**CANADIAN CANDU* PLANT HISTORICAL DATA SYSTEMS**
**A REVIEW AND LOOK TO THE FUTURE**

M. DEVERNO[1], J. DE GROSBOIS[2], H. POTHIER[1], C. XIAN[1], M. BOSNICH[2], J. HINTON[3], G. GILKS[2]

[1]Atomic Energy of Canada Ltd.
Control Centre Technology Branch
c/o Centre for Nuclear Energy Research
University of New Brunswick
Fredericton, NB E3B 6C2

[2]Atomic Energy of Canada Ltd.
Control Centre Technology Branch
Chalk River Laboratories
Chalk River, Ontario
K0J 1J0

[3]Atomic Energy of Canada Ltd.
Sheridan Park Research Community
2251 Speakman Drive
Mississauga, Ontario
L5K 1B2

*ABSTRACT*

*As part of several CANDU Owner's Group (COG) projects, AECL has conducted a review of current approaches and investigated solutions to plant process data collection, management, and use. Emphasis was placed on understanding the existing functionality and uses of plant data systems, their future needs and benefits. The result is a vision of a plant-wide Historical Data System (HDS) providing seamless access to both near real-time and historical data, user tool-kits for data visualization and analysis, and data management of the large volume of data acquired during the life of a plant. HDS technology is critical to the implementation of technical surveillance and analysis, predictive and preventative maintenance programs, and other efforts necessary to enhance plant safety, availability, production and productivity. HDS technology will lead to higher capability and capacity factors while minimizing operations, maintenance, and administration (OM&A) costs.*

## INTRODUCTION

As the operating environment of the Canadian CANDU stations mature, there is a much greater awareness of the increasingly important role of various plant information systems and how they impact the overall effectiveness and efficiency of station operations. Operational experience with existing plant data and information systems, and how they impact operational decisions, work procedures, maintenance, technical support programs, and overall OM&A costs, is enhancing this understanding.

As a result, plant-wide historical database systems are emerging as a critical information technology required to support all aspects of plant operations and maintenance with a primary focus on activities outside of the control room. This technology is playing a key role in the implementation of plant technical surveillance, predictive and preventative maintenance, and plant safety and licensing programs. The use of a plant-wide HDS has been identified as a basic requirement to support programs aimed at increasing plant safety, availability, and performance while lowering overall OM&A costs.

Substantial benefits are foreseen in the use of HDS technology for improved technical, maintenance, and operational activities in CANDU stations. The integrated and effective use of plant data is vital to reducing cost, avoiding unnecessary or unplanned outages or equipment failures, and optimizing all aspects of operations and maintenance. Plant-wide HDS technology supports these improvements through:

- reduced manual effort in data acquisition,
- increased reliability, timeliness, and accessibility of data,
- improved ability to correlate data from several sources,
- enhanced capability for data visualization and analysis,
- improved efficiency in reporting and the distribution of information,

* CANadian Deuterium Uranium

- reduced effort in performing post-incident analysis,
- improved detection and avoidance of problems,
- improved planning and coordination, and
- reduced overall maintenance effort and costs.

These benefits directly support plant operational improvement in key program areas such as:

- plant performance monitoring aimed at increasing plant availability, thermal and electrical efficiency, capability and capacity factors,
- safety and licensing programs in support of regulatory compliance monitoring and safety analysis, and
- predictive and preventative maintenance programs including Condition Based Maintenance (CBM) and Reliability Centred Maintenance (RCM) programs.

As part of several COG programs, AECL has investigated the current CANDU HDS implementations and issues [1], developed generic HDS requirements [2], and established requirements and recommendations for PC-based tools in support of technical surveillance and analysis [3]. The vision is to provide a flexible and expandable HDS platform that meets a wide range of data integration, data management, data archival and retrieval, data visualization and analysis, and reporting and storage requirements in support of potential HDS uses. HDS data storage, archival, and retrieval capability must include long-term (life of plant) information, easily accessible by plant staff, and cover a multitude of plant systems. The functionality and performance of the HDS must support a large number of users across all functional disciplines while at the same time being flexible and expandable to support yet undefined programs and activities. This is achieved by providing a layered client-server architecture with a core set of client, server, and integration sub-components that allow the system to be tailored to specific station needs. The HDS concept provides the basic building blocks and integration tools to enable data sharing and systems integration among a wide range of existing and future plant data systems. This concept, including user utilities and tool-kits, is built around the use of commercial tools and off-the-shelf products that can be easily integrated into a flexible HDS environment for the future.

## REVIEW OF EXISTING CANDU PLANT DATA SYSTEMS

Canadian CANDU stations have focused their efforts over the last several years on the development of Digital Control Computer (DCC) gateways and data servers, to get data out of the control room and into the hands of engineering services and technical unit staff. A priority has been placed on providing reliable and easily accessible data on-line to a wide range of end-users to improve technical surveillance of the plant outside of the control room, and relieve control room operators from the task of manually collecting process readings. This has led to the development of data systems that acquire and store data from the DCC's and other data sources, and provide access to the data on any desktop computer on the station Local Area Network (LAN). Generically, these systems fit the definition of a plant-wide HDS although in some cases their historical data capability is limited. In general, the current station HDS implementations consist of:

- interfaces or gateways to acquire plant process data from the DCC (and possibly many other sources),
- a means of managing and storing the data, and of providing remote network access to the data, and
- tools to extract, visualize, and analyze the data on the user's personal computer (PC).

The observations made during the plant data systems review [1] indicate that each CANDU station has taken an unique approach in developing its systems and are at various stages of development and implementation. This is not surprising, since each station developed its data systems at different times and according to different requirements and constraints. Key factors affecting each development effort include:

- a balance between short-term, medium-term, or long-term requirements,
- a trade-off between budget, development schedule, and functionality,
- available in-house resources, and
- technology options and constraints at the time of development.

