The Advantages of an Integrated Solution

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Abstract

This paper describes the Transportadora Brasileira Gasoduto Bolívia-Brasil S.A. (TBG) gas pipeline scheduling methodology and the advantages company gained by integrating the Energy Solutions International Inc. (ESI) pipeline software applications the Operational Management System (PipelineManager) and the Gas Management System (PipelineTransporter). Integration of the applications enabled TBG to generate a gas pipeline schedule by utilizing the maximum capacity of the pipeline without violating the operational and commercial constraints under day to day fully dynamic pipeline operation with changing needs for gas.

Integration of the pipeline business and operational applications mainly focuses on handling the shipper nomination changes and adjustments effectively on an intra-day and daily basis by hydraulically validating them using a fully transient predictive model. Validation ensures that changes in the nomination do not affect the pipeline integrity and operational constraints imposed by the transportation contracts such as minimum and maximum pressure requirements.

Introduction

The TBG gas pipeline conveys natural gas from Bolivia to Brazil states of Mato Grosso do Sul, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul. It transports large volumes of gas, operating at high pressure, and delivers gas to eight different distribution companies and constitutes an integrated gas transportation system.

TBG's pipeline was designed to transport up to 1.06 billion cubic feet (30 million cubic meters) per day of natural gas. Figure 1 gives an overview of the TBG network. It stretches 1,611.2 miles (2,593) km and has 15 compressor stations and 46 city gates for gas distribution. TBG receives natural gas from an interconnected pipeline from Bolivia and delivers it to Local Distribution Companies, PETROBRAS network, Refineries Plants and Thermaleletric Units in Brazil.

TGB employ a Gas Management System to facilitate the business processes of the pipeline, e.g. handling nominations; an Operational Management System is used to monitor integrity and provide predictive simulations. Complexity of the network and high natural gas demand from the customers enforced TBG to integrate the Operational Management System and the Gas Management System to handle various possible scenarios of pipeline operation, such as for example equipment failures and supply/delivery demand fluctuations.

Important Terminology

- **Gas Management System** – Software application used to manage the business aspects of the TBG gas pipeline such as nomination, scheduling, allocation and invoicing through management of gas transportation agreement between TBG and its shippers.

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- **Operational Management System** – Software application used to monitor the operational condition of the TBG gas pipeline. It simulates the real-time state of the pipeline based on the inputs received from the Supervisory Control And Data Acquisition System (SCADA) and also used to perform hydraulic validation of nominations and what-if scenarios using the predictive models.
- **Nominations** – Shipper requests to transporter for movement of physical quantity of gas from receipt point to delivery point on the TBG gas pipeline.
- **Hydraulic Validation** – Process of verifying the feasibility of transporting the nominations on a flow-day without violating the operational constraints using a Predictive Model.
- **Predictive Model** – Fully transient hydraulic model within the Operational Management System and is used to hydraulically validate the nominations and also to perform What-If analyses.
- **Schedule** – The gas schedule contains information about the volumes to be delivered at various delivery points and also instructions to pipeline operators and shippers.

Business Process Overview

The main elements of the transportation business process include Transporter, Shippers, Interconnected Pipelines and Local Distribution Companies. Figure 2 gives an overview of the transportation process.

- **Pipeline** – This is the Gas Pipeline Network. This pipeline network forms the hub of gas movement through the market.
- **Transporter** – This is the transportation company and pipeline operator. In this case the transporter is TBG.
- **Shipper** – Any company that has a commercial relationship with the transportation / operation company normally through a gas transportation contract.
- **Interconnected Pipelines** – These are the pipelines that are physically connected to the pipeline network that act as receipt or delivery points.
- **Local Distribution Companies** – They are located at the delivery points. Transporter does not have any direct commercial relationship (contract) with them, the shipper deals with them.

Transportation Contracts

Pipeline companies enter into an agreement with the shippers to move gas from one location to another, which is typically the production unit to the end customer. There are mainly two types of transportation contracts and they are classified based on the type of service needed.

