive model and analyzes the results and sends the resulting authorized nominations back to PipelineTransporter (PLT). When PLT receives the results, the scheduler validates this information and proceeds to generate the schedule by contract for Transpetro customers.

PIPELINE SIMULATION

The two worlds of operation and business are served by two very different systems. The operations sphere is served by a detailed hydraulic simulator. A rigorous, fully transient model is supplemented by integrated device models of compressors, regulators, after-coolers, etc. The real time model provides a set of pressure, flow and temperature profiles, linepack calculations, composition tracking, etc to help operations manage the pipeline. The real time model also performs a purpose for the predictive models supplied with the system.

PREDICTIVE MODELS

The predictive models fall into two general categories, look-ahead models and what-if predictors. The look-ahead model starts from a snap-shot of the current pipeline operation (the real time model) and runs into the future without any user interaction/manipulation. This assumes that if the current pipeline operation is maintained for the duration of the simulation, then the look-ahead model results will be reasonably representative of the future state of the pipeline. Survival time models can be said to be a sub-set of this genre.

While the real time model takes instrumented field data to drive its boundary conditions, predictive models cannot. Therefore some thought has to be given to how to "drive" the future boundary conditions. Even a simple look-ahead model, which starts from the current operational point, may benefit from the inclusion of device models. In particularly compressor stations and regulator valves device models are included, as opposed to "black box modeling". This gives a more realistic and therefore more accurate estimation of the future state of the pipeline, based on actual device operation, constraints and set points.

This means that the real time model has the same device models included to accomplish the following tasks:

- Tune the device characteristics to match modeled operation against measured operation
- Define the device operation philosophy to match real operation (e.g. discharge pressure control, speed control, etc) so that the predictive models can use these modeled devices to more realistically model future operation based on fixed boundary conditions
- Enable the predictive models to initialize from these devices included in the real time model

An example would be a compressor station running several units on discharge pressure control. The device model contains similar operational constraints to the real units, so that maximum speed, power, throughput, and discharge pressure, among others, are all adhered to in the model. In this way, even with a fixed boundary condition such as station discharge pressure control, the individual units will modify operation, trip, start up or shut-down based on constraint data included in the device model, and unit availability.

NOMINATION VALIDATION

Supply/Delivery Modeling

There is a dedicated predictive what-if model used exclusively for hydraulic validation of nominated gas quantities. The business application takes care of the requirements of the transaction and nomination processing. It allows the costumers to nominate the quantity of gas they contractually want, typically for the current and next gas day. If the nomination is in the form of an energy nomination (e.g. BTU's) then a heating value is used to convert to a gas volume representing one days demand.

This daily gas quantity is then used to predict the future demand for gas at each of the deliveries. If all of the deliveries have a nominated gas quantity, the predictive model can use these volumes as boundary conditions. Each delivery should have a nomination, and each supply should have either a nomination, or a (pipeline) operation based strategy to achieve a condition whereby the delivery loads and the supply strategies provide a predicted load forecast. This daily volume of gas is further broken down into hourly segments, in the form of a flow pattern. The daily volume is then converted into an hourly flow rate based on this load pattern. The accuracy of the load pattern determines how accurate the resultant boundary condition is. This of course determines how accurate our future hydraulic prediction will be. The accuracy of the model is pretty much a given, so what drives the accuracy of a predictive simulation is how accurately you can assume the future operation of the pipeline for the duration of the simulation period.

Once you have received the nomination volumes, assigned the flow patterns for the respective deliveries, you can start your predictive model and hydraulically validate the nominations. The model is configured to issue low/hi pressure alarms for pipes and deliveries, and also for pipeline inventories. Therefore the simulation engineer can determine from alarms and from the intermediate/final hydraulic state of the model how well the pipeline can supply and transport the gas needed to meet the nominated gas quantities.