## BRUCE NUCLEAR GENERATING STATION HDS ARCHITECTURE

Bruce A (Units 1, 2, 3 and 4) has developed the Plant Status Monitoring System (PSMS) which is a client-server system that serves real-time data to desktop applications in the DOS environment, for use outside of the control room [1, 4]. The intent of this system was to emulate real-time control room displays and provide easy access to historical process data on the desktop (over the plant LAN) for the purpose of technical surveillance and analysis. Bruce B has not implemented an HDS at this point in time, however, requirements have been written [5, 6, 7] and the station is in the process of procuring commercial off-the-shelf HDS hardware and software.

The PSMS system (see Figure 1) uses a 486/66 PC gateway computer with combined gateway and data server software running in the DOS environment. There is one gateway computer connected to each unit's DCCX. Data is received from the DCC by direct memory access (DMA) through a parallel connection provided by a standard interface card (IOBIC). The client applications run in a DOS environment and communicate with the data server through the Novell IPX broadcast protocol over a fiber-optic LAN. The data server and desktop applications were developed using LabWindows, from National Instruments. The desktop application provides real-time trending, x-y plot capability, control room display emulation, alarm annunciation with user-configurable messages, message logging, and graphic display printing. Data acquisition rates are configurable on-line ranging from two seconds to one day. Historical data is available on-line for various time spans, depending on the data rate. For example, two-second data is available for ten days on-line, and one-day data will be available for up to 20 years.

## DARLINGTON NUCLEAR GENERATING STATION HDS ARCHITECTURE

Darlington's HDS implementation, known as the Process Data Distribution System (PDDS), provides desktop access to archived DCC data [1, 8]. The system consists of an IBM RISC/6000 file server, which provides 3 Gbytes of on-line storage (see Figure 2). Currently, the server can store three to four weeks of DCCX data and ten days of DCCY data, which is time-stamped and synchronized with a satellite time signal. There is no gateway connection to the DCC's. Data is dumped from the DCC's to magnetic tape at midnight each day, and then transferred from the magnetic tape to flat files on the file server each weekday at 7 am. Data is also archived to optical disk once the magnetic tapes are full, in a separate operation.

Users extract data from the file server remotely over the LAN using an in-house-developed Windows PC client application. Users can define a required data set in terms of type of data, start and end times, update frequency, and system point tag names. When the "data get" is invoked, the application connects to the PDDS file server, reads the data from the flat files, writes the data to the user's storage area on another server, and releases the connection to the PDDS file server. Once the data is extracted to local files, it can be loaded into standard desktop applications such as Microsoft Excel. Users have access to four weeks of historical data, starting with the previous day, once the morning tape dump is complete. Users can also request that older historical data stored off-line on optical disks be manually loaded into the storage area, and can then access the data from the same application. There is no access to real-time or near real-time data outside of the control room.

## PICKERING NUCLEAR GENERATING STATION HDS ARCHITECTURES

The Pickering HDS functionality is provided by the Data Extraction System (DES) implemented at Pickering 'A' (Units 1, 2, 3, and 4) and 'B' (Units 5, 6, 7, and 8) stations [1, 9]. The original function of the DES was to provide near real-time monitoring displays for the Authorized Nuclear Operators in the control room and within the Pickering Emergency Response Centre (PERC). Limited access to historical DCC data is also provided by the system. The DES systems (see Figure 3 and Figure 4) provide gateway services to extract historical process data from the DCC's and both Pickering A and B are in the process of enhancing DES functionality to support HDS-like on-line capture and storage of DCC data on a file server, and to make data easily accessible to technical surveillance groups over the plant LAN.

In the DES, a Supervisory, Control, and Data Acquisition (SCADA) PC receives data from the DCC's through a gateway PC. View Station PC's in turn continually receive real-time process data from the SCADA PC over a dedicated control room LAN to drive advanced graphic displays in the control room. Both the SCADA and View Station PC's run FIX DMACS software, an industrial PC-based SCADA package.

There are several implementation differences between the two sites. Both Pickering A and B have a separate DES system and their own technical groups to develop and support each system. At Pickering A, the gateway PC (PCMUX) also broadcasts data onto the office LAN, to allow the PERC and Engineering Services staff outside of the control room to view the applications screens on a limited number of FIX DMACS View Station PC (View-PC) computers. Pickering A also has a FIX DMACS historical archive server, which provides historical data to one historical FIX DMACS View-PC. The FIX DMACS software on the historical archive server provides data archiving and retrieval to/from an optical juke-box, mapped as a network drive. Access to the historical data is currently limited to a single user. The Pickering B implementation differs in that the Pickering B DES includes a data storage and retrieval system on a Novell file server accessible only on the plant LAN. The gateway PC stores DCC data directly to the file server. The file server currently provides 24 hours of on-line data and Pickering B is looking at increasing both on-line and off-line storage by implementing an optical juke-box configuration. A PC-based desk-top extraction utility to extract data from the file server across the plant LAN has also been developed. Within Pickering B, the SCADA PC and the View PC's are connected to the control room LAN only, and are not available on the plant LAN. Due to the use of different data server technology, Pickering B currently provides on-line access to historical data for 5 users and plans to increase this in the future.

## GENTILLY-2 NUCLEAR GENERATING STATION SYSTÈME DE TRAITEMENT DES DONNÉES D'EXPLOITATION

The Gentilly-2 NGS HDS implementation, known as the Système de Traitement des Données d'Exploitation (STDE), translates literally to English as "an operation (or plant) data processing system". The objective of STDE was to provide system engineers with access to life-of-plant process data from their desktop PCs [1, 10, 11].

The architecture of STDE (see Figure 5) contains three levels of file servers, to protect against loss of data. Gateway computers (LCX and LCY) receive data from the DCC's and transmit it every five seconds to the first level file server (LCSD1). The LCSD1 server sends data files to the main file server (TDESD2) using network file services. The LCSD1 server has the capacity to buffer data for up to three days should the LAN or main file server fail. Catch-up time for a one-day loss of main server connection is two to three hours. The LCSD1 server is also designed to feed data to future real-time applications in the control room. The main file server (TDESD2) stores more than 100 days of historical data including alarm, incident-related, and test data on disk and archives the data in a carousel of magnetic tapes, which currently can store at least 250 Gbytes.