- Firm
- Non-Firm (Interruptible)

As the name implies, Firm contract nominations must be obliged by the transporter. Non-Firm contract nominations can be curtailed by the transporter, if the pipeline operation does not accommodate such requests.

Sometimes shippers may release the capacity from one contract to another and the transporter is also obliged to handle such requests. An example of that is called “Flexible Service”, in the Firm Service, which guarantees shipper to request over the capacity of a contract during weekdays, so that it can supply gas market demand during that period. The diference will be discounted from Total Week Capacity on next Saturday and Sunday.

Nomination Cycle

Shippers are provided with a start and end time to submit their nominations to the transporter. Dead lines will be different for daily and intra-day nomination. Daily nominations are requests for tomorrow’s gas and intra-day nominations are changes to the current day nominations which were submitted yesterday, and are updated in order to adjust operational or commercial conditions that were modified lately. If the shippers are unable to submit the nominations before the deadline, default nomination will be used.

Scheduling Cycle

At the end of the nomination cycle, the pipeline scheduler will review the nominations and perform all the necessary activies to generate the schedule and publishes it to the pipeline operators and shippers. This activity must be finished prior to the agreed upon scheduling time.

Scheduling Methodology

TBG receives natural gas from an interconnected pipeline from Bolivia and delivers it to the Local Distribution companies, PETROBRAS network, Refineries Plants and Thermaleletric Units in Brazil.

The methodology used in generating the gas pipeline schedule is as follows:

- **Nomination Process** – Shippers create the transport nominations in the web portal of the Gas Management System and tranporter performs the contractual verification of nominations. Interconnected pipelines and local distribution companies confirm the nominations submitted by the shipper through the web portal available in the Gas Management System. The Gas Management System generates summarized transport nominations for each receipt and delivery point.
- **Nominations to Delivery Flow Curves** – Once the nomination process is completed, the transporter sends the summarized transport nominations for each receipt and delivery point to the Operational Management System. The Operational Management System consists of the predefined demand patterns library for each delivery. Based on daily nominations received and demand patterns for each delivery, the Operational Management System will generate a flow curve to truly represent the demand for gas throughout the day and validates them using a predictive model.
- **Nominations Hydraulic Validation** – Once the flow curves are generated for each delivery, the predictive model can be set up to run and calculate the hydraulic state of the pipeline. The pipeline operator validates the predictive model results and, in some cases, may modify nominations to achieve the desired operational state of the pipeline. After achieving the desired results, the pipeline operator transfers the validated results from the Operational Management System to the Gas Management System.
- **Scheduler Validation and Publishing** – The gas pipeline scheduler uses the Gas Management System again to validate the results from the Operational Management System to generate the definitive gas schedule and publishes it to the operational department and to external shippers.

Figure 3 illustrates nomination and scheduling process.

Nomination Process

This module in the Gas Management System includes the transport request from the shippers and their contractual validation.The transport request is the volume to be nominated; this volume is divided into four services:

- **Required Quantity (QR)** – The basic part of the nomination volume.
- **Authorized Overrun (EA)** – An amount that the shipper is allowed to take above the QR.
- **Ship or Pay (SOPR)** – An amount that the shipper is allowed to take over time.
- **Imbalance** – The amount of gas accumulated by the daily differences between the nominated volumes that a shipper can take or return to the transporter.

These are valid for all receipt and delivery points. Also System Gas (Compressor Fuel) is considered as part of the nomination services that must be supplied at the receipt point.

The information received from the upstream and the downstream point operators (confirmations quantities) is used for volume verification among the parties but it does not have any contractual effect. Confirmation quantities may be maintained by the third parties (Producers, Interconnected pipelines, LDC's) on the Gas Management System.

In order to validate the information inserted by the shippers, the contractual validation works with the following information: Shipper data, type of services, contractual periods, contractual volumes, Maximum Delivery Quantity by points, etc. These validations take place as soon as the client inserts information into the system. The Nomination Process works on a daily (nominations for tomorrow's gas day) and an intra-day (re-nomination for current gas day) basis.