If the initial simulation does not give enough comfort zone for operations, they have a couple of paths to follow which can determine the next action. The model can be used to perform what-if throughput optimization, with the user manipulating compressor operation, optimizing/transferring linepack from one area of the pipeline network to another, and generally optimizing pipeline operation to ensure the nominated demand can be met. If this still cannot achieve the desired throughput rates, then the model can be used to determine what quantity of gas can be delivered, to assist in the nomination reduction schema. This may be something as simple as cutting the non-firm quantities of gas and re-running the hydraulic validation, or it may mean rejection of the nominations based on failure of hydraulic validation. Once the transactions are received from the hydraulic model, the nomination application can then make reductions based on the contractual requirements of each shipper's contract. This usually entails reducing "non-firm" customers first and then firm customers pro rata if necessary. This process, which is run on a daily basis, allows the pipeline to maximize throughput and assure the transactions of customers who have priority are met.

Fine Tuning Load Patterns

As we have seen before, to increase the accuracy of a predictive model, we must increase the realism of its boundary conditions. We know from the nominations the daily quantity of gas each delivery is expected to take (has contracted to). However, this does not take into account any hourly swing variations. The "flow pattern" applied to the volume should ideally mimic the load demand to the greatest extent possible. Each delivery can be assigned its own flow pattern, which in its simplest case would be a flat line for the 24 hourly periods. However, patterns can be defined and implemented to give more realistic load forecasts. Single step patterns, two step patterns, custom patterns based on typical demand are all usual. The system can also store the demand curve of the previous day, and use this to predict load demand. As with many attempts to increase the accuracy of simulations, additional data/inputs need to be supplied to the simulation, and the source and accuracy of this data cannot always be guaranteed. The end user is encouraged to monitor the load patterns, and modify/generate patterns as needed.

Energy Conversion

Quite often the business side works in gas energy (BTU's) and the production side works in volumes. The typical operator does not care much about energy flow rates. Sometimes the business world wants to know about pipeline pressures at delivery points. In practice, some pipeline operators will run with a very tight composition variance, and some will not. For the operators that have compositions that change significantly, there may be an interest in tracking and converting gas volumes into energy flow rates using model tracked Gas Heating Value (GHV).

While at first this may seem attractive, there are several problems with the execution. First, pipeline operations are using flows and pressures to control and monitor the operation. Secondly, exactly what GHV value should be used? The real time model cannot give any information regarding current and next day heating values. So the predictive model could be utilized to generate some form of tracked heating value (perhaps a 24 hour average), which could then be used as a conversion factor in the business application.

This assumes that the traveling time of the gas to the deliveries will be longer than the simulation period – otherwise the modeler will have to supply future composition boundary conditions to the predictive model.

This scenario still leaves a disconnect between the operations world and the business world. The business application will probably need to use a conversion factor to convert from energy to volume even before any simulations are performed. This then implies the two systems are using different conversion factors. Certainly the actual accounting and billing quantities will be from instrumented values. In effect, the heating value of the gas would need to change before any such analysis would benefit from a simulation that would perform heating value conversions. The advantages of this conversion then are somewhat unclear. However, maintaining nominations as an energy total and having the model process the nomination as such may be a more suitable approach. The model produces an energy flow rate profile, and the nominations derived load forecast is in energy flow rate. This still has the restriction regarding travel time and supply composition inputs, and as such would only be suitable for long travel times and near term (1-2 day) nomination analysis.

OTHER CONSIDERATIONS

Given that some effort is taken in producing accurate load forecasts derived from the nominations, the standard look-ahead and survival time models will benefit from using these boundary conditions to make the prediction results more accurate. Indeed, any predictive scenario analyzing current operation will benefit from more realistic predictive boundary inputs.

Finally, the nominations are used to determine if the current delivery rate is under, over or on target for the day, and can inform the operator by how much to compensate to make the scheduled volume. The application totals the actual delivered quantity per delivery, and every hour calculates the difference between the nominated quantity and the actual delivery (from the start of the gas day). So if more gas than scheduled is being taken, the operator can see at a glance how positive, or negative, that difference is. The application can also calculate one or two compensation strategies for the remaining gas day, to get back on schedule.

