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Short-Term Generation and Transaction Scheduling at Manitoba Hydro using the *Vista* Decision Support System

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ABSTRACT

A decision support system is being developed for short-term (less than one week) optimization of hourly scheduling of generation and reservoir operations for the entire Manitoba Hydro hydroelectric generation system. Manitoba Hydro is a provincially owned utility, whose mandate is to supply the electricity needs of the province and to maximize export revenues from surplus energy through long- and short-term transaction opportunities with neighboring provinces and USA utilities. Transmission system limits and HVDC line losses are important considerations in the scheduling of generation and the Vista Decision Support System configuration includes detailed representation of both the hydroelectric generation facilities as well as the transmission system. Bi-directional line limits and HVdc line losses, which are a function of line load and valve group configuration, are explicitly represented within the optimization of generation. Vista is now an integral part of operations and is used for a number of tasks. These include; hour ahead and day ahead capacity planning to provide information to the energy traders; scheduling of generation resources for the whole week for committed load, reporting on all generation plans inside the company and to external agencies. In the future, Vista will also be used for post-audits, outage planning and after the fact outage costing. The paper describes the solutions that were developed during the course of the project and some of the challenges encountered during its implementation.

1. Manitoba Hydro- System Overview

Manitoba Hydro has about 5000 MW of installed generation capacity, 95% of which is hydropower. Most of the hydroelectricity is generated at 3 hydro plants on the Nelson River in northern Manitoba, with an installed capacity of 3600 MW. Due to the geography of the province, Manitoba Hydro has an extensive transmission system including interconnections with Ontario, Saskatchewan and the United States. The northern hydrogenation facilities are connected the load centre in the

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southern part of the province and export markets via two 900 km long high voltage direct current (HVdc) lines.

The Transmission Services Department of Manitoba Hydro schedules the generation resources for the Manitoba Integrated Generating System. Generation resources consist of thirteen hydroelectric generating facilities, a conventional thermal generating station, two gas-fired steam generators and a natural gas-fueled combustion turbine totaling about 5200MW. The hydro generating stations, which comprise 95 % of the systems, are spread over four river systems -- Winnipeg River, Saskatchewan River, Nelson River and the Laurie. The drainage of these rivers is immense and extends to the foothills of the Rockies in the west to Northern Ontario in the east, as shown in Figure 1. Seasonal ice accumulation in lakes and rivers is common and has a significant effect on the hydro generating facilities, in terms of tailwater levels and conveyance.

