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Information technology impact on nuclear power plant documentation

Report prepared within the framework of the International Working Group on Nuclear Power Plant Control and Instrumentation

INTERNATIONAL ATOMIC ENERGY AGENCY IAEA

April 2002

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FOREWORD

As the majority of the nuclear power plants (NPPs) in the world were designed and constructed about twenty to forty years ago, these older power plants may have shortcomings in documentation on construction, commissioning, operations, maintenance, or decommissioning. Therefore, facility documentation does not always reflect actual plant status after years of plant operation, modification, and maintenance. To deal with these shortcomings, computer and information technologies that provide sophisticated and modern design tools as well as information processing and storage facilities can offer dramatic innovation from paper-centric documentation towards data-centric documentation.

This report addresses all aspects of documentation associated with various life-cycle phases of NPPs and the information technology (IT) that are relevant to the documentation process. It also provides a guide for planning, designing, and executing an IT documentation project. Examples are given to demonstrate successful implementations at plants. Finally, it discusses the issues related to the application of the IT in NPPs and the trends for applications of the IT at NPPs as well as the technology itself.

It is recognized that this can also improve configuration management, reliability of data, quality of personnel work, and ultimately plant performance, reliability and safety. The aspects of using the IT for NPP documentation are closely related to configuration management at NPPs. The report consists of nine sections, a reference section, and five additional appendices.

The development of this report which was initiated by the IAEA International Working Group on Nuclear Power Plant Control and Instrumentation (IWG-NPPCI). It is the result of a series of consultants meetings held by the IAEA in Vienna (October 1999, November 2000). It was prepared with the participation and contributions of experts from Canada, Germany, Norway, Sweden, and the United States of America. In addition, a related Advisory Group meeting on Information Technology Impact on NPP Design Process and Plant Documentation was held in Vienna, Austria in April 2000.

This report is intended mainly for the use of plant managers, project managers, I&C system designers, system engineers, operations managers, operators, and other plant information users.

Special thanks are due to B. Sun (USA) who chaired the consultants meetings and co-ordinated the work. Ki-Sig Kang of the Division of Nuclear Power was the IAEA scientific officer responsible for this publication.

EDITORIAL NOTE

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CONTENTS

1. INTRODUCTION

1.1. OBJECTIVE

For the existing nuclear power plants (NPPs), the most important criteria are safety, reliability and cost competitiveness in today's deregulated environment. To satisfy these criteria, the plant owners and operators need to use technological tools to comply with the safety standards and to improve the plant economy. As the bulk of the NPPs were built in the years 1960–1990 these older power plants may have somehow shortcomings in documentation on construction, commissioning, operations, maintenance or decommissioning. Therefore, facility documentation does not always reflect actual plant status after years of plant operation, modification, and maintenance. These older power plants share some of the common characteristics and shortcomings in terms of documentation:

- Documentation is dispersed;
- Main design principles are not readily available and sometimes lost;
- Original "know-why" is not readily available for use by plant personnel;
- Facility documentation does not reflect actual plant status after years of plant operation, modification, and maintenance;
- The documentation is largely paper-oriented.

To deal with these shortcomings, computer and information technologies that provide sophisticated and modern design tools as well as information processing and storage facilities can offer dramatic innovation to the traditional treatment of documentation at NPPs. Implementation of the new technology can also improve the configuration management at NPPs and result in overall improvement of plant performance and safety. The trend has been to move away from paper-centric documentation towards data-centric documentation where documents can be automatically generated from information stored in databases. The hardware and software technology available today provide the capability for electronic recording, storage, retrieval, processing and distribution of information [1–8].

To achieve the full benefit of electronic documentation management, there are still engineering and managerial challenges at NPPs. These include interface with the computerized engineering tools, conversion of paper documents into the electronic forms, infrastructure changes associated with workflow re-engineering, economic aspects of the process, etc.

The objective of the project is to prepare an IAEA publication that provides recommendations and guidance on the utilization of information technologies in plant documentation for support of plant operations throughout its life-cycle. It is recognized that this would also improve configuration management, reliability of data, quality of personnel work, and ultimately to improve plant performance and safety. The aspects of using information technology for plant documentation are closely related to configuration management at NPPs.

1.2. SCOPE

The scope of the technical report addresses aspects of documentation for all plant phases throughout its life-cycle, including design, procurement, construction, operation, maintenance, and decommissioning for both existing plants and new plants. Throughout the plant life-cycle, documentation is a very important item, because creating and maintaining documentation is a crucial component of the safety activities at the plant. In addition to safety considerations, a decision to apply information technology to plant documentation is related to many factors, such as the remaining plant life, other modernization projects undertaken at site and a possible need for a reconstitution of the plant design base. Besides, in assessing the scope and implementation of a documentation project for a NPP, there are many questions, which have to be addressed on a plant specific basis. Nevertheless, major considerations of relevance to documentation for nuclear power plants are discussed in the report.

The subject of interest for plant documentation covers both technology and those relevant to plant infrastructure. These include impact on followings:

- workflow process,
- compliance with plant configuration,
- electronic diagrams,
- computer aided design tools,
- information technology applications,
- documentation maintenance,
- scanning paper copies,
- economic aspects,
- configuration controls,
- intelligent features of scanning of drawings,
- electronic documentation management,
- relevant codes and regulations, and
- software quality assurance, etc.

The report is organized with the intent to provide readers a guide to plan and implement a documentation project with information technology for a nuclear power plant. The structure of the report consists of ten sections, a reference section, and five additional appendices. Section 1 describes the general background of documentation. To facilitate reading, Section 2 tabulates abbreviations and acronyms that are used in the report and provides concise explanations for technical terminology associated with documentation. Section 2 explains the requirements and needs of documentation throughout the plant life-cycle phases from the beginning design to the ending decommissioning. Special emphasis is made for considerations of licensing, regulations, codes and standards, and quality assurance. Section 3 describes the information process and technology, which address the needs and requirements that are described in Section 2. The information process consists of recording, storage, retrieval, processing, access control, publications, and distribution.

Section 4 leads a reader to plan an information technology project for documentation. The planning process is depicted to start with definition to be followed by methodology, total cost, justification and decision-making, and finally, organization and management of the project. In planning, it is important to identify the key characteristics, which include workflow, work order management, asset management, paper and drawing documentation, knowledge management, database and objects, quality assurance, and configuration management. Following the planning depicted in Section 4, Section 5 provides a guide on design and execution of the information technology project for documentation. Major items considered are re-engineering of work processes, design requirements, specifications, vendors and consultants, system maintenance and operation, and the change of infrastructure.

Section 6 offers examples of information technology implementation at several different countries for new plants as well as existing operating plants to illustrate the planning, design, and execution of the information technology projects. These include the existing US Browns Ferry Plant and Swedish Forsmark Plant, the modern French Chooz B Plant, the new Canadian, Korean, and European reactor designs, and the research reactor of Munich, Germany. After these examples, Section 7 addresses issues and concerns for application of information technology in nuclear power plants. Major subjects in the area include design basis reconstitution of as-built plant configuration, licensing and regulations, legacy systems, training, and the rapid changes of technology. To complete the report, future trends of information technology and its applications at nuclear plants are discussed in Section 8 along with the conclusions and recommendations, which are summarized in Section 9.

The Appendix provides additional information that is complementary to the main text of the report. These include licensing, methods of configuration management, Swedish experience on documentation project, software technology, and Internet.

The report should be of interest to the staff of the utility companies, reactor vendors, architect engineers, consultants, and researchers for their planning of utilizing information technology for NPP documentation.

2. REQUIREMENTS AND NEEDS OF DOCUMENTATION THROUGHOUT PLANT LIFE-CYCLE PHASES

2.1. PLANT LIFE-CYCLE PHASES

The plant life-cycle starts with a power plant project definition, follows by the phases of concept design and detailed design. After the construction and start-up phases, the plant is handed over to the owner/operator. Then the operations phase accompanied by the maintenance phase follow. The operations and maintenance phases are interrupted by periodical revisions and outages. The O&M phases last typically for about forty years. In the USA, some owners/operators apply for a prolongation of plant life to sixty years. At the end, the decommissioning phase terminates the life-cycle.

The bulk of the documentation is produced during the basic and detailed design phase and additional documentation is produced during the construction and start-up phase as well as modifications of the original designs from as-planned to as-built configurations. In the O&M phases, some documents undergo changes and new documents are required specifically for the operation of the plant.

2.2. SCOPE OF DOCUMENTATION

This section describes the scope of documentation for the NPPs as it relates to the requirements of information technology, which is considered a tool. Documentation is the result of the following activities:

- The recording of the decisions made while performing NPP life-cycle activities;
- The recording of the process and the basis of decision making;
- The documenting of interface and relations among the information objects that are recorded by the above actions.

The NPP documentation is the total information recorded as described above, in a plant rationalized information base. Once they are in an organized and systematic form, the documentation provides for easy retrieval and availability for use of the information objects and their relationships. The information object is a collection of information, which contributes to the definition of a plant object, its current state as well as its history. Whereas, the plant object refers to the physical NPP assets such as buildings, equipment, pipelines, cables, etc. In the plant life-cycle, many activities (such as a design activity) lead to the generation of information objects that are used to produce formal deliverables, initiate other activities, or to relate to the state of a physical plant object. The following items are examples that are related to the information object and the plant object:

- Engineering deliverables, such as drawings, component specifications, analysis reports;
- Action initiated, such as starting manufacturing after receipt of engineering approvals;
- Action initiated, such as calibrating instruments based on recorded requirements;
- Recording the status of pulled cables and the related length;
- Logging a preservation activity such as lubrication, for a NPP asset.