CONCLUSIONS

While still a relatively new technique, and one that requires some implementation efforts to achieve full benefit, the fact that we can perform operational validation of nominated gas volumes is attractive to many. The bonus of improving look-ahead, survival time, and general predictive model realism, and therefore accuracy, is also significant. Lastly, the real time advisory information, given on a delivery by delivery basis, can also be of significant benefit.

CASE STUDY

This case study details the deployment by Petrobras Transporte SA - Transpetro, a Petrobras subsidiary in Brazil, of a business system designed to combine and manage new gas transportation commercial and operational processes. These processes are divided into three main groups:

a) Nomination & Scheduling Processes,

b) Operational Processes

c) Measurement, Allocation and Billing Processes.

The system operates in real time, integrated to the Transpetro SCADA, with direct communications channels to the several agents and users for each process. There was special attention paid to the transition between the "As Is" model to the "To be" model, where new transportation logic was included. In the previous model, a simple hydraulic version was in place, while in the new model, the transportation business logic is “overlayed” onto the hydraulic model. To keep in place the basic ideology of the processes, we took a structured methodology, with special attention to the human element required in making determinations.

This project was born in anticipation of an important transformation in the natural gas market in Brazil. Petrobras previously sold all the gas on the pipeline system, and transportation was an embedded cost of this service. Since 2006, Petrobras has put in place a new business philosophy - transferring all the pipelines to a new special purpose subsidiary company Transport Dora Nordeste-Sudeste - TNS, and separating the buy/sell commodity portion of the company from the service of transporting gas for a fee. This new model, which changed the pricing structures for the gas industry, is the basis for financing new pipelines in Brazil, aiming at doubling the present installed network.

City gate price = (Commodity Price + Commodity Tax) + (Transportation Rate + Transportation Tax)

New pipelines built in Brazil have a Project Finance component structured within the transportation rates of the existing pipeline network. In addition, it is a substantial effort to synchronize new pipelines and compressor stations with the development of new gas markets, including the new interconnections contemplated by Local Distribution Companies.

TNS is a pro-forma company, being the real administration, operation and maintenance arm of the Petrobras Transporte SA – Transpetro network. Transpetro was created in accordance to the Brazilian Law that opened access to the Petrobras pipeline network (Art. 65 – Lei 9478/97). Transpetro is responsible for the operation of the majority of gas and liquid pipelines in the Petrobras system (Petrobras E&P is responsible for the operation of production lines).

The Transpetro Gas Control Center (CCG) is located in the city center of Rio de Janeiro, in the Transpetro main building, and has a contingency or backup installation located in Campos Eliseos, Duque de Caxias (1 hour away from the city center).

With the advent of selling transportation services within the gas networks, Transpetro assumed the role of organizing processes related to the gas selling and trading. This includes the measurement process, imbalance control (by Contract), the accounting for fuel related to compressors and heaters (included in the carriers' bill), solving for unaccounted gas related to measurement inaccuracies, and contractual penalties.

The transportation nominations and scheduling are now done under base Transportation Contracts, which include a component for the gas commodity and associated transportation service related to moving gas from each receipt to delivery point path. This could relate to numerous clients at a time. Also included in this component is the process for the billing for transportation services and payment of tax for this new service.

Under Brazilian law (Lei 9.478/97), the gas market in Brazil has been designated as open-access, which mandates pipelines to unbundle their commodity and transportation. A new regulatory framework, which should improve and clarify rules for gas marketing and pricing, is being developed for implementation in 2006.

With these changes in the Brazilian Gas Sector, a computer application was necessary with the flexibility to accommodate both a monopoly-type market along with a fully-developed open access market. This is necessary since Brazil has lines used specifically for the business of Petrobras alone along with open access lines that contain multiple shippers, shipper transportation contracts, and various agreements between the players.