Predictive Model

The predictive model is an offline fully transient hydraulic pipeline model with detailed pipeline, compressor and station equipment modeling. It can either start from a real-time state or an archived state. It can also be configured with a scenario composed of changes in the boundary conditions (temperature and pressure set points, valve and compressor states, etc.); flow rate changes are generated automatically from the nomination data.

Nomination Handling

The Nomination processing module in the predictive model takes the nomination volumes for the current and next gas days and generates flow curves for every delivery and supply point.

Normally, the nomination analysis is performed one day in advance, when all Shippers send TBG their requests for nominations for the next gas day. With this nomination information the Operational Management System user can run predictive simulations to analyze the hydraulic feasibility of the nominations requested.

The system handles two basic types of nominations:

- Pending Nominations
- Validated Nominations

One Predictive model in the Operational Management System is dedicated to the analysis of the Pending Nominations with the objective to obtain a set of Authorized Nominations to be sent back to the Gas Management System.

After the Gas Management System receives the Authorized Nominations from the Operational Management System, it generates the Validated Nominations that ultimately become part of the shipper's schedule. The Predictive Models can also use this validated nomination to calculate the hydraulic state of the pipeline as these represent the true estimate for the next gas day.

Pending Nominations

The Gas Management System must verify the Nominations received from the shipper against certain basic contractual and balance constraints. After that basic verification, these nominations, called Pending Nominations, must be hydraulically authorized by TBG's operations department to become Authorized Nominations.

The predictive model uses the Pending Nominations to generate the flow curves for each delivery point for the next gas day using the pre defined demand pattern for that delivery. These curves are used to run a series of simulations. The results of these simulations determine the hydraulic feasibility of the nominations. The Operational Management System user may modify some nomination values in order to make the system to stay within the allowable operating parameters. The nomination values submitted by the Operational Management System user after the hydraulic validation process is completed are known as Authorized Nominations.

Each nomination value is composed of two values: Firm and non-Firm. The total nomination is the sum of both values. The Operational Management System user will typically cut the non-firm values which are part of the non-firm contracts.

Validated Nominations

After the Pending Nominations are verified hydraulically they become Authorized Nominations and are sent back to the Gas Management System. At the Gas Management System the Authorized Nominations go through a last validation process to become Validated Nominations.

The Validated Nominations will be used by the Gas Management System to generate the final shipper schedule and the Operational Management System also uses these Validated Nominations to run predictive models to verify the hydraulic state of the pipeline as the real-time operation changes.

Current Day Adjustment

Current day adjustment is performed for intra-day nominations to compensate the volume differences arising from the pipeline operation. The Operational Management System can automatically adjust the flow curve for the remaining of day to compensate for any deviations between the current accumulated volume for the day, the total original nomination for the day and the estimated flow for the remainder of the day. In other words, if the volume originally estimated for the remainder of the day plus the real volume already delivered is different than the total current day nomination, the system can compensate for that imbalance adding or subtracting an offset value to the rest of the day flow curve.

Flow Curves Generation

Pending and Validated Nominations are received from the Gas Management System via an automated interface. Each nomination is converted to a flow curve for each delivery. This curve determines how the flow will behave in the future for a delivery specific delivery. Figure 4 shows an example of a flow curve.

The shape of the curve depends on the flow pattern selected for each delivery point. The nomination-processing module in the Operational Management System allows the following flow patterns:

- **Constant Flow** – The nomination volume is distributed as a constant flow rate during the whole gas day as illustrated in Figure 5.
- **Single Step** – The flow is distributed as a single step curve, where the user specifies the start time and the step duration. The nomination module automatically calculates the size of the step as illustrated in Figure 6.
- **Double Step** – Similar to single step, this processing mode generates a curve with two steps where the user defines the start time and duration of each step as seen in Figure 7.
- **Library** – The nominations are distributed as a user-defined curve. The Operational Management System supports several curves in the library to fulfill the different demand pattern requirements.