Today, in design and construction, documentation of design decisions that relate to system parameters, configurations, and licensing issues, etc. include reports, drawings, textual attribute values stored in a rationalized data base management system (RDBMS), and graphic objects stored in 3D computer aided design and drafting (CADD) files [2, 4, 7].

2.3. LICENSING AND REGULATION CONSIDERATIONS

2.3.1. Licensing

This section deals with the requirements provided by the licensing authority concerning the use of information technology (IT) as tools for enhancement of safety and reliability of NPPs and the method for licensing. As for all activities affecting the safety-related functions, the existing regulatory requirements shall be interpreted and applied. In addition, new requirements especially for IT tools shall be validated.

The requirements may be divided into four groups, namely:

- Quality assurance;
- Design, qualification and management of tools;
- Design of the IT infrastructure;
- Interfacing with the licensing authorities.

IT tools are significant for the safety of the plant as they may be used for various safety applications during the different life-cycle phases. Typical examples are tools for:

- Design of systems;
- Verification of design;
- Management of the purchasing;
- Management of operations;
- Management of maintenance;
- Management of modifications;
- Documentation management;
- Reporting to the licensing authorities.

It is important to recognize that errors in the tools can introduce failures in systems as well as in management of operations and maintenance. Often during implementation, the same tool is used for many activities. For this reason there is a risk that one error can result in faults or failures in many different activities, which is known as common cause failures. It is therefore important to analyse the nature of the errors and the impact on safety. A risk analysis and/or hazard analysis should be performed. The analysis may serve the base for a criticality index for all tools. As usual for safety issues, the safety analysis for the IT tools should be a part of the safety analysis report (SAR).

The starting point for the licensing of the tools during the life-cycle is a QA program for each phase. The document Ref. [9] provides the principles and objectives that can be adopted for such program. However, other documents are also available and in use describing similar programs as e.g. Refs [10, 11]. The QA program will be further discussed in Section 2.3.3, which follows the recommendation and interpretation of the international ISO standard for typical aspects of IT tools.

Today, there are a few regulatory requirements for IT tools. Normally, the general tool requirements are interpreted for the licensing process, design, and issuing of information to the regulators. Such aspects can be found in the different national regulations as given in Refs [10, 12–14].

General regulatory requirements

The document Ref. [5] describes the general requirements for tools. A summary of those that are relevant to plant documentation using information technology tools is given below [15–17]:

- The requirements of IT tools depend on the impact on safety and how V&V processes are used. The requirements for the IT tools that are relevant to safety shall have the same level as other safety requirements;
- The licensing authority shall be made available to all the evidence that the tools provide the adequate level of description;
- The documentation for QA shall be made available to the licensing authority. The policy for new version of tools shall be precisely described;
- Only those tools that are validated against the level of requirements should be used;
- The vendor of the tools should update experience feedback and make available the information about anomalies discovered by users;
- The strategy for use and V&V for tools should be defined in the QA plan.

In the life-cycle of a NPP, many documents must be transmitted to the regulator. The type and amount of these documents, particularly the licensing documents, are well specified. Typical examples are the SAR and the reporting of abnormal events. Adequately designed IT tools can produce many of these documents with relevant information. It is obvious that when a new tool is specified, the aspect for information to the regulator must be identified in its requirements. For example, the output from existing tools provides the technical information about the design of the plant. The special information to the licensing authority also includes the record for operation and events in the power plant.

Today, most of the regulations require transmission of information by typewritten, printed or reproduced paper. Submittal can, by exception, be done in micrographic, photographic or electronic forms. In addition, transmission of information in the licensing requirements must be done with a signed cover letter. As the practices are changing with technology and time, transmission by information network is yet to be formalized and accepted.

The licensing information of a nuclear power plant must be stored until the licensing authority terminates the license. Exceptions are made for temporary storage of background information to operational analysis or periodical safety reviews. The storage must include information about stamps, initials, and signatures. A special type of information is the document for qualification of components and systems. These must be stored during the lifetime of the plant. Therefore, a system for easy retrieval of documentation must be available.

When the tools for documentation undergo changes, the licensee shall maintain records of changes in the facility, procedures, tests, and experiments. To address the changes in the tools, there must be a procedure in order to do the following:

- Assure that the latest approved version of a tool is used;
- Protect against obsolete information;
- Collect experiences about the use of tools;
- Report errors to all users of specified tools.

2.3.2. Codes and standards

There exist many codes and standards for NPP applications. Among them, those established by the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), and the Institute of Electrical and Electronics Engineers (IEEE) are most relevant to the information technology tools for documentation [18–21].

International Organization for Standardization (ISO)

The most important chapters in ISO 9001 [11], for the tool QA program as described in Table I are:

Table I. Sections of ISO 9001 that are relevant to information technology tool

ISO 9001 Document	Key Content
Section 4.4	Design Control of the Tools, including design and development planning, organizational and technical interfaces, design input, design output, design review, design verification, design validation, and design changes
Section 4.5	Document and Data Control, including the handling of the issues, changes, and approval of document and data
Section 4.6	Purchasing of Tools, including evaluation of subcontractors, purchasing data, verification of purchased product, suppliers verification and customers verification
Section 4.14	Corrective Actions, including corrective and preventive actions

International Electrotechnical Commission (IEC)

While the aspect of software tools with respect to safety importance is identified in several IEC standards for the critical software of digital protection systems, the requirements described in these standards are largely applicable to other types of computerized tools. The IEC 61513, Ref. [16], concludes that tools shall be used in all phases of the life-cycle where benefits to the assurance of quality and reliability of the functions important to safety can be obtained.

This standard refers to another standard IEC 61880, Ref. [15], for further details. Requirements for tools in this IEC 61880 standard are grouped in the following topics:

- Software engineering environment;
- Tool qualification;
- Tool configuration management;
- Translators/compilers;
- Application data;
- Automation of testing.

The most important requirement is about the qualification of tools. It is recognized that the tools should be qualified to a level in accordance with the requirements of the tool and the consequences to safety if an error exists in the tool.

Institute of Electrical and Electronics Engineers (IEEE)

The IEEE organization has developed many standards for the QA of software. Many of these are useful for IT tools and the IT infrastructure. A summary of IEEE standards can be found in Ref. [18]. Within the guides provided by the standards, the concept of criticality index could be used to identify the requirements of the information technology for use in documentation from the safety standpoint. The criticality index is divided into the following three levels in accordance with the principles of safety as described in Ref. [20]:

SI-1: Tools that produce an output that is directly used for a safety activity or system and no method exists to validate the output;
SI-2: Tools that produce an output that is used for a safety activity or system and a method exists to validate the output;
SI-3: Tools that produce an output that is used without impact on safety.

2.3.3. Tool qualification

An important activity required by the QA program is the qualification of tools. The major elements for such a qualification process are described in this section.

Suitability analysis

A suitability analysis is a process to verify if existing or commercial available tools are suitable for the planned life-cycle activities and to define the specification of development of new tools. The first step in a suitability analysis is to perform a task analysis of the work to be done in a life-cycle activity. During this step, important characteristics are described for the IT tool as:

- Work flow, responsibility and task for organizations;
- Interfaces to the users;
- Input data requirements;
- Output requirements;
- Interfaces between organizations;
- Compatibility and interfaces with other tools;
- Hardware system and infrastructure requirements;
- Operations and maintenance of the tool.

These characteristics can be used for describing a specification for development of a new tool or for purchasing existing ones. With the results from the suitability analysis, candidates for existing tools are evaluated and a preliminary selection of suitable ones is done. Eventually through iterations, the characteristics of the tool can be modified to match existing tools or a program should be started to initiate the development of a new tool. Sometimes, such analysis can result in changes for the workflow or the organization of the company.

Tool verification and validation

After selection and purchasing of a tool or finalizing of the development of a new one, the tool has to be verified and validated. The V&V process is done to meet the requirements of specification through the suitability analysis. The elements of the tool V&V can be considered in three steps; audit, prototype, and error reporting, as in the following:

- Evaluation of the development program and the tests which have been carried out by the development team (audit);
- Testing with a pilot demonstration with the organization which shall use the tool (prototype);
- Evaluation of operating experiences of purchased tools (error reporting).

It is important that the V&V for the tools shall include the specified interfaces for input and output data and the interfaces among the organizations. If it is necessary, integration with other tools should be verified.

A justification is necessary once the tool qualification is completed. The documentation for the justification may include the following elements:

- Tool is accepted for use, or should be modified;
- Tool is included in the QA program for the organization that will use it;
- Documentation for the use and maintenance is available;
- Description of restriction and limits are provided;
- Policy for updating and error reporting is in place.

Based on the justification document, the use of the tool is approved and placed under configuration control by the responsible organization.

2.4. DESIGN PHASE

As significant amount of engineering and its associated documentation effort is made in this phase, design phase documents should be produced according to schedule requirements. There should be sufficient schedule contingency to allow for approval and the incorporation of the latest inputs and requirements, particularly those of the regulatory authority. The design document structure for engineering is divided as follows;

- Drawing
- Specification
- Calculation
- Report
- Procedure and others.

Based on above structure, the field of engineering document are clarified as follows;

- Architecture engineering
- Civil/structure engineering
- Electrical engineering
- Instrument and Control Engineering
- Mechanical engineering
- Nuclear engineering
- Plant design
- Quality assurance
- Project administration
- Project controls.