End-user PC desktops are supported by client applications that run remotely on a host UNIX computer (TDEST), which is connected to the main file server through an FDDI ring and fire-wall. The fire-wall provides data security by allowing only authorized users to access the data. The predominant desktop environment is MS-Windows and end-user applications run in the X-Windows environment. Functions of the end-user application tool suite include data extraction and logging, trending, event search capability, and support of alarm page extraction.

Gentilly-2 currently restricts the use of and access to STDE data to technical staff outside of the control room. It is the intent of the system developers to maintain a station policy and procedure requiring all data be verified by appropriate engineering support, technical unit, or nuclear safety staff before the data can be provided to operators or used for licensing purposes.

## POINT LEPREAU GENERATING STATION GATEWAY COMPUTER SYSTEM

Point Lepreau's HDS implementation, referred to as the Gateway Computer System (GCS), provides near real-time and historical plant data collection and distribution capability [1, 12]. The system collects data from a number of sources, including the DCC's, the Safety System Monitoring Computers (SSMC), and $D_2O$ Vapour Recovery System (DVRS). Data extraction can be performed from any desktop computer connected to the site LAN. The system was designed to support the addition of other plant data systems. For example, the system is being expanded to link to the Chemistry Monitoring System.

Within the Gateway computer architecture (see Figure 6), the Gateway computers are connected to DCCX, DCCY, DCCZ, DCCW, and DCCS via the AECL-developed PDLC card. The file servers are connected to the gateway computers via a Banyan Vines LAN. Ethernet active hubs are used, which support both fiber-optic and thin coaxial cable links. The gateway computers and file servers run on the OS/2 platform and are programmed in Modula-2. The on-line historical data archive is provided by a helical scan tape storage and retrieval system, with 50 Gbytes of capacity.

Data is collected at 100 millisecond, two-second, and six-second rates, and stored in flat files on the file servers. End-users extract data from the file servers using an in-house-developed DOS client utility called System Engineer's Data Extractor (SEDE). End-user client data can be visualized using the System Engineer's Monitoring System (SEMS) utility, which will run continuously under OS/2 Presentation Manager. SEMS is used to monitor live or real-time data, which is broadcast every six seconds from the gateway computers. The majority of technical staff use SEDE to extract data to a standard file format (e.g., a .DIF file), which can be viewed with any off-the-shelf spreadsheet package, such as Lotus or Excel. Trend plots can also be created using spreadsheet tools. Users can configure their own desktop environments, spreadsheet macros, and plots. Spreadsheet set-up and configuration tends to be labour-intensive, due to an individual approach by each user. Trend plots can take up to an hour to configure and tune. As an alternative to using spreadsheets and graphics packages, Point Lepreau is also developing the "Plant Analysis Workbench" (PAW), which is a custom developed PC-based tool for data extraction, analysis and visualization. When complete, this system will allow end-users to do statistical analysis and trending of historical data retrieved from the GCS.

## LIMITATIONS WITHIN CURRENT HDS IMPLEMENTATIONS

As outlined in the preceding sections, there is wide diversity in HDS design and implementation in Canadian CANDU stations. Although not applicable to all of the implementations, current limitations include:

- insufficient data acquisition from all data sources including the DCC's,
- limited historical data storage and retrieval capability for both short-term and life-of-plant data,
- HDS server and LAN architectures that limit transmission flow and create data bottlenecks,
- limited accessibility to the HDS across the entire plant,
- the lack of user-friendly end-user tools for data extraction, visualization, and analysis that allow customization and a full range of functionality without requiring computer programming skills,
- insufficient integration of plant HDS information with data from work management and other business systems,
- the lack of data validation and security services, and
- the need for large and costly support teams to manage and continuously improve the systems and to customize user interfaces.

These limitations and issues ultimately decrease the effective use and benefits of a plant-wide HDS and must be addressed within the framework of short-term and long-term strategies for plant information system technologies and the implementation of common HDS environments across the Canadian nuclear industry.

## A MODEL FOR PLANT-WIDE HISTORICAL DATA SYSTEMS

The vision for future plant-wide historical data systems is an architecture that is flexible, expandable, open, reliable and supportable, in order to allow for the integration of next-generation systems and technologies into the HDS. The plant HDS must be able to support many remote users and interface to multiple plant data systems. Data management *facilities* must exist to maintain and coordinate the large amount of data within the HDS and the design must allow for component failure or shutdown due to maintenance with minimum impact on the data collection and overall system performance.

Figure 7 shows a block diagram of the generic HDS architecture within the context of an overall information technology plant data system capable of supporting long-term plant data requirements [1, 2, 3]. The desired HDS architecture is a client-server design capable of supporting many remote end-users, and multiple interfaces or gateways to other plant data and information systems, all supported on-line over the station LAN. The HDS must provide interfaces to a large number of plant safety, control, and special data acquisition systems. Gateways and fire-walls are required for data buffering and for protecting the functionality, performance, and integrity of the control and safety systems from which data is being acquired. Interfaces are also required to support HDS maintenance and system management. Individual users from all plant functional disciplines require tool-kits for HDS data access, data interpretation, display, analysis, reporting, storage and archival activities required for their job functions [3]. This includes interfaces to system responsible engineers (nuclear and balance-of-plant systems), program responsible engineers (physics, chemistry, thermodynamics, safety, licensing, etc.), maintenance and production staff, and management. HDS interfaces to portable hand-held computers and data acquisition systems are also necessary in order to support the acquisition and storage of data from field instruments and devices not connected to the station LAN [13]. Multiple on-line HDS data servers may be required to achieve the desired performance, capacity, and maintainability. Additionally, the HDS must provide horizontal integration of its data with other plant databases and information systems including work management systems, maintenance management systems (including condition based maintenance and reliability centered maintenance components), material management systems, and others. To achieve and maintain this overall level of integration, the HDS must be based on open architectures, industry standards, and commercial products and components that will minimize the effects of hardware and software obsolescence. To meet these goals, HDS functional requirements have been developed [2, 3, 4, 7] for data sources, data types, storage and retrieval, analysis and visualization, validation, security, configuration management, and communications. These requirements are outlined below.