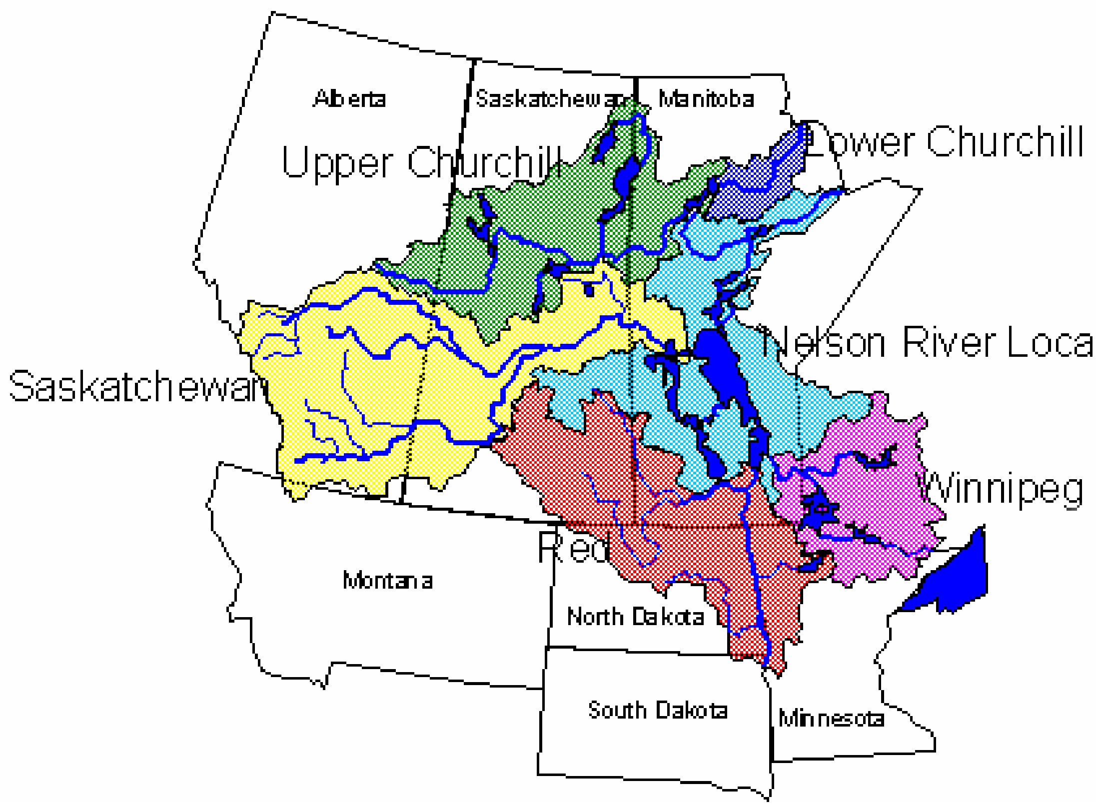

Figure 1 – River Basins

The generating system utilizes both AC and HVdc transmission to carry the energy to the load areas. About 3600 MW of northern generating capacity is transmitted via two HVdc systems to AC transmission network in the south of the Province of Manitoba. The generation system supplies loads to three distinct areas, and bi-directional transfer limits are established for inter-area transfers. In addition, the provincial transmission system is interconnected with Ontario to the east, Saskatchewan to the west and USA to the south. The configuration is fairly complex with about 75% of the generation being dependent on the HVdc system. The DC transmission losses are significant and an important consideration in the scheduling process.

The primary function of the generating system is to serve the Manitoba load while its secondary function is to generate revenues on the export markets. The amount of surplus energy varies significantly based upon Manitoba Hydro load and water supply conditions. There is seasonal reservoir storage to supplement current river flows. Under normal water supply conditions, the generating system has significant surplus energy and capacity for exports. The export and import of energy is structured into a portfolio of bi-lateral transactions ranging from long-term contracts, short duration opportunity sales (weekly to seasonal), next day (next day up to a week) and real-time sales (next hour and balance of day).

In the past, Manitoba Hydro has placed emphasis on the long-term scheduling of generation and water releases resulting in the development of in-house models and software tools to support this function (Ref 1). Short-term scheduling encompasses the current day and the next seven days. It requires the allocation of generation resources and transaction opportunities to meet the Manitoba load in an efficient manner. The short-term scheduling functions have not received as much attention as long-term scheduling at Manitoba Hydro, and the need was identified to acquire a comprehensive tool that would consider all the important components, i.e., hydraulic and thermal generation resources, transmission system and market opportunities. In 2001, Manitoba Hydro contracted Synexus Global Inc. to set-up and install the *Vista* Decision Support system.

2. *Vista* Decision Support System

Vista DSS is a comprehensive tool for generation scheduling and has nine main modules, of which seven have been implemented for Manitoba Hydro. The entire DSS is contained within a powerful, intuitive user-interface, operating in a client-server configuration under the Windows operating systems. The overall DSS Interface structure provides the means to access the different modules that comprise the DSS, which include the following modules:

- Data *Vista* for defining system configuration, facility data, operational constraints related to water levels and flows, value of generation, outage or maintenance schedules
- RT Data *Vista* for processing real-time data including SCADA data, weather forecast, backroute inflows
- Inflow *Vista*, for generating short-term and medium-term inflow forecasts
- Load *Vista*, for defining system load forecast
- Xchange *Vista* for defining transaction opportunities including thermal generation resources
- ST *Vista* for short-term hourly scheduling over a two week horizon.
- *Vista* Service for automatically loading and processing input data from external sources

The role and purpose of the various *Vista* modules and their use at Manitoba Hydro is discussed in more detail below.