Because of these changing market conditions (which included the execution of new transportation contracts and business arrangements), Transpetro faced the need to expand its vision in defining processes and systems. The pipeline transportation sector requires a short-cycle information system. There is only one day between the customer transport nomination and the actual movement of gas. This necessitates the ability to respond to business and events in a real-time manner. Reliable and sophisticated information systems are vital in order to administer and operate the pipelines from an administrative and physical infrastructure standpoint. This is just one more factor in the need for integrating the business and operational aspects of the pipeline networks.

In order to accomplish its goals, Transpetro needed to marry the SCADA systems (which deal in a continuous 24-hour cycle connected to the physical infrastructure) with the Gas Business Systems (which are transaction oriented, and can usually be accommodated during normal business administrative hours).

ADVANTAGES REALIZED WITH A REAL TIME BUSINESS/OPERATION INTEGRATION

- Real-time information is widely available throughout the organization to everyone who needs it.
- Transpetro is able to deliver an improved service by enabling executives to directly control the operation of their business systems.
- Line pack management is more efficient, enabling an increase in the transportation capacity of the pipeline network.
- Operations can now respond, in real-time, to business events. When an operational event occurs, all systems that can utilize information are informed.

"Project Malhas", which was the initial project that brought the need for integrated systems, kicked off in July 2005. This project brought together SCADA and commercial software applications for Transpetro's natural gas pipeline business. This paper has attempted to describe the deployment of these advance applications systems, operating in Real Time.