A large number of HDS data sources are envisaged since the HDS is intended to be the repository of all historical plant process data, independent of its point of origin. These systems include DCC's, the Plant Display System (PDS), SSMC's, process controllers, special data acquisition systems, chemistry monitoring systems, manually collected data via hard-copy and hand-held computers, and others. The HDS is not intended to be used as a data repository for engineering, work management, material management, and financial information systems. However, the HDS user tool-kit must be capable of accessing and using the data from these other systems in order to provide users with a truly integrated environment.

A wide range of data types must be supported to provide an accurate picture of current and past plant operations. The correlation of events (alarms or equipment operational status changes) with process data (flows or pressures) is required in order to provide detailed analysis and diagnoses of plant operation. Test data and results from analysis and modeling tools must also be stored by the system and be accessible on-line for the verification of results. The HDS must be capable of handling analog and digital data, calculated values, end-user calculated values, alarm and event logs, and test logs. Future considerations also include the use of digital video signals and technology.

Plant data must be collected and stored as a function of its fundamental accuracy and time resolution. Several years of on-line data must be accessible to provide the ability to pick up seasonal variations and perform long-term monitoring functions. Historical data permits the user, with the appropriate software tools, to estimate the condition of equipment and components, and to explain operational trends and deviations, predict and ultimately avoid failures. In the following list of requirements, on-line data is defined as data available within seconds after a user request is initiated, while off-line data is defined as data available from HDS archives. Ultimately, the off-line component of data storage may not be required as higher capacity storage media is now becoming available that may provide the ability to have life-of-plant data stored on-line. Data storage requirements include:

- scanning and storage of a minimum of 20 000 tags per CANDU unit,
- configurable scan rates for tags ranging from milliseconds, seconds, minutes, hours, days, with change of value, event triggered, and burst capabilities,
- capability to store data from special data acquisition systems which previously collected high frequency data within fixed time intervals,
- a minimum of five years of on-line data,
- life-of-plant data available as either on-line data or archived in accessible off-line storage, and
- configuration tools to facilitate revisions of tag information such as tag descriptions, units, alarm types, sample frequency, etc., with historical data.

In order to take advantage of the plant-wide HDS, data retrieval must be user-configurable and retrieval response times must be in the order of seconds. Both near real-time and historical data must be available to the user to support the operation and maintenance functions of the plant. The retrieval of life-of-plant data is required by users in such areas as equipment surveillance (i.e., pump seal monitoring and motor current signature analysis), performance monitoring, regulatory compliance monitoring, and equipment maintenance. Users involved in many areas of Nuclear Plant Operations and the Balance of Plant will also require near real-time data for analysis and modeling. Data retrieval requirements include:

- users access to on-line and off-line data using well-defined data retrieval functions,
- data access and retrieval using industry standard interfaces such as structured query languages (SQL),
- data retrieval functions for browsing system information and the selection of data from tag lists, tag descriptions, and alarm lists from both on-line and off-line data,
- the ability for users to save their own data retrieval configurations,
- warning messages to notify users of data access or retrieval errors, and
- retrieval functions capable of handling different sample frequencies, time gaps, overlaps, and time synchronization problems between the various data sources and interfaces.

The plant-wide HDS also requires a wide range of data analysis and visualization tools [3] to support the varied and specialized tasks performed by users. These tools can be integral to the plant-wide HDS or may be part of a separate stand-alone tool-kit. The requirements for data analysis and visualization tools include:

- user-friendly Graphical User Interfaces (GUI) with HDS Application Programming Interfaces (API) to support user access and retrieval of HDS data from all previously defined data sources,
- capability to select from pre-configured displays and trends,
- capability for users to easily configure and save custom displays and trends,
- data interpretation and display functions including multiple window displays of historical trends (graphic and numeric), charts, lists, 2-D and 3-D graphics, and data editing,
- data analysis functions including data editing and filtering, standard and complex mathematical analysis, curve fits, statistical analysis, limit and spread checking,
- real-time and near real-time monitoring functions including trends, animated graphics, virtual instruments, process schematics, bar-charts, boundary checks, and the triggering of other actions and processes based on current plant events, and
- user-configurable reporting and data storage including plotting capabilities, importing and exporting of data and object linking data elements (graphs, plots, charts, etc.) to word processors, spreadsheets, and other standard office software for automatic report generation.

Data validation is required to ensure the accuracy of data that is relied upon by station personnel in order to make decisions for maintenance, performance enhancement, troubleshooting, problem avoidance, and other tasks. Data validation requirements include:

- data gathering interfaces that monitor data transfers and log errors,
- consistency checks of related data streams, and
- validity checks from any on-line instrumentation.

Data security is required to maintain the integrity of the plant data. It is necessary to eliminate the possibility of unauthorized system access or data corruption. Specific data security requirements include:

- data protection, such that data gathered from plant interfaces cannot be modified by users or system maintainers,
- security features to prevent unauthorized access to all or selected data contained in the system,
- utilities to allow security permissions and user accounts to be setup and modified,
- security measures to control data entry into the system such as user-derived points or manually entered data, and
- utilities and procedures for backups of data.

The requirements of configuration management are to identify the system configuration at discrete points in time, control, and verify all configuration changes. These requirements include:

- procedures and utilities to ensure that configuration modifications are made in accordance with approved verification and validation standards,
- tools to define and modify the standard configuration for users from a central point,
- the ability to deliver or update versions of software to users from a central point, and
- provisions to maintain a common database for storing system events, remedies, status, and configuration details.

The data communications in the HDS must allow for the movement of large amounts of data between networked computer systems and minimize the effect of possible communication bottlenecks affecting data transfers between the HDS data sources and users. Similarly, the communication infrastructure must accommodate future communication trends. Communication requirements include:

- the use of industry standard communication protocols such as TCP/IP,
- the use of industry standard hardware that supports high speed data transfer to LAN systems, and
- the ability to implement future upgrades to the hardware and software as LAN systems evolve to higher bandwidths, video data, and to new technologies such as asynchronous transfer mode communications.