3. Scheduling Concepts

Vista is designed to aid dispatchers in the decision-making process of unit generation and water release scheduling. The basic optimization problem is to resolve the economic trade-off benefits of current and future hydropower generation, within the operational constraints of the water resource system and the inherent uncertainty of future events such as inflows and price variability. It is affected by both short-term (e.g. current week) operation and longer-term (e.g. annual storage reservoir operation) water use decisions. The scope of the overall scheduling problem is reduced by the decomposition into two smaller problems, i.e. the long and short-term time horizon. *Vista* can provide the long-term generation scheduler (LT *Vista*), which deals with operational issues of reservoir management using a larger time resolution, typically a week. It can also be used to determine the value of water in storage and/or target water levels or discharge. However, Manitoba Hydro uses its own model for long- and medium-term scheduling (Ref 1).

The short-term generation scheduler (ST *Vista*) concerns the hourly unit generation schedule that will maximize the net benefit of the operating decisions. The optimization model dispatches generation according to one of two similar, but different criteria. Either the value of generation is maximized in accordance with prescribed market values, or the cost of meeting the system load demand with the available resources is minimized, including generating facilities and import/export opportunities. ST has several options for defining end-of-period water levels. For seasonal reservoirs, the value of water in storage curves, determined by the long-term scheduler, can be used to determine the trade-off between benefits during current week vs. expected future benefits. Alternatively, firm target water levels can be used to guide the optimization.

4. Short-term Scheduling Environment

ST *Vista* has a number of features that make it a very powerful tool for dispatchers. These relate both to functionality and user interfaces. ST *Vista* is designed for real-time operation, i.e., it will automatically advance in time and re-fresh data. It supports multiple-users that can share information through a common 'offical' schedule. The ST *Vista* user-interface has spreadsheet-like tables that summarize all inputs and results on an hourly basis over the planning window. There is also a user-configurable Report Generator to build custom views. The ST user-interface allows to perform the following tasks:

- Review, edit or refresh all the basic data that affects the hourly generation
- Schedule the Generation Dispatch, including the specification of "must run" cases, such as Automatic Generation Control (AGC) plants, optimization of the hourly generation, and simulation of water levels and flows for what-if analysis. Several alternative schedules can be developed simultaneously, and compared explicitly.
- Display of schedule results, which can be viewed in a tabular or graphical format.

* Publish to and/or receive schedules from the shared offical schedule.

In ST *Vista*, two primary analytical functions are available to the scheduler: an optimization engine to derive an optimum hourly schedule for the next week or two, and a detailed hydraulic simulator, to perform a simulation analysis of the system . Simulation is useful to manually fine-tune the optimum schedule to adjust for small changes in operations. The scheduling horizon is also flexible and user can select the number of hours to be considered in the analysis.

5. Generation System Representation

In *Vista*, hydroelectric generation facilities and associated river systems are modeled in great detail, along with the constraints imposed on the operations. Complicated hydraulic connectivity can be represented, including storage reservoirs with multiple outlets and plants that receive water from different sources. As an example, the connectivity of the Upper Nelson River is shown in Figure 2.

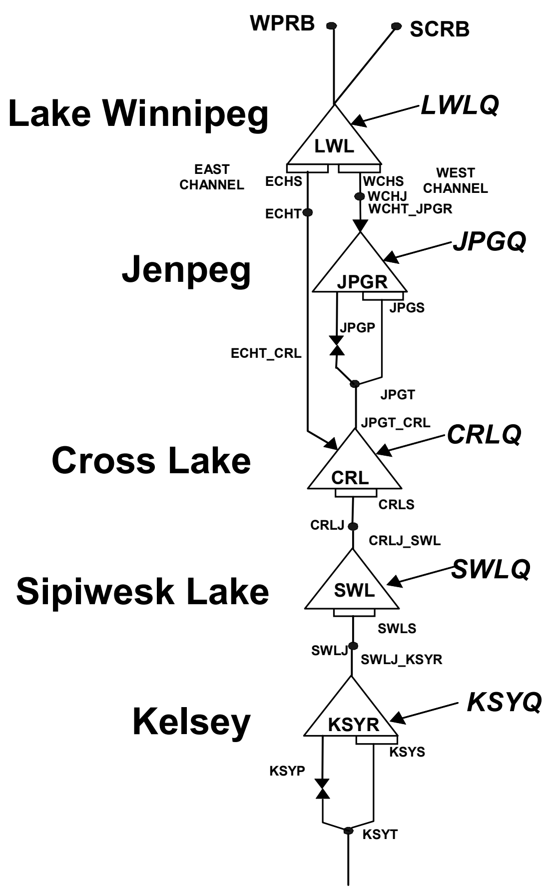

Figure 2 – Upper Nelson River Configuration.