The documentation for scheduling and resource allocation should be prepared for the beginning and planning stage. Then the conceptual design is established with the basic arrangement of the buildings and general arrangements. The basic design comprises the basic arrangement of equipment, allocation of sufficient space for positioning, transport of material, erection, operations and maintenance, etc. Further, the basic loads are calculated and introduced into the basic design, which includes the position of anchoring for the main equipment. For an example, the analysis report such as heat rejection optimization for sizing condenser should be performed during design phase to prepare technical specification. All construction drawings are generated in the design phase. This may amount to about 300 000 drawings comprising for example formwork drawings, isometrics, support drawings and circuit diagrams.

2.5. DOCUMENTATION FOR PROCUREMENT AND MATERIAL MANAGEMENT

Beginning with the tendering activities, information related to items being purchased is generated and augmented as the owner/operator advances through the different phases of procurement and material handling. The type of related information being generated includes the following:

- Formal engineering documents, equipment and facility to be purchased, requirements related to manufacturing, packing and delivery;
- Contractual and pricing information;

- Formal and unofficial correspondence associated with the order;
- Information that identifies a class of material, equivalent to an internal stock code;
- Supplier documents, providing the details required for installation, preservation, and maintenance;
- Records tracking the state of the procurement and material handling process;
- Asset information as recorded on receipt of the item.

Furthermore, the activities covered by the procurement and material management include the following items:

- Tendering activities;
- Post order engineering activities;
- Expediting;
- Inspection;
- Materials shipment and delivery;
- Material receiving and warehousing;
- Material preservation;
- Distribution for erection;
- Management of spare parts.

These activities set the stage for identifying the requirements for the documentation processes associated with procurement and material management. The requirements on document may provide a high level mapping on the sharing and use of the information/documentation generated by different groups of activities in the life-cycle.

An information system would be useful to facilitate the recording, storage and subsequent access of the data by those involved in the activities listed above. The recording and storage of information would also include establishing relationships among different classes of data. The data could consist of records in relational databases, paper documents, electronic files of different formats, all interrelated in a way that leads to ease of access based on well-understood, business related criteria. Examples of such cases include:

- Extracting tender documents based on an Engineering Quotation Request (EQR) number;
- Accessing contractual information including correspondence based on the stock code number associated with an order;
- Extract all the supplier drawings related to a specific equipment asset.

2.6. DOCUMENTATION FOR CONSTRUCTION

During the construction phase, a large amount of drawings and documents that are generated by the design staff are used for the following activities by taking piping construction as an example:

- Scheduling the construction work;
- Planning the construction sequence;
- Planning the material take-off;
- Planning the resources as number of welders;
- Preparing the examination tests for the welders.

Documentation such as work plan procedure is also generated during the construction work. These are reports about the work progress, lists of open items, time schedules for the various activities, etc. Furthermore, tests and examinations are documented. Among those, for example, the weld inspections data have to be documented and stored. After construction, the as-built situation has to be captured. The deviations to the as-planned situations are marked on the drawings and a new index is given.

2.7. DOCUMENTATION FOR OPERATIONS

2.7.1. Operations

At the end of the commissioning phase, the as-built drawings together with the records and documents are transferred to the plant management system. To avoid inconsistencies in the documentation, the data model of the planning system has to be reconciled with the data model of the operational system. If this is done through an electronic document management system, the data and documents can be readily transferred. Otherwise, the ambiguities have to be reconciled by administrative measures. As significant amount of work is wasted for searching documents and installing private data pools and archives, the data and documents should be kept in an engineering data management (EDM) system that allows the electronic storage of data and documents combined with searching algorithms and revision management.

In addition, the operations phase itself also generates new types of documents. Among those are access rights, dose rates per person, spare part lists, schedules for inspection interval, lists of anticipated modifications and many others.

2.7.2. Maintenance

The maintenance activities can be subdivided into the following two main issues:

1) All activities that go along with the operations itself and during the operations;
2) Maintenance activities during the modification period that is kept by the owner/operator to be as short as possible for power production purpose.

During the operations, failures and abnormal behaviour of systems are reported in a databank. The impact of the problem is evaluated and countermeasures are planned if necessary. The countermeasures are scheduled and executed following extensive work preparation and documentation.

For the safety relevant systems, documentation has to be prepared for internal acceptance by the upper management and external acceptance by the regulatory authorities. All the documentation that address change request during maintenance must be compiled from the existing documentation. After the modification is performed, the documentation and the associated new drawings for the system modification must be fed back to the archive to reflect the proper as-built situation. Although this type of work has been done largely as paper work, it can be augmented and supported by an EDM system.

2.7.3. Modernization

As an extension to the NPP maintenance activities, modernization is discussed in the context of the EDMS that may play a key role in the planning, execution and the retention of the plant configuration management. Throughout the plant life-cycle, the NPP will undergo numerous changes that are designed to improve the safety and the efficiency of the plant. These changes might involve replacing existing equipment with more modern equipment, adding new components or extension to existing systems, or modernizing computer based systems with new hardware and software, etc.

By their nature, most modernization initiatives, have to be planned in advance and are performed during scheduled plant shutdown periods. The time windows offered by the scheduled shutdown is usually very short, thus requiring careful planning and a high degree of precision during the execution of the task. The modifications, more often then not, involve dismantling of exiting equipment and/or other affected components, installing and reconnecting the new items, and testing the new configuration. If the change impacts other systems, they have to be tested as well to ensure that they remain fully operational and will operate within the plant safety boundaries.

The design and the implementation of these improvements may be contracted out or may be performed by the plant engineering and maintenance staff. Irrespective of who performs the design and executes the changes, there has to be a complete reliance on having accurate documentation. Incomplete or incorrect information can jeopardize the implementation schedule, introduce safety breaches or may result in delaying of the plant start-up.

From a document management perspective, the information that is needed to be accessible to perform the planning of modernization must include the following:

- The information defining the changes in the drawings and documents associated with the modification;
- Change Request documentation providing the background and the justification for the changes;
- Documentation relating the current state of the components affected by the change, including maintenance records;
- Specifications defining the components to be purchased;
- Historical records of associated information, particularly those relating the current configuration to the design basis and safety operational boundaries.

Organizing the documentation in coherent collections that provide logical and manageable work packages is another important aspect associated with the NPP EDMS. This takes additional importance when the work is subcontracted to outside entities not fully familiar with the plant configuration and the design basis impacting on the change.

After the planning and detailed design phases are completed and new equipment has been purchased, the documentation generated will define the following:

- The execution sequencing, which may include work to be done prior to the maintenance shutdown;
- Details of the interfacing between the new components and existing equipment;
- Impact on other systems;
- The execution of the modifications to maintain the plant within the safety operating boundaries.

The execution of the physical modifications is initiated through the regular maintenance work order system (see Section 4.3.2) thus providing the standard documentation associated with any type of maintenance task. During the execution of the change and immediately following the change, all affected documentation shall be modified to reflect the "as-installed" state. All records associated with component testing, system testing, calibration, equipment alignment, and quality assurance must be stored within the EDMS and become the revised information documenting the modified plant configuration.

2.8. DOCUMENTATION FOR DECOMMISSION

The requirements for decommissioning documentation should be considered at the design stage for a new reactor installation or as soon as possible for existing installations. Full details of the design specification and information relevant to the siting, final design and construction of the reactor installation should be retained as part of the information needed to assist in decommissioning. Essential information required for decommissioning purposes at the end of the operational lifetime should be identified. This information should be collected, maintained and revised throughout the operational lifetime of the reactor. Such information may include as-built drawings, models and photographs, the construction sequence, piping, details of construction, cable penetrations, repairs or accepted deviations in components and structures, and location of reinforcement bars.

Accurate and relevant records should be kept of the operating phase of the installation in order to facilitate successful decommissioning. These records should be configured so that those relevant to decommissioning may be readily identified. In addition to drawings and diagrams, photographic records of the construction and operational phases should be kept. Those records should include:

- Details of the operating history of the reactor, including records of:
  - Fuel failures and fuel accounting;
  - Incidents leading to spillage or inadvertent release of radioactive material;
  - Radiation and contamination survey date, particularly for plant areas that are rarely accessed or especially difficult to access;
  - Releases that could potentially affect groundwater;
  - Radioactive inventory;
  - Wastes and their location.
- Details of modifications to the plant and maintenance experience including records of:
  - Updated as-built drawings and photographs, including details of the materials;
  - Special repair or maintenance activities and techniques
  - Details of the design, material composition, and the history and location of all temporary experiments and devices.

It is essential that planning for decommissioning includes full knowledge of relevant data as made available at the construction and operational stages and the possible creation of new records if any. Early planning for decommissioning is needed in order that decommissioning oriented documents be made available in good time and without undue delay. This requires the early establishment of a data acquisition system including radiological measurements, three-dimensional computer aided design (CAD) simulation, identification of as-built drawing, etc.

3. INFORMATION PROCESSES AND TECHNOLOGY

The section provides an overview of the relevance and potentials of IT for NPPs documentation. It describes general trends and specific aspects of IT that satisfies the requirements of NPP as depicted in Section 2. The concepts of enterprise resource planning (ERP), engineering data management (EDM) and product data management (PDM) are also introduced.

3.1. INFORMATION TECHNOLOGY TO ADDRESS NPP REQUIREMENTS AND NEEDS OF DOCUMENTATION

For many years, the approach for building information systems has been to start from the existing work processes and development needs of the specific customers and then to establish a tailored system that solves those problems. Often in-house development and own IT staff were used to design and maintain these systems. As problems have been solved one at a time, isolated systems of different ages and technology have been the result. In many cases, these "legacy" systems have become obsolete, but still are considered as vital for business operations.