## HDS MANAGEMENT AND IMPLEMENTATION ISSUES

As each plant HDS has become more widely used and integrated to a host of other systems, a number of issues have surfaced with respect to work practices, data ownership and management, security, reliability, data validation, and restrictions on access and use of the data based on software classification and quality levels.

The introduction and evolution of HDS environments in the stations will result in two fundamental developments that will affect day-to-day operations, decision-making, and work flow: data traditionally available only to the operators will be available to engineering, maintenance, and nuclear safety staff; and data traditionally not available in the control room will be made available to operators. These developments, in conjunction with the introduction of surveillance programs and enhanced maintenance programs, will significantly alter roles, responsibilities, and work procedures.

One of the more complex challenges to the successful development and implementation of an integrated plant-wide HDS will be the overall strategy, governing policies, procedures, and mechanisms for data ownership, maintenance, and management. As the HDS grows and interfaces with a greater number of plant-wide data providers and users, the issues associated with data management increase in importance. It is conceivable that, in the future, the HDS will be expected to handle anywhere from 1-5 Gbytes of new data daily. Two strategies for handling this issue have been raised. One strategy is to implement tight configuration control over what data is archived, in what form, and how often. The alternative to this is to provide tools to the end-user, who in turn would take responsibility for configuring and defining data formats and storage strategies. A likely scenario as the HDS evolves, will be that both approaches will be used together in balance. Critical process data will be under tight centralized configuration management, while end-users and system responsible engineers will have sufficient tools and system resources to allow them to configure their systems to their specific local needs. Data archiving functions would be handled transparently by the HDS.

System security to ensure data integrity and to prevent unauthorized access must be addressed. One approach is the use of network fire-walls (as implemented within the Gentilly-2 STDE system), whereby an agent process acts on behalf of the end-user client process, and interacts with the historical data-base archive server for the purpose of data extraction. This approach eliminates the possibility of unauthorized system access, data extraction, or file corruption. Using this approach provides a high degree of confidence that once the data is captured by the system and validated through consistency checks and/or even manual inspection (where practical), its integrity is maintained over time. Similar strategies could be implemented if the HDS were developed as a plant-wide "client-server" system.

System reliability becomes an increasingly important issue as the station HDS is relied upon in supporting many of the day-to-day functions of engineering services and operations staff. One of the key success factors in achieving this goal is to ensure that the design implements an architecture and functionality that will meet system reliability and performance requirements. Simple strategies such as hardware redundancy, back-ups, software error and exception handling, and system diagnostics may increase the up-front development cost, but quickly justify themselves once the system is in service.

Data validation is another increasingly important concern and is an issue both inside and outside of the control room. Current Canadian CANDU practice limits HDS use in the control room to display-only systems with the onus on the operators to validate the data against qualified panel instruments and displays. Similarly, data validation is also an issue as data is relied upon outside of the control room for surveillance, maintenance, safety and licensing analysis. Currently, the onus is on the user to perform validation and consistency checks before making any decision based on HDS data. This is done by comparing data on the desktop to data acquired in the field, and checking that measurement instruments are within calibration tolerances. As HDS use becomes more wide-spread, data validation issues must be addressed in terms of software classification and qualification as discussed below.

Software classification and quality assurance is a key issue in the implementation of a plant-wide HDS, particularly as HDS data is requested for use by control room operators, safety, and licensing functions. The software classification and future development of an HDS in Canadian CANDU stations should be based upon the Ontario Hydro - AECL Software Engineering Standards (OASES). The OASES categorization of software and software-controlled systems in nuclear applications is based on the failure impact the software may have on the ability of the larger system in which it is a part, to perform any of its necessary safety functions. Within this framework, software failures are classified as Type I, II, or III (Type 1 failure being the most severe), and software quality category levels are defined as Levels 1 through 4 (Level 1 being the most rigorous) [14]. Clearly, the software failure type and software quality levels are linked to the end-use of the HDS data. HDS failures classified as Type III with software quality levels categorized as Level 4 are appropriate when the data use is not safety-related or when data can be validated from other qualified sources. The failure classification and software categorization levels will require reassessment when used outside of this context. Additional emphasis would have to be put on system reliability, data integrity and validation. Qualification of pre-developed software used in the HDS software development life cycle would also have to be considered [15].

## OPPORTUNITIES FOR PLANT-WIDE DATA SYSTEMS INTEGRATION

A wide variety of applications have been identified as benefiting from better use of plant data through the implementation of plant-wide historical data systems. These have been grouped into the following categories:

- Engineering Services and Technical Surveillance Systems,
- Control Room and Operational Systems,
- Production Management and Work Control Systems, and

- Safety and Licensing Support Systems.

Although each station is slightly different, the engineering service groups are generally known as technical units. System engineers and specialist (program) engineering groups (thermalhydraulics, physics, chemistry, etc.) interact daily with operators, production, and maintenance staff. Their job functions include technical surveillance, troubleshooting, production support, maintenance support, project support, and operations support [3]. Their goals are to increase plant performance (capacity factors), availability, and safety. The technical units have a fundamental need for accessible plant data for analysis in support of their job functions. The implementation of a plant-wide HDS will have a significant impact in optimizing technical surveillance programs in support of:

- system and plant performance improvements,
- maintaining, modifying, and managing the plant configuration,
- regulatory compliance and environmental monitoring,
- troubleshooting, post-incident investigation and analysis, and
- maintenance support, including CBM and RCM programs, implementing a wide range of system and component monitoring in the areas of pumps, valves, turbines, electrical equipment and motors, plant chemistry, and others.

Historical data is also of value in control room and operational systems. With a properly qualified HDS, or other methods of data verification and validation, historical data can be use within:

- critical safety parameter monitoring,
- flux mapping and fuel handling,
- shutdown system monitoring,
- operator day logs and alarm recorders,
- advanced decision support systems including real-time simulation and analysis, and
- plant display systems.