Hydroplants and spillways (flow release structures) can be represented in detail. Flow through spillway structures is modelled as a function of head and opening. Tailwater elevations can be modelled as a function of total discharge and/or downstream water levels, if there is a backwater effect. Unit characteristics are represented as follows:

- power as a function of head and discharge,
- max/min limits of what as a function of head,
- rough zones of what,
- Eligibility for various spinning reserve duties.

Hydroplant representation is illustrated in Figure 3.

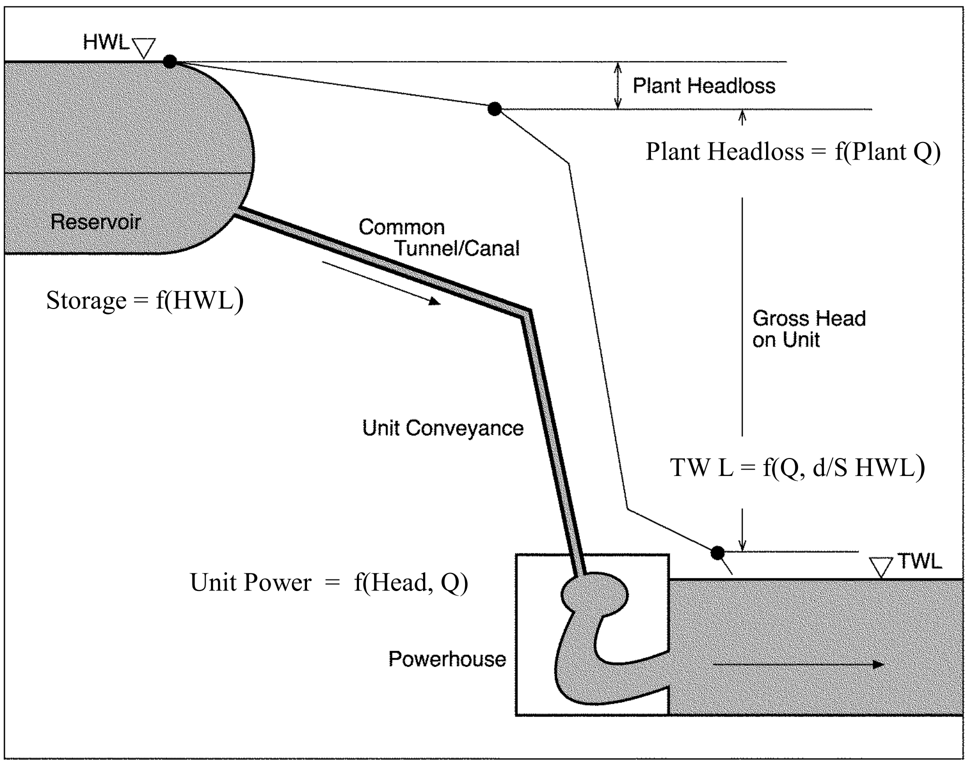

Figure 3 – Hydroplant Representation

Similarly, various spill structures can be assigned to spill flow arcs, including tainter gates, orifices, stoplog structures and valves. Uncontrolled diversion tunnels and channels are also supported. The Muskingum channel routing method is employed to route river flow between projects.

6. Other Generation Resources

While 95% of Manitoba Hydro's generating facilities are hydroelectric, the system also includes several thermal plants and may include wind generation is planned into the future. These facilities have to be considered in scheduling generation to meet load. In *Vista*, thermal plants can be represented as a purchase opportunity, with a minimum and maximum capacity and price specifed, or as an external energy source. If thermal generators are represented as a purchase opportunity, the optimization will determine how they are utilized based on load, price and other resources. Conversly, if the generation is specified as an external energy source, then scheduling the resources is no longer part of the optimization, and a prescribed generation is used. The external energy definition can also be used to represent wind generation and non-utility generators (hydro indepentents).