Scheduling Process

This module in the Gas Management System includes the final verification of the Authorized Nominations which are hydraulically validated and also generates the schedule to be published to the clients and pipeline operational department.

During the verification, the Gas Management System user verifies all the information gathered from the clients to make sure that everything matches in order to get the scheduled volume. Once the verification is done, the Gas Management System user (scheduler) has the option to validate this information by sending it to the Operational Management System to get the nominations hydraulically validated.

If the option is to send the nominations to the Operational Management System to be hydraulically validated, the Gas Management System sends the daily nominations (tomorrow's gas day) or the intra-day nominations (today's gas day) by delivery point to the Operational Management System. Predictive model is run to analyze the results and sends the resulting nominations back to the Gas Management System. The Gas Management System user further validates these nominations and proceeds to generate the gas schedule. The scheduling process uses various rules in order to schedule volumes to each service for a given contract. The Scheduling Process works on a daily and intra-day basis.

Conclusions

The seamless integration of the Operational Management System and the Gas Management System enabled TBG to utilize the maximum capacity of the pipeline and thus maximize the revenue of the company. The integration also enabled the gas pipeline scheduler and control room operator the ability to plan for the future, for example allowing for improved operational strategic planning to accommodate both scheduled maintenance shutdowns and changes to nominations. Furthermore, the use of a predictive model to validate the operational constraints on the pipeline provides a great measure of operational safety, including the possibility to foresee new conditions during the gas day due to an emergency that may drive operation to a potencial risk. Then, Control Room is able to modify its previous plan to Compression Stations, for instance, adjusting TBG's gas pipeline to maintain deliveries even facing a new scenario.

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Srihari Kumar Vanam is a project lead at Emerson. He has 11+ years of experience in implementation and maintenance of pipeline applications which typically deal with operational and commercial aspects of the oil and gas pipelines. He was also involved in developing project specific modules in the above pipeline applications to meet the client's requirements. He graduated in chemical engineering from NIT Warangal, INDIA and also a certified project management professional (PMP).