FIGURES

Figure 1 – Today's Business Cycle

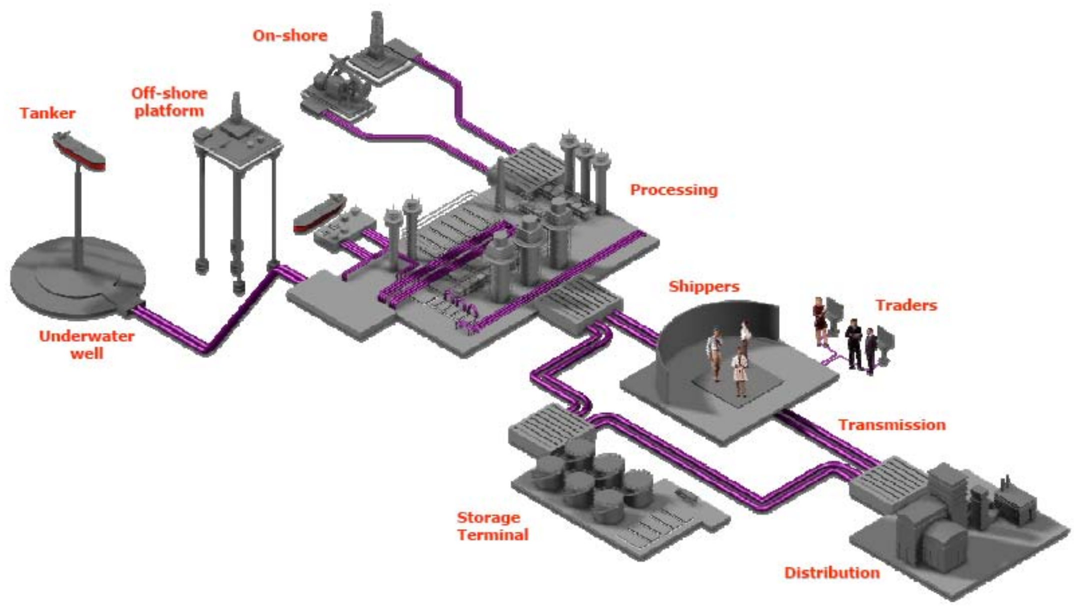

Figure 2 – Business Workflow

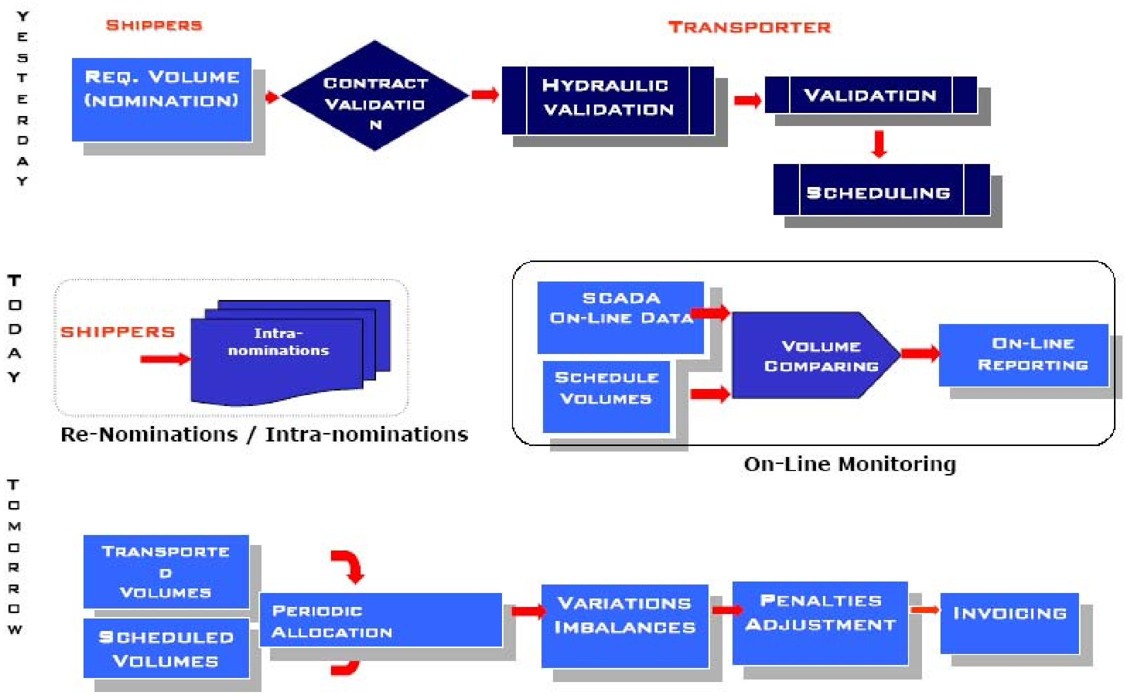