As the progress of IT advances rapidly, standardized databases and software tools have made application development easier. At the meantime the growing need for integration has increased the number of interfaces and led to high costs. In addition, the complication of distributed multi-tier architecture, rapid technological change and the requirements for system quality have made in-house software development of information systems impractical. A clear trend in building information systems in the nuclear industry is toward using commercial off the shelf (COTS) components and software tools (also see Appendix D and E). Nevertheless, it is advisable that in-house expertise on configuration control and quality assurance should be maintained.

3.1.1. Information technology aspects

In the past decades, a great deal of hardware and software advancements occurred. This can be best visualized by the introduction of the personal computers with its advantages and disadvantages. In former times, the mainframe computers stored all valuable information and only terminals were accessed to the mainframe computers without the capability to include computation and intelligence. Today, a lot of software functionality has been implemented into the PCs, with much faster and user-friendly solutions compared to the mainframe computers.

On the other hand, this fast development of PCs led to the development of many individual solutions for the plants that are not well linked together and integrated. Therefore, it is very important that the individual "islands of information" are reconciled. The same trend can be seen in software development. The recent introduction of integrated products shows the tendency of using more centralized and generalized systems to replace the individual solutions.

A trend to standardization of processes and software has been observed. Enterprise Application Integration (EAI) is a common term for modernizing and linking together the existing legacy systems and new computer applications of an enterprise. EAI encompasses modern multi-tier software architectures and different middleware technologies, such as cross-platform communication using message brokers, message queuing approaches and application servers managing common databases. Following this philosophy, the problems of interfaces among the applications are reduced and the communication is improved.

A number of commercial products have been developed to address the needs of documentation and information management. The following gives an overview of electronic documentation management systems (EDMS). Further details can be found in Appendix D. Some issues related to configuration management (CM) are discussed in Appendix B.

Engineering data management (EDM) refers to the management of documents using computers and mass storage. There are typically many kinds of documents such as letters, reports, specifications, CAD-drawings, invoices, sales orders, photographs, phone interviews, or video news clips, etc. An EDM system allows its users to create, store, edit, print, process, and otherwise manage (e.g. version control) documents in image, video, and audio, as well as in text form. An EDM system usually provides a single view of multiple databases and may include scanners for document capture, external tools for editing the documents and printers for creating hard copy. Server computers are typically managing the relational databases that contain data and links to the documents, and the actual documents.

Commercial EDM systems can be geographically distributed. In addition, the Internet/Intranet is an effective tool for communication between the sites and the headquarters. The information can be exchanged through e-mails or viewed using browsers simply. Even a video conference may be performed using the Intranet to save travelling time and costs. The same can be done for communication between owner/operator and constructor/vendor by using a specifically adjusted extranet.

3.1.2. NPP requirements aspects

The documentation referred to in Section 2 is the starting point for defining requirements to IT based systems. A main focus is the workflow activities that necessitate decisions and rationalize these decisions. Documentation of the design phases should be put into a database of information that will constitute the backbone of a rationalized database system (RDBS). The subsequent life-cycle phases will use and refine this database so that design basis are constantly kept updated and well tracked.

Typical NPPs have huge amount of documentation. The relationship among the documents must be established. This is a way to fulfill the tractability requirements from the regulatory authorities as well as the needs of operation and maintenance. While the documentation of many power plants that were designed and built in the 1960s and 1970s are largely in paper forms, it is advisable that at least the documents that undergo constant changes should be transformed in electronic database format. Using tractability as a key feature of rationalized database. By means of links or advanced search and filtering mechanisms, the rationalized database solution automatically identifies information within the databases that are related.

The owner/operator should be aware of the fact that hardware and software of computers are also ageing and becoming obsolete quickly. Some current document management systems do not separate the representation of the information and the way this information is implemented. For these types of systems, a neutral format such as The image film (TIF) or continuous acquisition and life-cycle support (CALS) formats should be considered for the archiving the "living" documents. Obviously, it is an advantage if the archive could be kept 'living' which would permit a refined search of the information in the archive. This is possible if there is a clear separation of information representation and implementation in the archive.

3.1.3. Safety aspects

Due to the focus on safety for a nuclear power plant, special attention on linkage functionality between the numerous pieces of information is needed. The user of an EDMS should be supported by a system that has a search algorithm to find all relevant document that are involved in a case of equipment failure or accident. This functionality presumes a consistent use of concepts within the documentation. That is, the data model behind the documentation should represent the plant model with the links represented in different reaction chains. Aiming for a rationalized database is a step in the right direction to achieve this functionality. For example, in the case of a fatigue of certain pipe fitting, the corresponding cut of the fitting, the isometrics, the P & ID and the associated stress calculations should be available. Beside this, design basis documents describing the reasoning for the design of pipe and fitting should be available.

The EDMS used for safety considerations should also be capable of keeping track of all changes and modifications in the plant, to reflect the proper situation and current status of the plant. For example, the change request should always include the proper amendment or modification of the documentation including the changes in the SAR.

It should be recognized that the introduction of a rationalized database system for engineering data management for the whole plant life-cycle must ensure the quality and correctness of the system and that the functionality thus provided must be rigorously verified and validated. In observance of this the owner and operator of the plant must make a plan on how to achieve the acceptable level of quality for safety considerations. The framework of the plan is also given by the regulatory bodies as described in Section 2.3. Overall speaking, higher quality documentation with fewer traces of inconsistencies increases the safety of the plant as a whole.

3.2. RECORDING AND STORAGE OF INFORMATION

The recording of information is the entry point of information coming into the document management system. Storage of information is the step between the recording and processing/retrieval of information. Recording can be done by means of several types of tools such as CAD systems and word processor. Storage can be done by means of methods such as microfilm, paper, magnetic disks etc. In the context of information related processes, there are two main treads; the activities and participants that generate information and those using the information that are previously generated.

Individual users can be information providers and information consumers at the same time, using existing information to produce new information. In the past, activities involving the "consumption" of information is involved with significant cost of ownership throughout the NPP life-cycle. Some of the cost is due to an insufficient production or update of information. The implementation of a rationalized database moves the focus from consumption to the production aspect. The increased cost to produce better documentation will be outweighed by the decrease in the cost of information consumption. Therefore, information technology can play a significant role in reducing the cost of ownership by facilitating the recording, storage and retrieval of the information required to perform various activities in the plant life-cycle.

The effectiveness of IT tools in facilitating the use of the documentation produced during the design and procurement stages of the plant life-cycle, is greatly dependent on how the information is stored, rationalized and opened for use by external applications. It is therefore critical to understand the information needs of the consumers in order to best architect the information model populated by the "information providers". In addition, the O/O must have an IT development strategy that provides a clear understanding of the scope of future information needs.

3.2.1. Rationalization of information

This section enumerates important factors that influence the rationalization of available information. They are both challenges and opportunities challenges because there are legacy systems that cause problems, and opportunities because new IT solutions can put an end to these problems.

The process of establishing and maintaining the rationalized information base is highly dependent on the type of project. In the case of construction projects, the relationship and the manner in which the EPC's and the O/O work together to achieve results become the determining factor. If the EPC have documentation available that can be used to recreate rationalized knowledge and the EPC understands the information needs of the O/O, there are chances that the rationalization process will yield results. The rationalization process should render the following results:

- Sources of information that are leveraged and accounted for;
- A streamlined and rationalized information data model;
- Elimination of current and future use of "rogue" applications;
- Provision of optimized techniques to record new information so as to ensure that the plant configuration is maintained at all times.

The ultimate goal of the rationalization process is for NPP staff to be able to access the correct and complete documentation they need, when they need it. Thus, a highly beneficial model is practical if all participants of the IT project are motivated to perceive it as a critical goal throughout the plant life-cycle. There are many factors that may motivate the users of the documentation and the members of the IT documentation project. Some of the major factors presenting a challenge are described on the following sections.

Document and data diversity

Regardless of which type the IT project is, the existing documentation are often represented in many formats. At one end of the spectrum, there is the modern digital environment where the information is available to access in electronic format and containing built-in relationships between data objects. At the other end, the native format of the data is sometimes paper or raster based, such as those from suppliers, regulatory agencies, etc., with little inherent data access potential. The diversity is not only a challenge to the current workflow processes, but also a challenge in the accomplishment of the rationalization process.

A challenge is the process of defining an architecture that would generate sufficient functionality associated with the paper and raster media and to integrate it with the accessible data produced through the applications supporting the document management. The result needs to be a coherent data model that delivers the rationalized information base.

Entrenched work processes requiring re-engineering

Work Processes that previously sustained producing and storing documentation and 'silos' of information need to be redesigned in order to support the desired data model for an EDMS. The cost/benefit of these old work processes is often low-value, but nevertheless, they are needed for the running of the plant. A motivation to carry through a renewal with modern IT technology is to remove, inefficient work processes, change existing tasks and replace them by better and more dependable working tasks.

By planning for and addressing the challenge early in the implementation process, there is a great opportunity not only to streamline the operation but also to provide meaningful feedback about the system during the design and implementation phase and thus steering it in the right direction.

"Rogue" applications

"Rogue" applications are often referred to as some already existing information bases that are the result of attempts by individuals to automate certain portions of their work. In many cases, they are adopted by a group to fill the gaps in the NPP's information base. These rogue applications become a problem when they compete with the main information system being adopted by the organization.

An appropriately designed rationalized database will eliminate the need for making new 'rogue' applications by enveloping their functionality and providing the information they generate, within the confines of the rationalized information base.

The changing state of information technology

Implementation and maintenance of an IT based system is a work in progress until the plant is decommissioned. The rapid changes in the technology offer new opportunities for improving the information model and further facilitating access to plant documents. The same rapid changes may also be destabilizing as they may require numerous software and hardware updates, put system vendors out of business or render file formats obsolete. A challenge is to understand that changes are unavoidable. Rather than concentrating on stopping or resisting change, the emphasis should be in managing the changes in a such way that takes advantage of opportunities while mitigating the associated risks. Further details are discussed in Section 8.4.