Production management and work control can also benefit from the integration of HDS data with plant work management systems contributing to:

- outage and maintenance planning,
- CBM and RCM programs,
- plant configuration management and the tracking and verification of operating orders,
- on-line operational flow sheets, and
- risk and reliability analysis of plant systems and components.

Plant-wide HDS information is also crucial to a variety of safety and licensing support programs such as:

- radiation monitoring including post-accident monitoring, radiation dose information, and dose management,
- regulatory compliance monitoring to verify component and system performance are within safety margins,
- testing, parameter verification, and calibration of safety-related systems and components, and
- on-line analysis and simulation models for primary heat transport circuit analysis, heat balance, and simulation of reactor operations.

## SUMMARY

It is clear that plant-wide historical data systems including data extraction, interpretation, analysis and reporting tools are steadily increasing in importance across virtually all areas of plant operations. The implementation of HDS technology is critical to the execution of technical surveillance and analysis programs, operational analysis, production and maintenance, and safety and licensing programs. The current introduction of plant information systems is having a major impact on the daily operations of the plant at all levels. Although there has been significant progress, there is also a great diversity amongst Canadian CANDU plants in HDS design and implementation philosophy. This has resulted in the duplication of effort and has required large in-house capabilities to design, implement, and support the installed systems.

The requirements for HDS technology to support all aspects of nuclear plant operations and maintenance are becoming much better understood as the use of HDS technology evolves within the plant environments and industry studies are conducted to derive generic requirements and specifications [1,2,3]. The introduction of new technologies and the advancement of off-the-shelf HDS products including database systems, data visualization, and analysis tools is now permitting the introduction of historical data systems with significantly less development effort. Similarly, world-wide competitiveness and the recognition of the value of integrated data systems has also led to the development of off-the-shelf HDS products with built-in data links to CBM programs and large integrated work management systems.

The industry must continue to strive for reduced OM&A costs while at the same time increasing plant performance and safety. The use of HDS technology providing easy data access, visualization and analysis capability to all plant staff will directly contribute to these goals.

## REFERENCES


[1] DE GROSBOIS, J., BOSNICH, M., HINTON, J., GILKS, G., "A Review of Plant Data Systems in Canadian CANDU Stations", Atomic Energy of Canada Ltd., CANDU Owner's Group Report, COG-95-265, Revision 0, 1995 October.

[2] POTHIER, H., DEVERNO, M.T., "Historical Data Systems: High Level System Requirements", Atomic Energy of Canada Ltd., CANDU Owner's Group Report, COG-96-150, in preparation.

[3] XIAN, C., DEVERNO, M.T., "PC-Based Tools for Technical Surveillance and Analysis", Atomic Energy of Canada Ltd., CANDU Owner's Group Report, COG-96-131, in preparation.

[4] JASZKUL, P., "Bruce GS A Plant Status Monitoring System (PSMS) Design Requirements", Ontario Hydro, 1995 January.

[5] LEE, K.S, RECOUSO, G., "Bruce NGS B Plant Status Monitoring System Survey Report", Ontario Hydro, 1994.

[6] KWAN, D.Y.W, "Bruce Generating Station B Plant Status Monitoring System Preliminary Technical Requirements", Ontario Hydro, 1994.

[7] GOMAA, H., "Bruce Nuclear Generating Station B Plant Process Data System Technical Requirements", Bruce Nuclear Generating Station, TS-NK29-66400-013, 1995 August.

[8] LAROSE P.A., "PDDS Process Data Distribution System Presentation Slides", Ontario Hydro, 1994.

[9] SHEK, C.F., "Data Extraction System, Pickering A Nuclear Generating Station, Presentation Sides", 2nd COG CANDU Computer Conference", Toronto, 1995 October 1-3.

[10] COURCHESNE, Y., "Traitement des donnees d'exploitation (TDE)", Gentilly-2 Nuclear Generating Station, 65313-6, 1991 October.

[11] GOUR, N., GAILLARDETZ, C., "Implementation of a Plant Data Management System at Gentilly-2, Presentation Slides", 2nd COG CANDU Computer Conference", Toronto, 1995 October 1-3.

[12] STOREY, H., PATTERSON, B.K., FRANCIS, D., "Point Lepreau's Local Area Networked Based Station Control Computer and Generic Monitoring System: Live and Historical Plant Data Collection and Distribution System", NB Power, Point Lepreau Generating Station, 1992.

[13] KENNEDY, E., "Hand-held Electronic Data Collection and Procedure Environment", Atomic Energy of Canada Ltd., CAN/CNS Conference, Fredericton N.B., 1996.

[14] ARCHINOFF, G.H., LAU, D.K., DE GROSBOIS, J., BOWMAN, W.C., "Guidelines for Categorization of Software in Nuclear Power Plant Safety, Control, Monitoring, and Testing Systems", COG-95-264, Revision 1, September 1995.

[15] TREMAIN, D.R., AHLUWALIA, D.S., DE GROSBOIS, J., ECHLIN, E.G., "Guide for the Qualification of Software Products", COG-95-179, October 1995.