Figure 3 – Application Integration

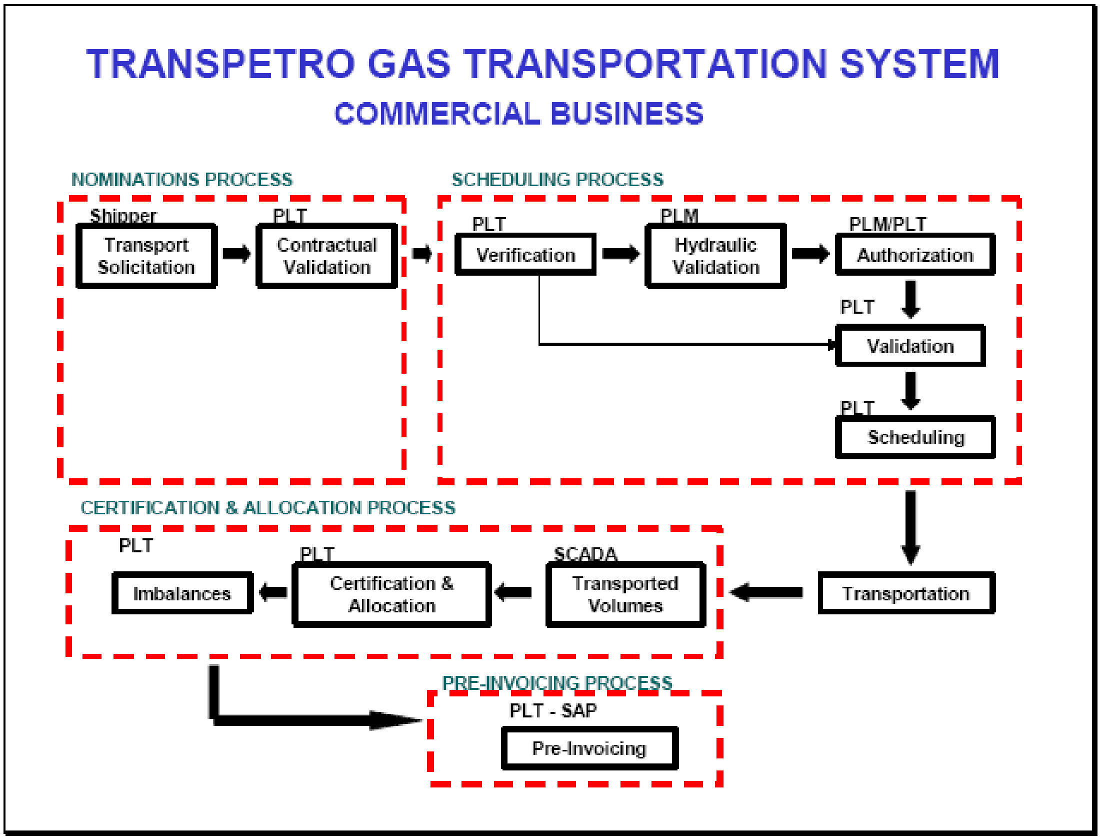

Figure 4 – Nominations based flow patterns