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Figures

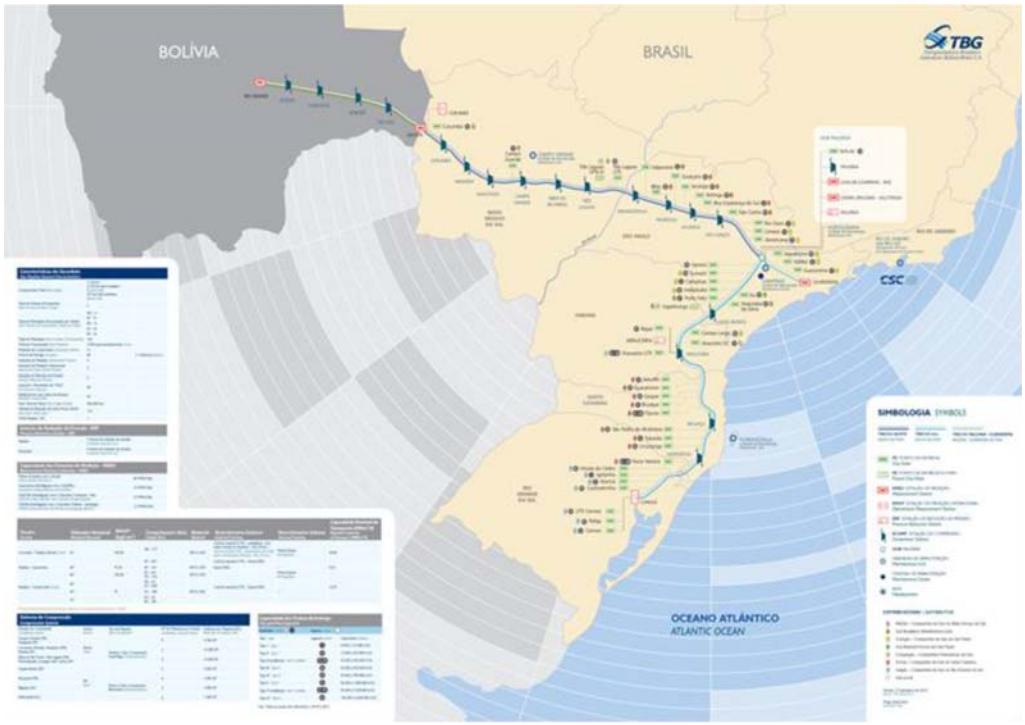

Figure 1. TBG Pipeline Network

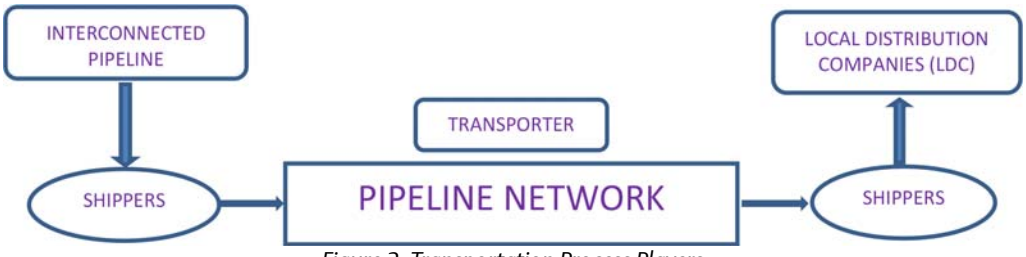

Figure 2. Transportation Process Players