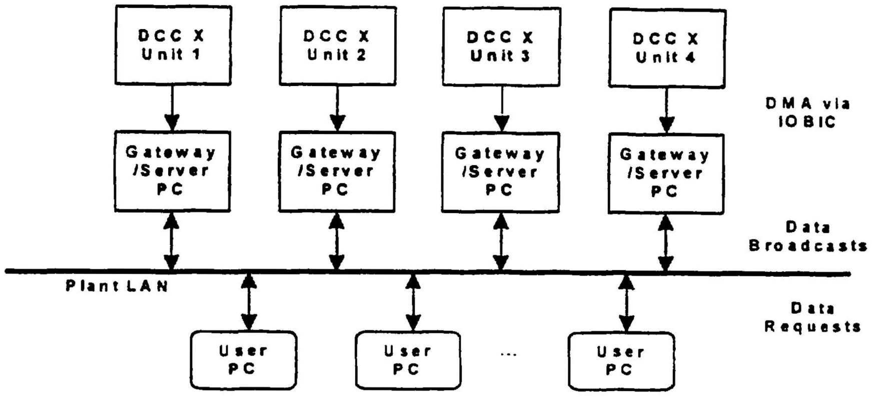


**Figure 1. Bruce A NGS Plant Status Monitoring System**

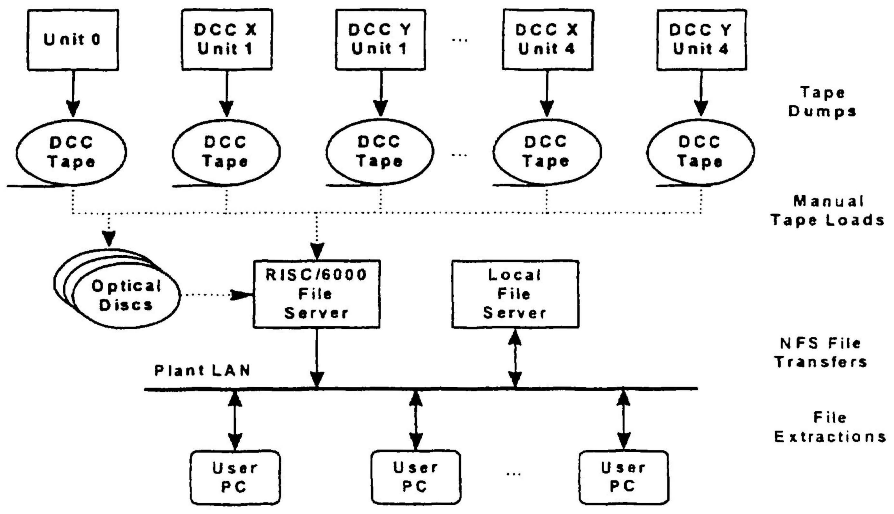


**Figure 2. Darlington NGS Process Data Distribution System**

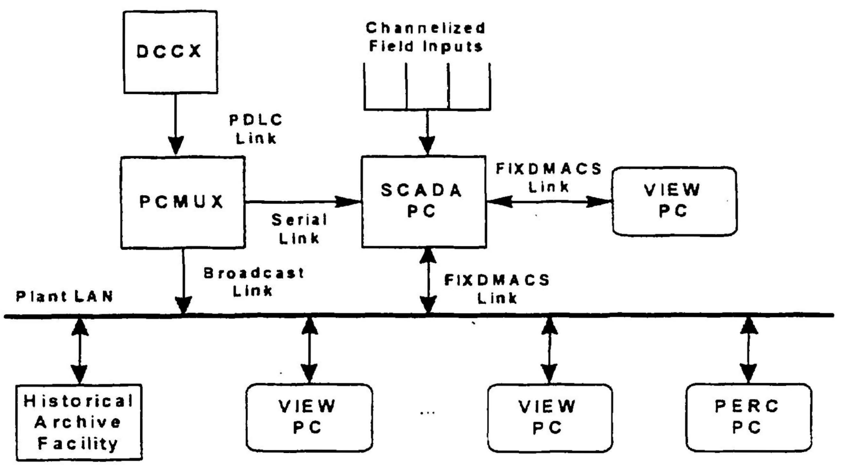


**Figure 3. Pickering 'A' NGS Data Extraction System**

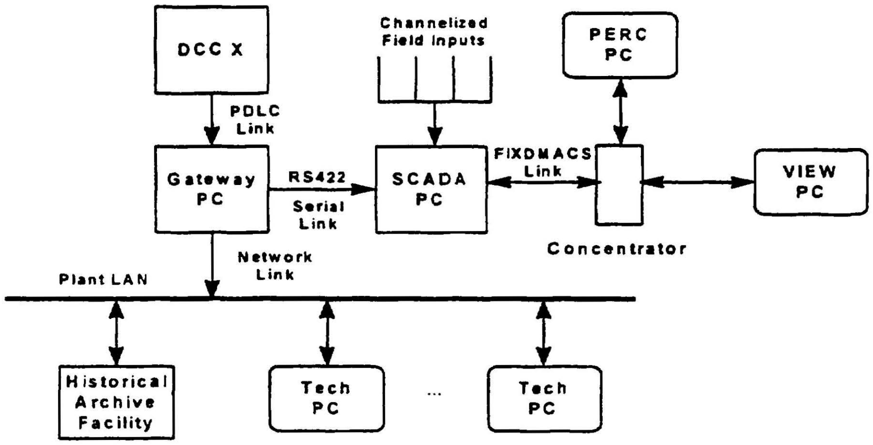