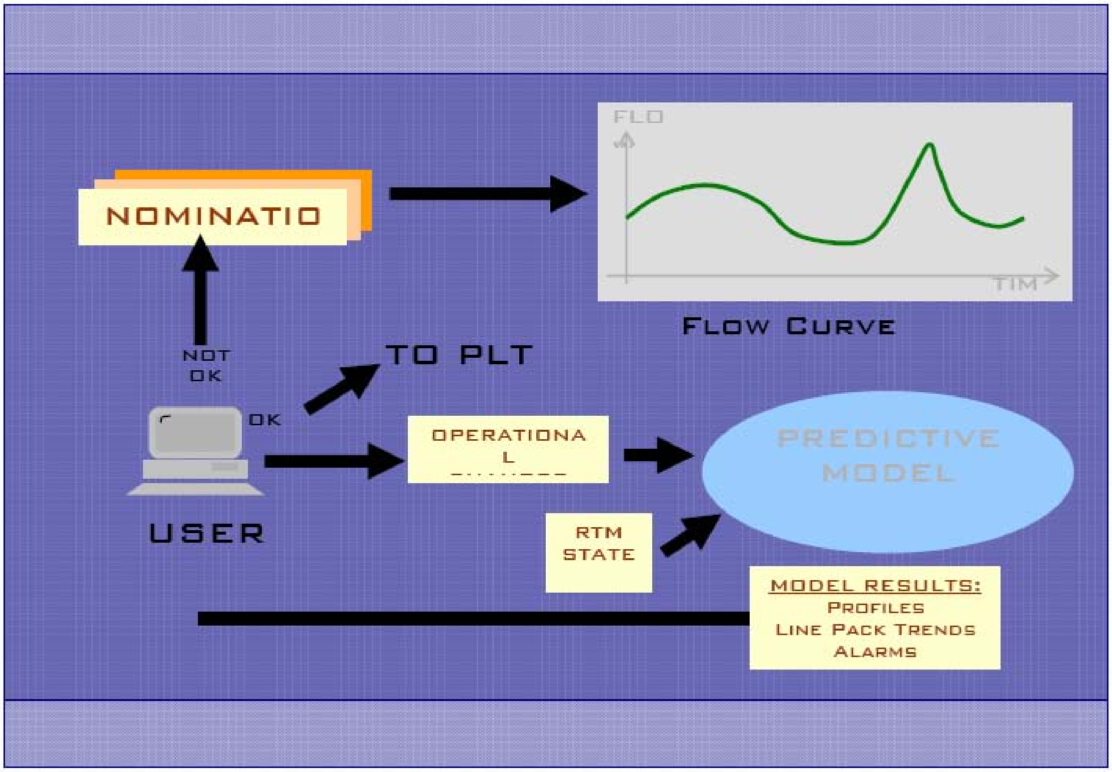

Figure 5 - Northern network

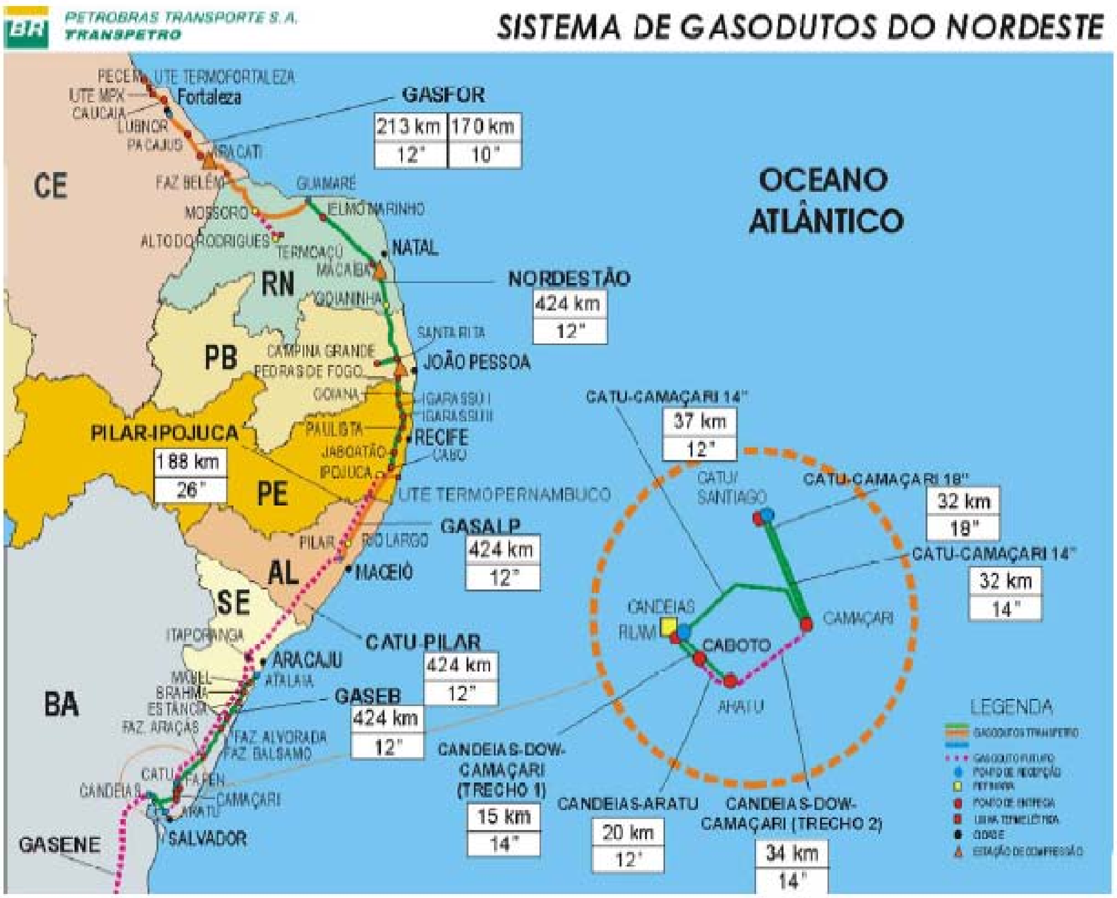

Figure 6 – Southern network