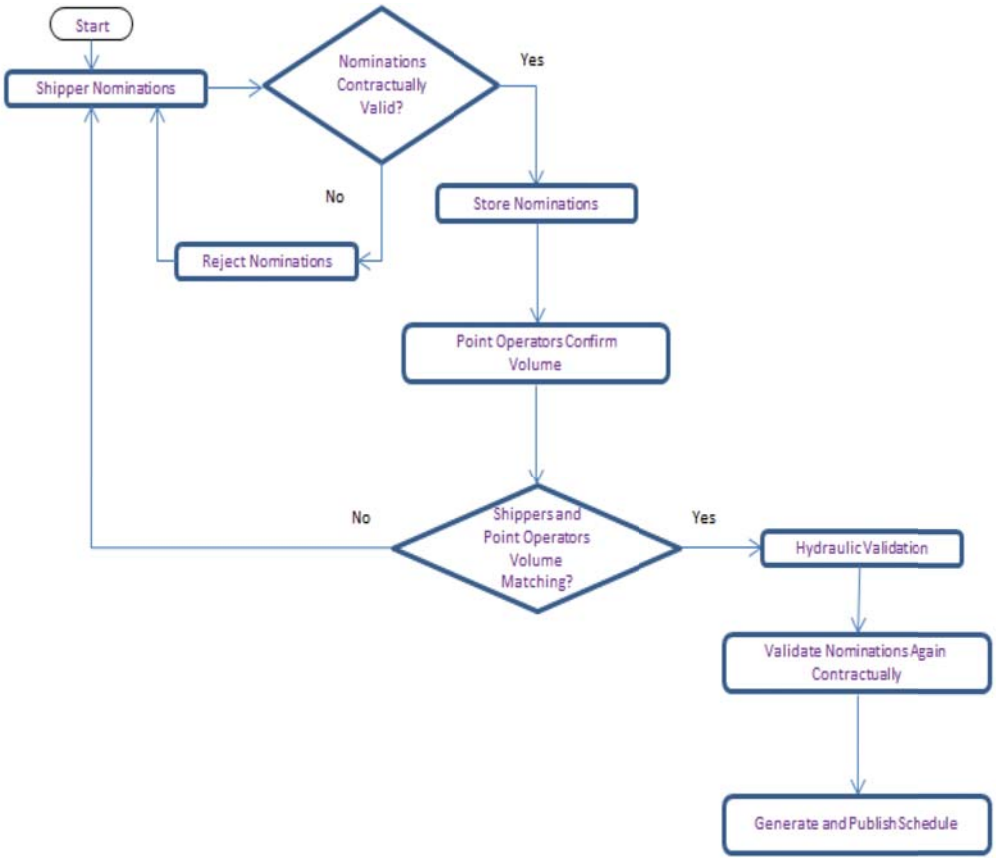

Figure 3. Nomination and Scheduling

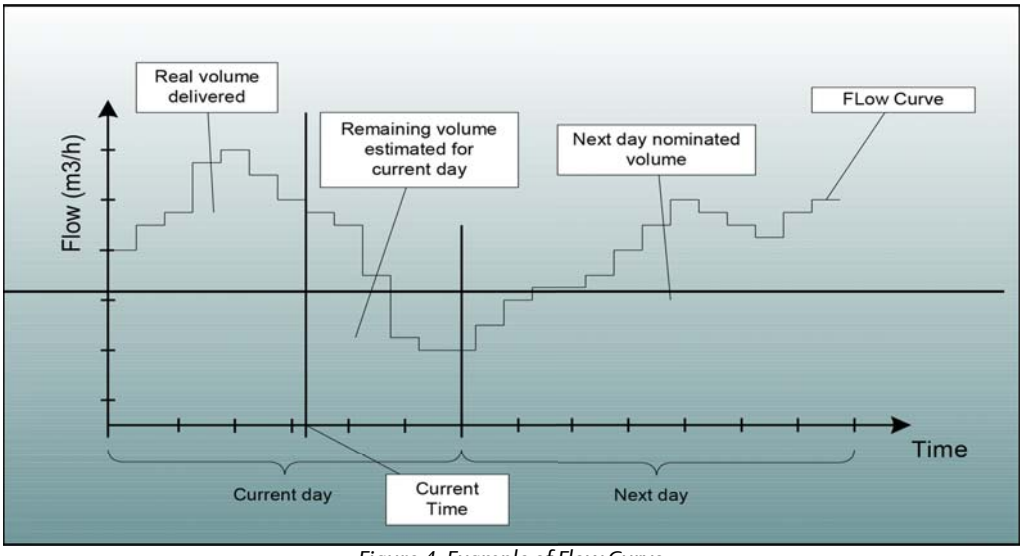

Figure 4. Example of Flow Curve

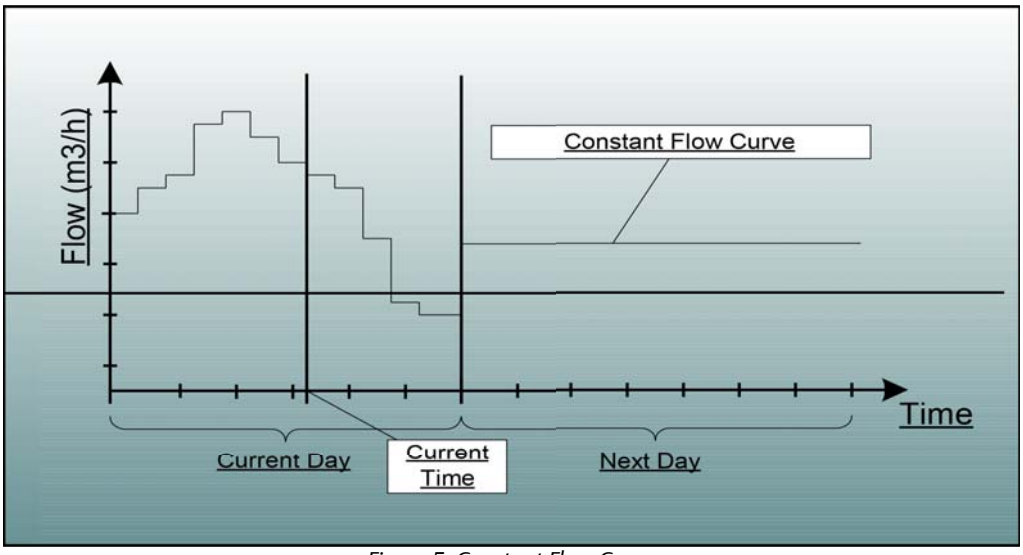

Figure 5. Constant Flow Curve