The problem of constantly changing IT solutions is a widely recognized problem outside the NPP domain as well. An appropriately designed rationalized database must thus be structured into two levels; an upper level (often referred to as the 'knowledge level') in which knowledge is represented in a way independent of implementation and IT tools, and a lower level (often referred to as 'symbol level') that implements the information represented at the upper level. Changes in IT will thus only affect the lower level and the upper level of plant knowledge and information may be kept unchanged. Migrating to newer IT solutions means to redefine the mapping from the 'knowledge level' to the 'symbol level'. This is further explained in Section 9 referred to as 'knowledge management'.

3.3. RETRIEVAL OF INFORMATION

Retrieval is the process of getting or recovering information from storage. Retrieval of information is generally supported by techniques that include the following:

- Menu driven techniques;
- Keyword driven processing;
- Various navigation techniques;
- Hyper-text based navigation;
- Attribute driven processing;
- Object oriented techniques;
- Knowledge management techniques.

For older NPPs in which many documents are paper based, the conversion of the traditional paper and microfilm media to electronic file systems should be done with an understanding of the abilities to access the NPP documentation over the full plant life-cycle. The pace of change affecting IT systems and file standards is such that over the thirty to forty years of plant life-cycle, several major systems migrations will probably be required to maintain the ability to continue to access the Documentation.

In planning the implementation of an IT system, the long term archiving and retrieval aspects should be considered in addition to the focus which is normally placed on the system functionality and architecture, as they relate to "on-line" access based on the factors discussed in Section 3.2. A long-term strategy should be developed to cover the following:

- File formats that are as close to established universal standards as possible;
- Document management system selection in the context of:
  - Product life expectancy;
  - Operating systems stability;
  - Database engines stability.
  - Hardware platform stability, including those for storage systems;
- Ability to migrate information to a new rationalized information base.

The strategy must provide ingredients to ensure the tracking of technology, file formats, changing standards and platform (hardware and software) obsolescence.

3.4. PROCESSING OF INFORMATION

In the computer infrastructure for the nuclear power plant, the information is available to the users in accordance with their needs. Generally, the information is generated by and also used in different work processes and activities. Different sources of information are generated and maintained by the following:

- External organizations e.g. vendors, regulatory authorities;
- Internal departments as for design, maintenance and operation, etc.;
- The process systems.

To address the processing of information, it is important to understand the typical users and their need for information as well as the availability of information for use in IT applications.

3.4.1. Users of information

There are different users of plant information in various functions of the plant organizations, such as operation, maintenance, technical support, design and safety.

Operations

Staff members of the Operation Department are primarily using the sources containing the real time or historical process information. Other major information in documents is the operating, alarm or emergency operating procedures and the technical specification, which provides the condition for operating the power plant. For the purpose of coordination with the maintenance and especially for lining up the systems, some information for planning and work permits are made available during operations. The Core Physics Department provides information for manoeuvring the control rods and fuel management. For fault tracing during process or equipment alarms, documentation for the design is needed. Technical specifications are required for planning of the plant operation during disturbances and alarms or for executing periodic surveillance and testing.

Maintenance

For planning maintenance activities input is required from the operations about the condition of components and the failure records. The Departments for Technical Support or Operations typically provide the needs of preventive maintenance. Information about plant modifications and replacement of equipment that scheduled for outages is provided by the Technical and Design Departments. Additional information for planning the maintenance as for spare parts, lubricating materials, hiring of personnel and maintenance contracts is provided by the administrative systems. Procedures for preparation, executing and finishing of the maintenance and records of previous maintenance actions must be available with detailed information. The information needs for maintenance is dictated by a work process where the many information sources from operations, technical support, design and licensing etc. are integrated.

Technical support

Historical process information may be used for evaluations of long-term operations and improvements of systems or operation procedures. Examples of important types of information are the condition monitoring of components and the water chemistry for the reactor primary system. For analyzing incidents and to write reports, the transient process information must be available. A statistical evaluation of component failure reports is used for replacement of weak components. During complex transients and emergencies, information about the design basis for each system must be available for technical support to the operators.

Design

Design documentation is the backbone of the information base in a NPP. The main responsibility of a design department is to know how the systems in the plants are built and the functions for plant operation and safety. The knowledge and information bases include the background for the system design as standards, process simulations, calculations, transient and safety evaluations, and interface among different systems. A major task for design is to plan and organize modifications of existing equipment or installation of new ones. The members of the Design Department who often act as project leaders must have the information available related to their task. As more and more design work is outsourced today, the design Department should be the focal point to provide relevant information to the subcontractor.

Safety and quality assurance

The Safety Department of a NPP is responsible for the interface with the regulatory body. Depending on the organization, the department can be responsible for the safety analysis report (SAR). However, this responsibility can be distributed to the organization for each reactor plant. Therefore, the department needs information of all applicable licensing materials, standards, regulatory guides and other documents that are referred to in the plant safety report. All correspondence to and from the regulatory body and meeting notes must be available in the documentation. The QA department is responsible for the QA manuals, procedures and their implementation for the whole company. The different organization units may be responsible for their parts of the QA manual. Evaluation of audits and sometimes of V&V activities are done by the QA department and should be stored in the IT system.

External organizations

Information of NPPs must be transmitted to and from associated external organizations. Typical examples are:

- Regulatory authority for safety analysis and different kinds of operational reporting;
- Vendors for execution of contracts;
- Third parties or consultants for design or other independent reviews;
- International utility or plant organizations for safety or operational reporting.

The trend is that this information transfer to and from the external organizations will increase in the future. A result of the deregulation of the power market in recent years led to increasing work outsourced to external contractors. The utility will concentrate mainly on operation and maintenance rather than design and installation. The aging of power plants may result in increasing amount of plant modifications and backfitting, thereby make the information transfer with external organizations more important than before.

3.4.2. Sources of information

As described in the proceeding section, there are different types and sources of information that are required for treatment and processing. Most of the information may be provided by a well-structured engineering document management system (EDM). Other information is provided by different kind of databases and by real time or historical process information. An overview of the different information sources relating to a typical existing plant is illustrated in Table II as below:

Table II. Different information sources of a typical NPP

INFORMATION	SOURCE					
	Electronic Document Management		*Process information*		*Component database*	*Design database*
	Internal Doc.	External Doc.	Real time	Historic		
Process operation and Maintenance						
Operation procedures	x		x			
Technical specification	x					
Work permits	x		x	x		x
Maintenance planning	x	x		x		x
Fuel management				x		x
Preventive maintenance				x	x	
Modification planning	x					x
Human resources	x					
Maintenance records	x					x
Technical support						
Long term operation				x		x
Transient records				x		x
Failure reports	x		x			
Standards and codes		x				
Project management		x				x
Installation planning		x				x
QA and safety						
Dosimetry	x					
Access control			x			x
SAR	x	x				x
Document register	x					
Correspondence	x	x				
QA manuals	x	x				
Qualification records		x				
Handed over records	x					
Audit reports	x	x				

3.5. ACCESS CONTROL

The section addresses access control systems as part of the implementation of an IT system for management of the NPP documentation. Access control is generally used to enforce a sufficient degree of quality assurance, configuration control and data security. Access control needs to filter the viewing of information, based on the security clearance assigned to the user of the information system. In this case, access to view information could be filtered based on:

- The security level assigned to the document that are viewed only by users with matching or exceeding security levels
- Through the implementation of user groups whose members are the only users allowed to view the information that are restricted to members of the group.

For example, contractors may not be permitted to view certain proprietary documentation and correspondence may be restricted to certain groups of users or based on their positions within the organization.

Access control also needs to regulate or limit what the plant staff can do to the information once they have accessed it. In general, this will be related to the specific work process and the users role within that workflow. For example, a designated engineer or programmer may modify a document while a reviewer may only comment on it.

3.6. PUBLICATIONS AND DISTRIBUTION OF INFORMATION

As information is stored in data banks or an EDM system, a publication system should be capable of merging different formats from different servers and neutralizing them. A publication tool should be capable of treating one report with multiple annexes that consist of e.g. spreadsheets, transparencies, AutoCAD drawings and so on as one document.

The distribution function for documentation management should consider both short term and long term relationships. For short term relationship, distribution should deal with e-mail or ZIP-files for larger files. For long term relationship, the intranet and extranet relationship should be used.

4. PLANNING OF INFORMATION TECHNOLOGY PROJECT FOR DOCUMENTATION

4.1. PROJECT DEFINITION

The definition of an information technology (IT) project should start with an analysis of the as-is situation. The findings and problems that are identified in the analysis may serve as the requirements and needs for the introduction of an engineering data management (EDM) system as described in Section 3. In the analysis of as-is situation on documentation, typical deficiencies and shortcomings on the plant concerning documentation are the following:

- As-built plant status is not reflected by the documentation;
- A huge effort in engineering work is wasted and not adding values for searching the documentation;
- Paper documentation is worn out and cannot be handled nor upgraded;
- A large amount of information and data are distributed in different tools, databases or private desks;
- Reduction of experienced staff who know the cross-references.

For defining the project, it should be considered that all documents treated should be available on each user's desk by simple search and retrieval. This may involve changes of work process. A cost/benefit analysis should be undertaken for the specific situation under consideration. This should comprise the evaluation of the cost for the hardware and software, the network capacity, and the training of the staff. In addition, the cost for transferring the paper documentation to the electronic format should be quantified. An estimate should be made for the cost for operation and the maintenance of the system as well. The costs should be balanced out against or outweighed by the savings in manpower and working time. In many instances, there are hidden benefits that cannot be expressed in term of quantified cost savings. A good EDM also system increases the quality of the documentation and helps standardization of all documentation in the company.