7. Transmission System Representation

Vista has multi-area capability and the transmission system is represented by regional load buses and tie-lines. Generation facilities, load and transactions are then assigned to regional load buses. The Manitoba Hydro transmission system is complicated with a number of load buses, transmission lines and inter connections to outside of the province. The HVdc lines connecting the northern plants to the load centre and export markets in the south are an important consideration in scheduling generation and transactions. In addition, there are a number of AC transmission lines with bi-directional line limits that have to be respected. The load bus and transmissioin system configuration for *Vista* is shown in Figure 4 below.

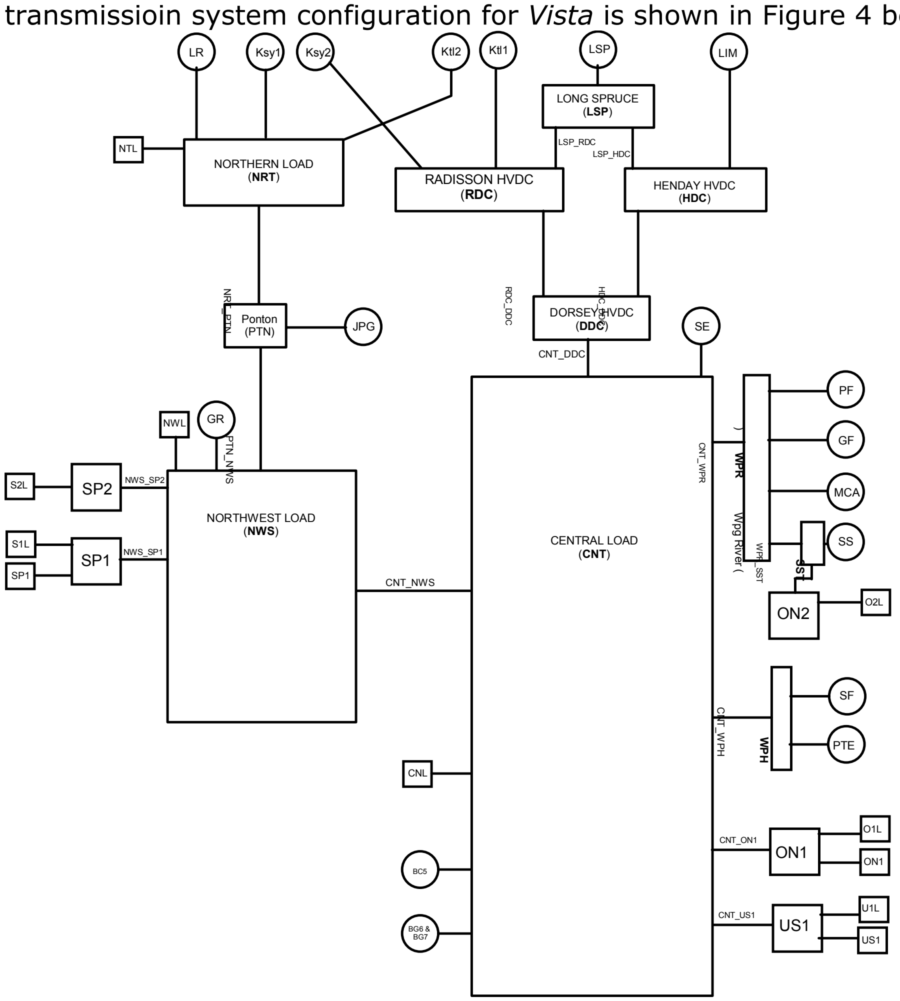

Figure 4 – Load Bus Transmission System Configuration

The HVdc transmission system consists of two lines referred to as Bipole 1 and Bipole 2. From Gillam in northern Manitoba, they follow a 900 km route through the Interlake region to Rosser, 26 Km from Winnipeg. The HVdc system includes three converter stations; Radison and Henday located in the north, and Dorsey near Rosser in the south. The conversion process, whether it is from AC to DC or DC to AC takes place through controlled switching of current by converter valves. The converter valves are interconnected with AC transformers, in a configuration know as 'Valve group'. The valve group configuration at both ends of the DC line has to be the same as this affects both losses and the maximum carrying capacity of the line.