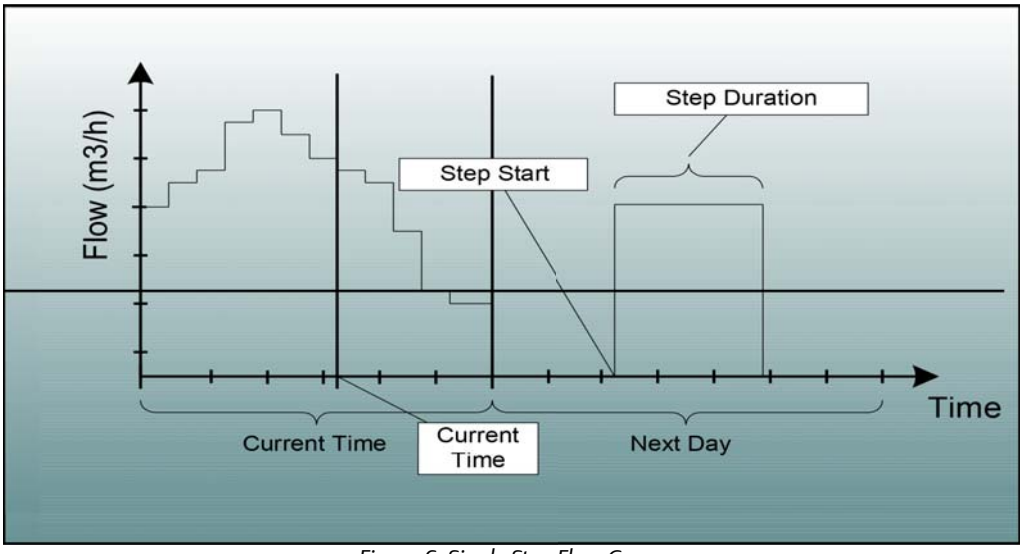

Figure 6. Single Step Flow Curve

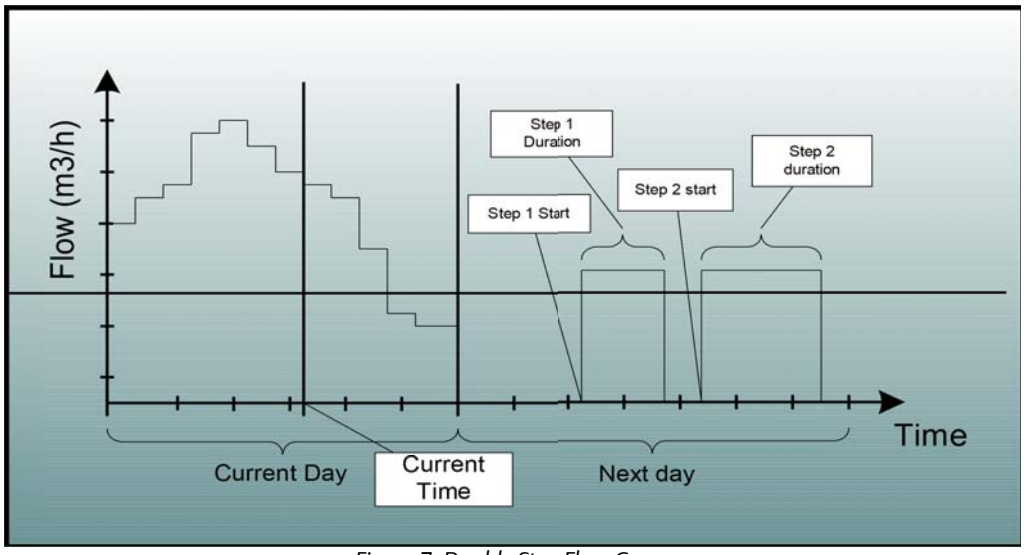

Figure 7. Double Step Flow Curve

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