Figure 4. Pickering 'B' NGS Data Extraction System

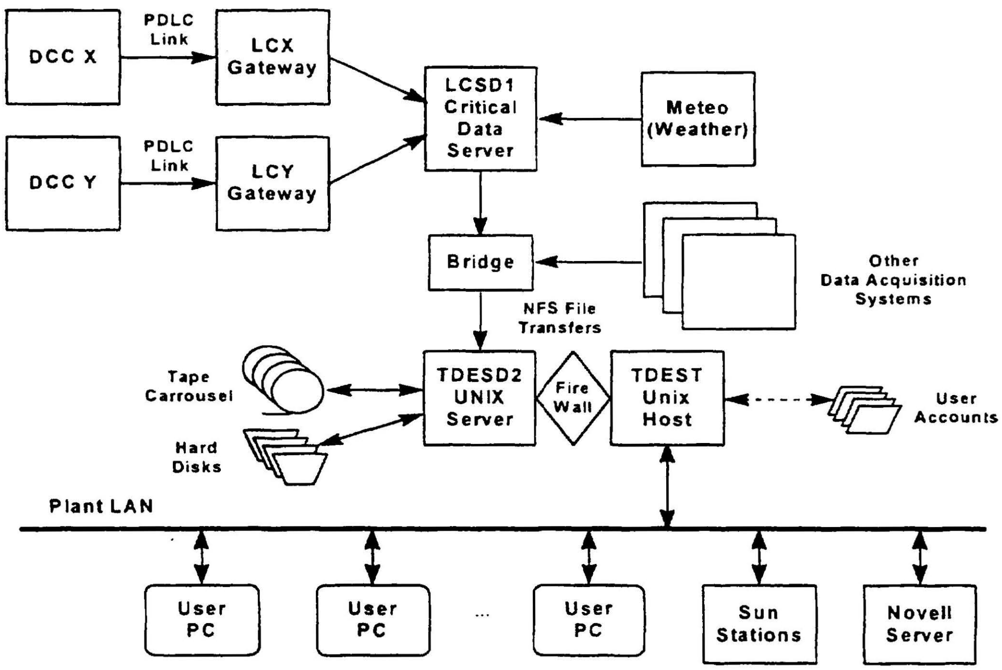


Figure 5. Gentilly-2 STDE System

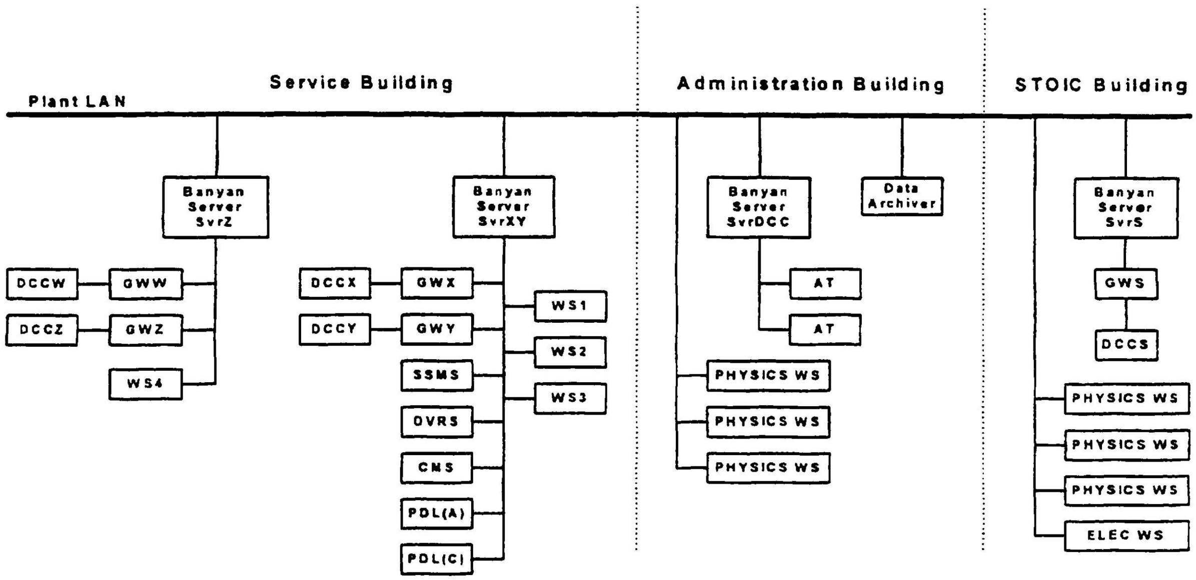


Figure 6. Point Lepreau Generating Station Gateway Computer System

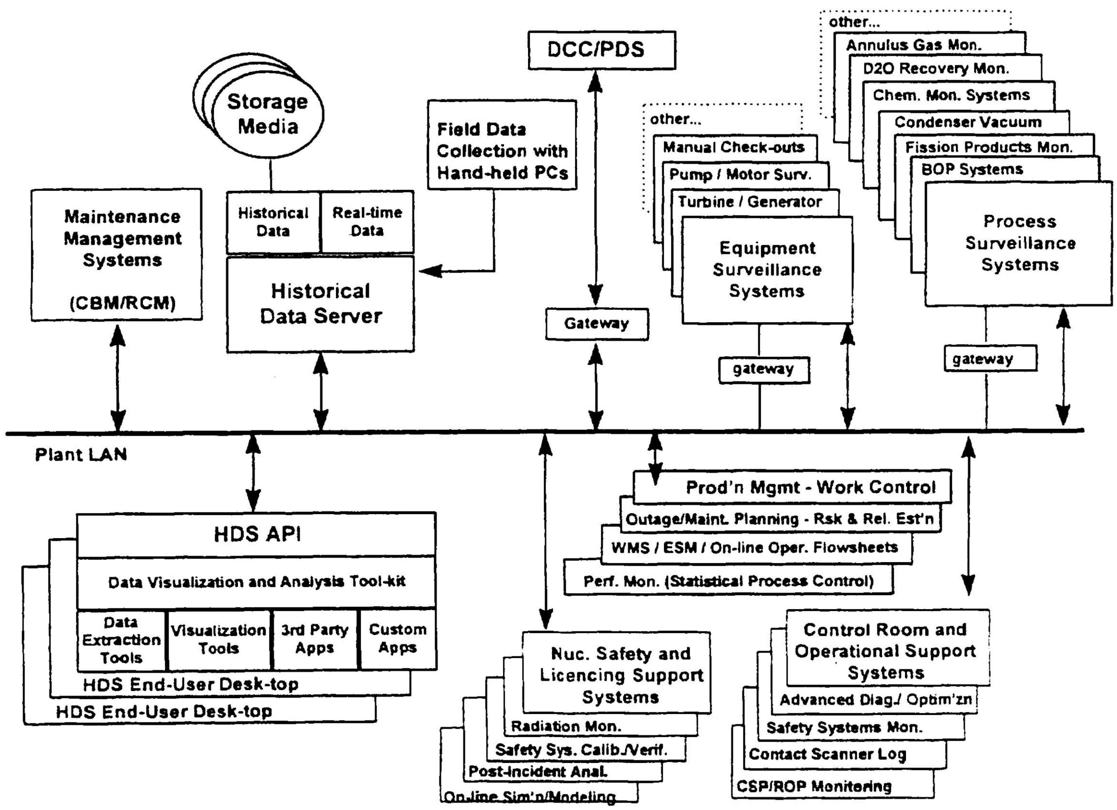


Figure 7. Integrated Historical Data System Architecture