Bipole 1 has 3 valve groups on each pole, and Bi-pole 2 has 2 groups with a Star and Delta transformer configuration, effectively yielding a 4 valve group configuration. Valve groups may be unavailable due to maintenance and this affects the maximum carrying capacity and line losses. The DC loses are a function of line resistance, voltage (function of valve group setting) and current flow on the line. The loss relationship used in *Vista* is of the form,

$$MWloss = A(VG\ config) * LineMW^2 + B(VG\ config) * LineMW + C(VG\ config)$$

The Manitoba HVdc configuration is shown in Figure 5, below

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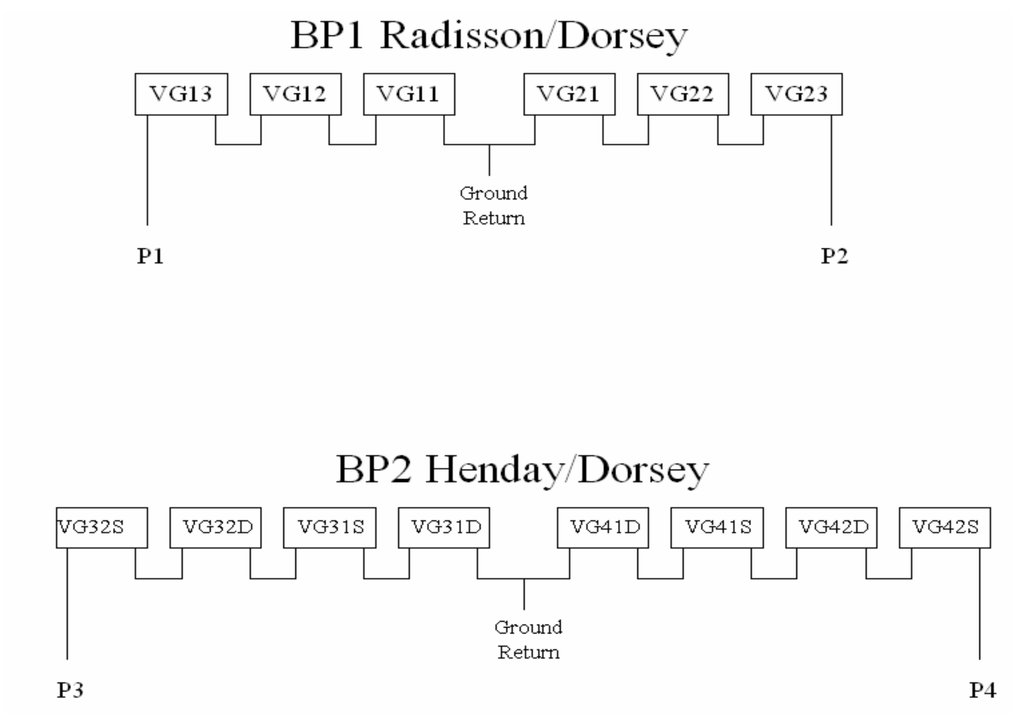

Figure 5 – HVdc Valve Group Configuration

8. Load and Transactions

Accurate load forecasts are an integral part of scheduling generation resources in Manitoba.

In *Vista*, multiple customers can be defined, with each customer mapped to a load bus. Long and short-term load forecasts can be generated or imported for each customer. In the Manitoba Hydro configuration, several customer loads are defined, including

- Central, Northwest and North bus , that represent the Manitoba Load
- USA, Ontario, and Saskatchewan that represent external transactions.

The load forecasts are updated twice per hour and feed into *Vista* automatically, as discussed in more detail in the Data Integration section below.

Multiple transaction opportunities can be defined in *Vista*, these are mapped to load buses and are defined in terms of;

- Type of transaction, i.e., purchase or sale,
- Period over which the transaction is available,
- minimum and maximum capacity, and
- price.

In the Manitoba Hydro application, transaction opportunities are defined on the USA, Ontario & Sask load buses. These represent the spot market opportunites that exist at any given time. Longer-term contracts are modelled as load on these buses, positive or negative load depending on the type of transaction. In real-time, as contracts are firmed-up, they are tagged and become part of the load.