In the project definition, improvements due to introduction of engineering data management (EDM) are typically the following:

- Documents treated are available by simple search and retrieval;
- Documents are reliable and unambiguous;
- Information can be discussed on teleconferences;
- Change of working processes leads to improvement in efficiency;
- A higher quality and better standardization of documentation is obtained;
- Long time storage of documentation is organized for the whole company and not by individual organization units;
- Easier to compose packages that include many different individual documents.

A step-by-step method is recommended to introduce the EDM system to the whole staff. It should be initiated like a pilot project to start with a smaller group that is favourable to the introduction of the new IT tool. After the pilot project runs well, further units working together should be introduced to the EDM system. At the very end, the whole plant and perhaps, the headquarters are covered. Often times, the introduction of an EDM system is initiated by a policy decision for the whole company.

4.2. METHODOLOGIES AND APPROACH

The planning stage of an IT project primarily includes the issues of requirements specification and cost benefit analysis performed at the client side before any contracts with the vendors are made. The key decisions about the scope, goals and system architecture are made during this early phase. Such decisions are made after investigation of available standard systems on the market and discussions with vendors. In addition, the general approach to running the project should be defined as well. This includes project organization, end user participation and quality assurance, etc. The specific methods and tools for system specification, documentation and project management should be select or outlined.

The general approach to apply IT should be part of the technology strategy of a NPP or of the partners involved in the design and construction of a new plant. It is important to recognize that development of an IT project may lead to an issue that requires a change of existing organization. This often means a redefinition of the work processes as well as the use of multi-disciplinary design team that consists of different engineering disciplines and end users. Generally, management of documentation and information is considered an integral part of the plant organization. However, documentation can also be seen as a specific aspect or subtask within the total IT project.

The planning approach is affected both by the intended scope and functionality of the information system and by the existing technical solutions on the market. The strict quality requirements and limited volumes of the NPPs stress the use of standardized and proven solutions and experiences from other industries, in particular the process industries (e.g. the pharmaceutical manufacturers face similar documentation and traceability requirements.).

However, there should be a focus on the important issues specific to the NPPs. Thus two main questions that should be addressed are:

- How should in-house involvement and actual software development and programming be utilized?
- How should the integration issues be resolved? Should there be a single or multiple suppliers? Who would be responsible for linking the applications?

The owner/operator of the NPP should sort out these questions, as they would impact on the project definition greatly. A structured life-cycle model for IT projects is needed to enable project management and allocation of responsibilities. Section 5 is organized according to more general subtitles in order to group the essential requirements for design and execution of IT project for documentation.

In principle, the current or new work processes should be first analysed to identify key features and current problems. The roles of humans and computers should be specified explicitly. This creates a list of functional requirements for the information systems and a list of manual tasks. Next, the required computer functions are refined and re-structured in order to identify the future subsystems and modules.

Process characteristics, such as timing requirements, volumes of information and operations, and their importance in terms of risks and economic values, may be used to determine the priorities and non-functional requirements (e.g. availability) of computerized functions. Suitable requirements for future expansion or modification should be defined independent of the current software or hardware. This is an iterative process. The design constraints should be identified and the total solution should be evaluated to find a 'global optimum'. This means that the work processes and initial task allocations may need to be changed during the design process.

The new IT and software architectures may have profound effect on the ways projects are carried out in practice. Recent trends of nuclear power applications emphasize the use of COTS that usually provide higher quality and reduced costs, at the expense of limited possibilities for customer specific solutions. This directs the role of the client to the following iterative tasks:

- Analysis and redefinition of work processes;
- Specification and prioritisation of requirements (originated from management, end users or authorities);
- Review and evaluation, or audits, if necessary, of suppliers and their solutions;
- Negotiations of contract and agreement about the roles and responsibilities of each partner;
- Refining requirements together with the suppliers;
- Review of the detailed specifications produced by the suppliers;
- Tailoring of the purchased standard software;
- Monitoring the implementation;
- Planning for participation in the end user training and commissioning of the system;
- System validation and acceptance;
- General project management;
- Planning and carrying out quality assurance activities during all project phases;
- Setting up an organization for operations and maintenance.

There are different practical working approaches, design methods and documentation standards that can be used for each of these tasks. They will be discussed in more detail later in the corresponding paragraphs.

4.3. NUCLEAR POWER PLANT CHARACTERISTICS

4.3.1. Workflow

As the documentation is stored in an electronic format, it can be made available to everybody who is associated with it. With the access capability through the digital media, the working processes that depend on the use of documentation can be streamlined into effective workflows. The workflow thus takes over the control of the administration of the working sequence. With this feature, administrative measures are supported so that the documents can automatically flow among a specific working process to improve its efficiency [6].

The major elements of work processes for the various activities in an organization that need to be considered for an IT system are:

- Management of technical data and design;
- Financial;
- Human resources;
- Operation;
- Maintenance;
- Purchasing;
- Reporting to authorities;
- Site access control.

To illustrate the effectiveness of streamlining documentation in a workflow, an example on design may serve as a good demonstration. During the design work, a lot of drawings are produced, reviewed, approved, released and distributed. Furthermore, different people at different sites sometimes revise drawings due to different reasons. So, a working sequence, or called workflow, can be set up related to specific persons or roles. As a document enters this workflow, it follows the prescribed sequence. The location and status of the document in the workflow can be monitored and controlled by the responsible managers, thus avoiding bottlenecks in due time.

4.3.2. Work order management

In the nuclear power plant maintenance work, significant amount of work is associated with administrative activities which are called work orders, such as writing, reviewing, scheduling, planning, and closure, versus actual work in the field [6]. Improvement to the work order process can be made to include the capability that allows a planner to completely assemble a plant work order electronically, including processing work instructions, associated surveillance instructions, technical guidance, and other references. The package is then in electronic storage available for review by other work order planners.

Typical work order process at plant site consists of the following main activities:

- Initiation planning and securing resources and material;
- Safety analysis;
- Plan of work order (converting work request to work order);
- Work control;
- Scheduling of work order;
- Worker order material;
- Supervisor approval, including approval by operations shift supervisor;
- Perform work;
- Close work order;
- Lining up of systems for operations and confirmation of configuration with the operators;
- Document control.

The application of IT allows the redesign of the work order process to eliminate redundant entry of data and unnecessary steps in the workflow of the process. The redesign also allows for automatic electronic routing of work orders and permits in parallel, and utilizes electronic signatures for document approval. The results show that filing and distributing of thousands of hard copies are no longer done, manual revision verification are not needed, and manual tracking of documents are not required. The IT for the work order management system can allow for access to information including financial, personnel, asset, and inventory, thus providing electronic development, distribution, documentation, and control of plant maintenance work. Thus, the use of IT for work order management can enhance greatly the efficiency and productivity of operations and maintenance at the nuclear power plant sites. Another aspect will be that reporting to the authorities for changes in safety systems can be streamlined.

4.3.3. Asset management

The section covers planning within the context of existing facilities as well as that of built projects. Asset management and documentation are presented as a critical part of maintaining NPP plant configuration control. Managing the information pertaining to the NPP equipment and maintenance records, should be a key objective when the implementation of an IT system is planned. The information related to the plant equipment is divided in two key areas:

- Equipment function data, normally associated with the equipment tags and described in the design documentation;
- Equipment asset data, representing the physical equipment or device used to fulfil the equipment function normally associated with a serial number.

The asset management component of the system provides:

- The ability to record and access the tag of a specific asset;
- The ability to maintain a status record of the plant equipment assets including current assignments, deposition if out of service, etc.;
- The ability to access the historical information of the plant equipment assets, which includes preservation records, location record, service record, and exposure record;
- The ability to access the associated documentation at the correct revision level, including design data, supplier information, registration documentation and maintenance instruction.

In the context of the NPP configuration management, the asset management aspect of the IT documentation system being considered is critically important. It documents what is currently being used to operate the plant and the available spare assets. The asset component of the IT system is often referred to as the plant component database. Another important part of asset management is the standardization of tags identification for the whole plant.

While asset management is required during the equipment design installation and plant operation, its requirements must be understood and factored into the system architecture of the IT system. The utility as the main stakeholder, should work with the EPC early in the design phase of the project to ensure that the design equipment information is provided for the plant's asset management system. Very often, the component database used by the EPC may be used by the utility as a starting point.

4.3.4. Paper and drawing documentation

There are some general guides for the procedure of conversion from a paper based documentation to an IT system. The following are some criteria for considerations:

(1) Safety impact;

(2) Amount of accesses;

(3) Amount of periodical changes;

(4) Quality of the existing documentation;

(5) Media applied for the existing documents.

In item (1) as listed above, the highest priority must be given to the documentation that are relevant to safety and those associated with the licensing authorities. The content of the safety documentation is governed by the specific guidelines of the individual country affected. The basic design philosophy as specified and recorded is clearly illustrated in this documentation. Therefore, it is necessary to know the cross references among different objects and their documentation. Further, the decisions made in the design process should be traceable. An important part is the documents related to the V&V activities, like qualification of components and equipment. Both types of documentation must include the results of the final design calculations, analyses, tests, etc

In items (2) to (5), the existing documents should be sorted according to their specific number of accesses and modifications. So, one can set up the following matrix as an example:

Table III. Documentation matrix

Document type	Document characteristics		Number of accesses			Number of modifications	
	Medium	Quality of doc	Per day	Per month	Per year	Per month	Per year
Design basis							
System description							
System diagram P&ID							
Piping calculation Isometric							
Piping fabrication Isometric							
Civil plans							
Steel structure plans							
Operational handbook							
Logic diagrams							
Component specification							
Weld inspection specification							
X-ray diagrams							
Ultrasonic inspection results							

From this matrix, a priority for the conversion may be derived. The documents with the highest rate of modification should be addressed first. As the documents with the most frequent access rate are worn out first, they should also be the first to be digitised. The same is true for objects with a poor original documentation.