9. Constraints on Operations

Vista has an array of both hydraulic and transmission constraints that can be used to capture license requirements and operational preferences (Ref 2).

In the Manitoba Hydro application, a range of both discharge and water level constraints are imposed on the short-term operations; reflecting both license limitations as well as long-term water management decisions. Given the sheer size of the drainage area for the four main river systems and long travel times, water management decisions for the two largest storage reservoirs, i.e., Lake Winnipeg, Cedar Lake as well as the Kettle forebay are made as part of the long-term decision process. They are captured in the short-term model as flow constraints or input as a table of water levels and value of water in storage. In addition, there are limits on the rate of change of discharge and/or water levels at a number of projects. Constraints that relate discharge in one period to another (referred to as dynamic discharge constraints) are employed to induce smooth operations of spillways. A number of tie lines have bi-directional line limits.

10.Data Integration

Operational use of *Vista* requires both real-time data and /or forecasts of various inputs. RT *Vista* is a module for downloading and processing data from various external sources. Data sources can be defined and a service set-up to run, download, process and save information to the *Vista* database on a continuous basis. In the Manitoba Hydro application, a database table (referred to as *Vista* import table) was used as a placeholder. Script files were developed to move and process data from the various corporate sources, as well as to populate the *Vista* Import table.

On the *Vista* site, a number of data sources were defined, including the following data types:

- EMS SCADA data
- Inflow Forecasts
- Load Forecasts
- Interface load forecast (firm contracts)
- Market Prices
- External Energy Source schedules
- Outage schedule
- Rating Curve Adjustment factors (to account for the effects of ice on spillway rating curves and tailwater curves)

In addition, *Vista* Service automatically calculates unit discharge from power and water level readings, as well as local or incremental side inflows between projects.

11.*Vista* and the Business Process

Generation scheduling is conducted by the Transmission System Operations Division of the Transmission and Distribution Business Unit, whereas marketers belong to the Power Sales & Operations Division of Power Supply Business Unit. This is further complicated by a Standard of Conduct that states that transmission information cannot be shared with marketers. One of the principal benefits of *Vista* is to provide a common tool that helps schedulers and marketers take better advantage of the available generation capacity and market opportunities, while restricting access to the transmission data. The business process is summarized below, and illustrated in Figure 6.

Once a week, long-term water management decisions are reviewed and adjustments are made to constraints and/or value of water in storage curves. A one-week optimization analysis is performed daily, reviewed and saved to the official schedule. Unit commitment schedules are exported to external agencies.

The weekly schedule provides hourly targets for load and scheduled exports. The optimizer is run twice per hour for the next 24-hour period. It provides a generation schedule required for the next hour to meet committed load, as well as a recommended transaction schedule for the remaining 23 hours. Marketers have access to the official generation and recommended transaction schedules, and are responsible for updating the market prices.