For the benefit of easy access, all the paper documentation should be scanned in digital forms. Different types of scanners may be used according to the format. The recommended format is TIF format as standard for long term archiving of documentation for reports and drawings. One may also consider the factor whether or not to make the documents "intelligent". This consideration should account for the costs of treating the documents manually. But it should also account for the fact that an efficient searching algorithm can remarkably reduce the time for searching, thereby increase the efficiency.

4.3.5. Knowledge management

When introducing an IT system, it is also possible to implement the concept of knowledge management. The term knowledge management may be interpreted as the process of capturing, maintaining and reusing the incorporated information in a comprehensive and systematic way. An emphasis should be put on the words "comprehensive" and "systematic". Comprehensive means that ideally all type of enterprise activities should be under scrutiny and there should be an ongoing justification of the set of information to be managed by the system. However, handling all information using this systematic way may be unfeasible or impractical because of the huge amount of information and its complexity.

Systematic means at least two things. First of all, one should try to establish a common information model that can be used to describe all information to be managed. The second implication is that the information model should regularly be revised to reflect new needs and insight of the organization. Each single type of information in the information model should have its own name. For composite information, the larger element should be further refined by naming each individual element within it. The information model should at least fulfill the following criteria:

- Each information type name must be widely used and understood in the organization;
- There should be no duplication in the naming of the elements, i.e. each information element should have only one name;
- The set of information types should be expandable.

The last requirement is particularly important to be able to have a living information model, a model that reflects the current needs of the enterprise. The knowledge management should include formal and informal knowledge. This means that all existing IT systems should also be included in the knowledge management plan. Moreover, informal information should be associated with the formal systems whenever appropriate. If the enterprise succeeds to make this tight integration of all formal knowledge sources, they will be in a much better position to achieve a rationalized information base.

The inclusion of informal information is a challenge to the knowledge management. It is particularly difficult to foresee the future needs of this type of information. It is also sometimes difficult to detect its mere existence, because it may easily evade the attention of the people responsible for the knowledge management process. A typical example is rationales remaining in the minds of those people who originally made the decisions. Such cases can probably not be eliminated, but they may be reduced in number by the enforcement of a premeditated knowledge management strategy.

Knowledge should preferably be stored in an electronic format in an EDMS. In this way the access of knowledge can be facilitated by computerized techniques for retrieval. However, for this to happen, knowledge must be captured by the data system that assists in the knowledge management. Capturing of knowledge may take place at the following points in time:

(1) When knowledge came into existence;
(2) When the staff decide knowledge should be managed;
(3) When knowledge is first needed.

The best possible way to capture knowledge is as referred in number 1. However, this is not always possible. The next best point in time is number 2. At this stage one still have time to integrate the knowledge into the electronic management system so that it can be useful when situation number 3 occurs.

The description given above pertains to a NPP that has a fully developed knowledge management plan. However, for most NPPs, they have only a fragmented knowledge capturing plan, based on non-coherent legacy systems. In case such a typical NPP should desire to implement a full knowledge management plan, the only feasible way would be to take it step-by-step. A strategy should be made on how to achieve this in the long run. One should therefore try to record both feasibilities and obstacles. The following issues should be considered:

- How can a "knowledge culture" be established at the plant?
- What existing sources of knowledge are at disposal? Are those resources available for knowledge management work?
- How do we deal with legacy systems? Can they be used within a knowledge management framework? Is there duplication of information within these systems, which can be rationalized by automatic means?
- Identify computerized tools to assist in the knowledge management. A standard should be used for the knowledge storage, as it minimizes the dependencies on the knowledge management tool set.
- Identify additional information for knowledge management, which may be continuously revised.

4.3.6. Database and objects

Generation, capture, management, sharing and utilization of information are paramount in the construction, operation and maintenance of nuclear power plants. Even if the business area is relatively stable, the cost structure, complexity and safety requirements continuously increase the role of organizational learning, optimisation of operations and tight control of procedures.

Managing the huge amounts of information created during different life-cycle phases requires clear concepts, procedures and tools. There is a need for a rationalized information base, which is introduced and described in Section 3, as a basis for both manual and computerized information management. This model should include concepts for describing:

- Organizational structures and individuals;
- Work processes and work flows;
- Different types of documents;
- Relationships among these concepts;
- Quality control related documents;
- Informal information (correspondence, meetings, personal notes);
- Previous versions, planned modifications;
- whole-parts hierarchies (product structure);

This cumulating information repository, the 'rationalized information base', should provide virtually all the information related to a nuclear power plant including, for example:

- Technical design data: design rationales, requirements, functions, implementation;
- Design data basis for the whole plant;
- Technical systems and components including their functions, operational states and configurations;
- Safety analysis;
- Operational environment, buildings, rooms;

- Operating experiences;
- Training materials, procedures;
- Operational history;
- Design management history;
- Maintenance history.

The knowledge base should be considered by the users as a unified data set, even if distributed to different computer applications so that they don't need to know its internal structure. Basically, all information should be available to persons authorized to have it. This is why common information models and integration of software applications are important and should be available during the early phases of plant design.

The formal part of information can be coded into relational databases describing different types of plant objects, their key attributes and relationships among them. This corresponds closely to the product structures found in product data management (PDM) systems. A NPP needs to combine product data from a large number of manufacturers with the database initially designed for a limited purpose such as plant maintenance and materials management. As new users and applications have emerged, this has often led to confusion about concepts and limitations in the expressive power of the data structure. At the same time, the database has become rather extensive, including for example:

- Hundreds of database tables;
- Multiple process plants (units and auxiliary processes);
- Hundreds of buildings and thousands of rooms;
- Hundreds of systems and tens of thousands of functional units;
- Hundred thousand components;
- Tens of thousands of storage items.

Basically, the rationalized information base consists of information objects that describe the actual plant. The requirements of project management and quality control mean that procedures shall be applied in creating, modifying and distributing information. To enable this, single information objects must be grouped as configuration items that are subject to configuration management, such as freezing and change control rules. A configuration item may be, for example, a document or a set of objects in a database. Currently, only documents generated on the basis of database contents are within strict configuration control provided by PDM systems. Many existing power plants are performing the configuration control manually.

Current design tools may not include support for configuration of objects in the database itself. However, there is a clear need to approach in this direction, as it may be identified as a requirement by the customers when purchasing new information management systems

Design data packages generally have extensive collections of configuration items that are transferred between partners for carrying out specified tasks; especially those associated with project milestones, initiation of major maintenance and modification actions. Typical characteristics of databases include the following:

- Amounts of information
- Number of users
- Location of users
- Numbers of transactions.

4.3.7. Quality assurance

For each phase of the life-cycle, there is an associated software quality assurance plan. The plans should conform to the requirements in ISO 9001 [11]. Each plan must be an integrated part of the overall quality assurance of the company. A part of the plan is related to the use of software IT tools. Engineering companies or utilities are typical users of IT tools for their working processes. These companies will define software requirements, purchase the software and integrate it into the existing infrastructure. A quality assurance plan normally contains the following elements:

- A description of the organization and management which can influence quality;
- A description of methods to specify;
- A description of provisions to be used for supervision of suppliers;
- A description for adaptation and integration of the purchased information technology package;
- A description of the verification of the final integrated EDMS;
- Procedures for maintenance and operations;
- Training for EDMS;
- Safety analysis;
- Security and configuration management.

Information technology tools and packages

The use of IT tools and packages is similar to the use of standard software in many aspects, In many NPP modernization projects, COTS are being applied for integration into a digital protection system. A modern digital protection system can be designed with hardware and software modules that are integrated into an existing plant infrastructure. Many software functions are identical for protection, I&C or administration systems. During the past years, standards have been developed and recommendations are described to perform the quality assurance for a protection system. For this reason, valuable information for QA for IT tools can be obtained by studying these documents. However, it is observed that there are differences between the QA plans for development of software and those for the integration of software into a system. Therefore, typical standards for development of software may not be applicable to engineering organizations or utilities. Some examples of QA are given in Refs [15, 16, 18, 22].

Support information

The quality assurance plans need support from documents that describe the following:

- Company's policy and overall QA program;
- Safety analysis report;
- Applicable codes and standards, regulators requirements;
- Identification of all tools used and their ranking;
- Ownership for all tools and the database service including configuration management;
- The plant network and associated networks including integration and installation plans;
- Users manuals.

Requirements

The requirements are items in the first phase to be carried out. The quality assurance plan for the first phase of work before purchasing new software or to modify existing software should contain descriptions for:

- Work flow analysis;
- Software characteristics;
- Quality assurance for suppliers;
- Suitability evaluation of standard software on the market.

Purchasing of IT packages

Tools, software for the infrastructure and workstations are mainly purchased as standard packages that are available on the market. Important points that need to pay attention during the purchasing process are:

- To verify the suitability of the software against the software requirement specification;
- To verify the quality of the software by a qualification process, either by performing quality audits at the vendors or by analysing the experiences of software already sold;
- To establish procedures for reporting of observed errors during the lifetime of the purchased software.

Adaptation

The purchased IT packages must be adapted to the workflow, user interface and infrastructure. Critical points are:

- Control of all changes made to the standard purchased item;
- Validation by prototyping in a target environment.