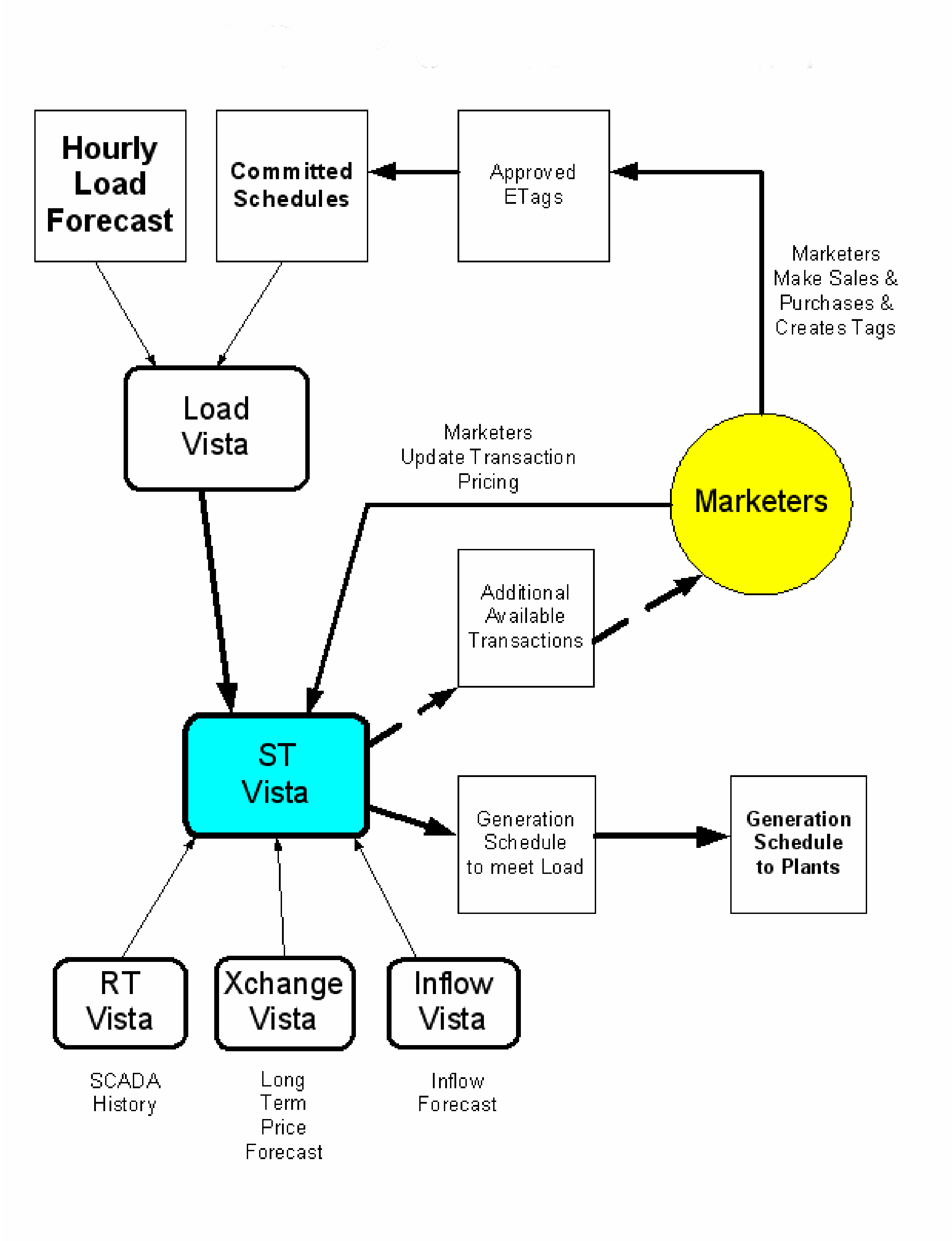

Figure 6 – *Vista* Buisness Process

12.Benefits of *Vista*

Once fully implemented, *Vista* will provide numerous benefits to Manitoba Hydro. Hourly generation and transaction schedules will be optimized while considering the capabilities and limitations of the hydroelectric generation facilities and the transmission network. This was not possible in the past. *Vista* also provides a recommended (optimized) schedule of transactions and accurate hourly capacity forecasts. The detailed modeling also provides the opportunity to improve water management and better cycling of units, yielding significant economic benefits. In particular, operations in the cascade of plants on the Winnipeg River have been difficult to optimize in the past. With the model and improvements in control systems on site, economic and coordinated operation can be used that will have significant increases in the generation as well as the ability to shift the generation into the peak hours.

The forecasted benefits from *Vista* will require changes to field equipment, however, the model has made it possible to analyze the improvements and assist in business case analysis to justify the site improvements.

In addition, the ability to optimize schedules with maintenance outages and/or respond to a forced outage is important. *Vista* also provides a centralized location for all hydraulic data and automatic computation of power discharge, local inflow as well as updating of inflow forecast. The comprehensive report generator provides access to real-time data and schedules, and allows users to customize reports. *Vista* has post-audit capability that allows users to initialize the scheduler in a historic week, optimize and compare the results against actual operations.

The Manitoba Hydro project has significantly advanced the *Vista* model with more complex transmission requirements. One new requirement was also based on the Standards of Conduct that prohibit marketers from accessing any transmission information. This required a new and very sophisticated security module that now allows the model administrator to hide menu items associated with the transmission system. The new security module also allows the administrator to set read-only and read/write access to all menus for all users.

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Authors

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