Operation

After the adaptation phase is done, the software will be used by many users for various applications at different sites. Critical points for the operational quality are:

- Access control to protect information against unauthorized modification and disclosure;
- Input data validation to assure consistency with the plant data base;
- Output verification if such is required;
- Reporting of observed errors or potential improvements;
- Reliability of long time storage of important information.

Maintenance

Important points to be included in the qualification plan for maintenance are:

- Identification of the authorized organizations "ownership" for different parts of the software;

- Procedures for control of changes and modifications;
- Interactions between new or modified software and other software should be analysed;
- Configuration management;
- Strategy to analyse and correct reported errors from software vendors or internal users;
- The policy to use external experts or outsourcing.

Qualification of information technology packages

An important topic in the QA plan for applying information technology for documentation is the qualification of the IT packages. This qualification can be carried out as described in the IEC 61880 supplement 1 [15]. This report describes three steps in the qualification process as:

(1) **Evaluation of suitability**
The objectives of the step are to confirm that the characteristics of the IT packages conform to the functional, performance and architectural requirements. The evaluation should be first done before purchasing and later on after integration.

(2) **Quality evaluation**
The goal for the step is to provide evidence that the IT packages have been developed and verified in accordance with the defined QA program.

(3) **Evaluation of operating experiences**
The objectives of the evaluation are to provide evidence that operating experiences are used for deficiency detection and that a system for reporting of operating experiences is in place after purchasing of the IT packages.

4.3.8. Configuration management

Configuration management is a discipline that applies technical and administrative direction to the development, production and support life-cycle of an item for which configuration needs to be maintained. The discipline is applicable to hardware, software, processed materials, services, and related technical documentation. CM is an integral part of life-cycle management.

The objective of an operational CM program is to establish consistency among design requirements, physical configuration, and facility documentation, and to maintain the consistency throughout the operational life-cycle phases, particularly as changes are being made. These basic relationships are depicted in Fig. 1. The physical configuration (" the plant") should conform to the design requirements, which are established by the design output documents. The facility documentation, which includes as-built drawings and operating (including maintenance) procedures, should accurately reflect both the physical configuration and the design requirements. Changes to design requirements should be reflected in both the physical configuration and the facility documentation. Changes to either the physical configuration of the facility or its documentation should be supported by, and be consistent with, the design requirements.

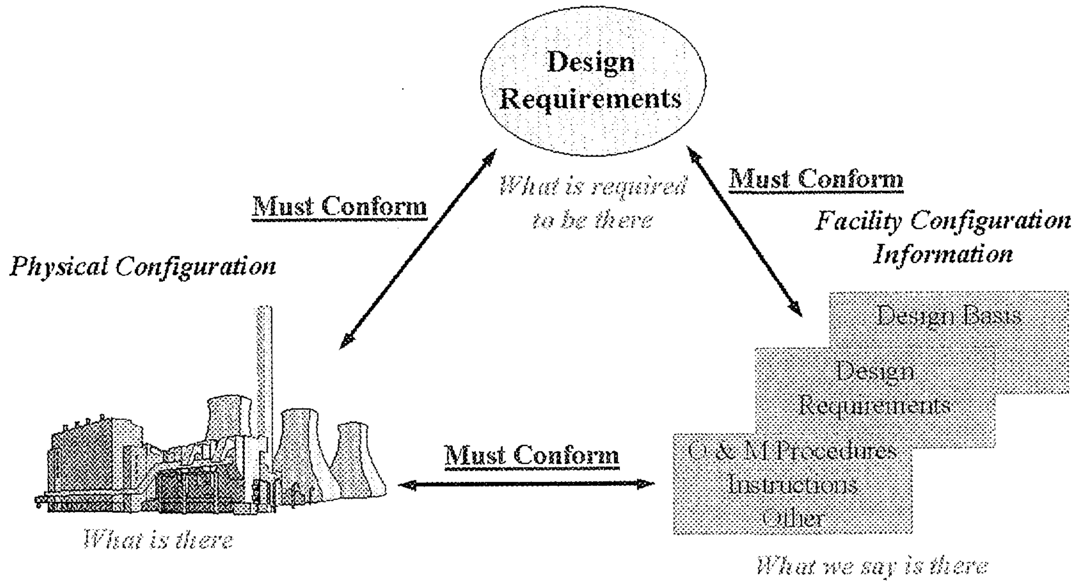

FIG 1. Configuration management.

4.4. TOTAL COST OF OWNERSHIP

A critical justification for the introduction of IT based documentation system is reducing the total cost of ownership, i.e. the life-cycle costs. The cost reduction may be achieved by:

- Making information easy to access when performing activities that involve documentation
- Delivering information for critical decisions associated with operation and maintenance of the plant
- Facilitating the recording and the updating of the NPP documentation, during the execution of operational and maintenance activities.

In order to realize the cost savings anticipated when justifying the implementation of the system, the affected work processes must be reviewed and revised. This action often referred to as "work process re-engineering" is a critical component of the system planning and cost considerations. The work process review should also help with the prioritization of the implementation of the various components of the EDM system. The prioritization should be based on targeting first the areas that have the most impact on reducing the plant costs.

The impact on of the proposed system on the TCO would have to take into account the costs incurred to:

- Procure the system;
- Prototyping;
- Tailoring and implementation;
- Maintain and support;
- Re-engineer and implement the affected work processes;
- Training and change the culture in the organization.

The projected savings associated with above items should be obtained at a sufficient level of detail and early in the project in order to demonstrate that the TCO is significantly reduced for the remaining plant life, including decommissioning at the end of the plant life-cycle.

4.5. JUSTIFICATION AND DECISION MAKING

Justification is the process to prove that the proposed development of a new IT system, an IT-tool or a modification of an existing one have sufficient reasons to be practical and economical. This section describes how such development is proposed and evaluated. The current practice is that for each working process, there is a responsible organization. This organization will develop and maintain a process that is used by other participants in order to obtain a well-defined goal. Interfaces among different organizations exist that specify the definition of information exchange and IT strategy for integration. (See Fig. 2) The main aspects for such information exchange and integration are:

- To prescribe which information is needed as an input to a working process and in which form this information should be delivered;
- To describe how the input information is treated during the process and to determine the steps within the process as for drafts, reviews, acceptance and versions;
- To specify the tools needed for the working process and for development and maintenance;
- Responsibility for development, support and maintenance of the process and the tools;
- To interpret the company policy for integration of software, hardware and user interface;
- To specify the output;
- To determine access control;
- To determine the procedures registration and storage of information.

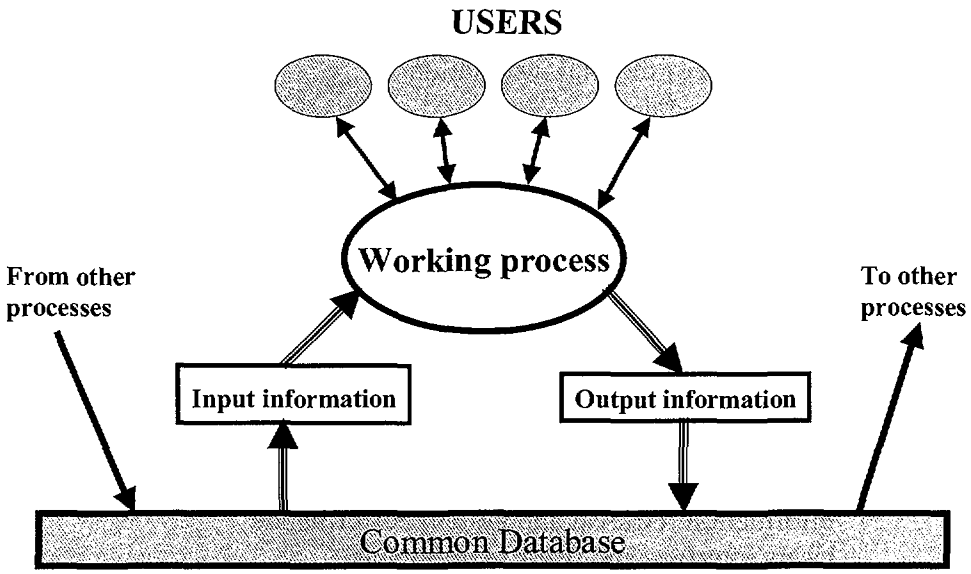

FIG 2. A working process model.

Proposals for modification of existing working processes or for using new or modified IT tools are dictated by the owners/operators. Before making the decision to start the development, a pre-project normally is decided on a lower level in the organization, which include following elements:

- Description of the idea and purpose;
- Task analysis of the proposed new working process or the modifications of the existing ones;
- Planning of simple trial use where the end users are involved;
- Analysis of costs and benefits, including costs for human time, software and hardware purchase and commissioning;
- Study of integration of new tools into existing databases or hardware structure;
- Market survey and evaluation of available standards or rules;
- Description of security rules;
- Description of flexibility and strategy for long time maintenance.

The justification process is described in Fig. 3. Based on the outcome, it is decided to propose to go further or not to start the development. This is typically done by a justification report. An example of a content of such a justification report is given in Table 4.

Table IV. Example of content in a justification report

Introduction
  Ideas
  Goals for the new information technology system
Trial Installation
  Description
    General
    Users
    Training
    Software and software integration
    Work flow
  Evaluation of the trial installation
    General
    Verification of the overall goals
    Verification of the work flow
    Verification of the training
    Verification of the users interface
    Information storage
    Information retrieval
    Performance
Comments from users
Detailed system description
Conclusions and proposals
  Information retrieval and system performance
  Users interface and users requirement
  Users documentation and training
  Coordination with other IT tools
  Costs/benefits
  Organization

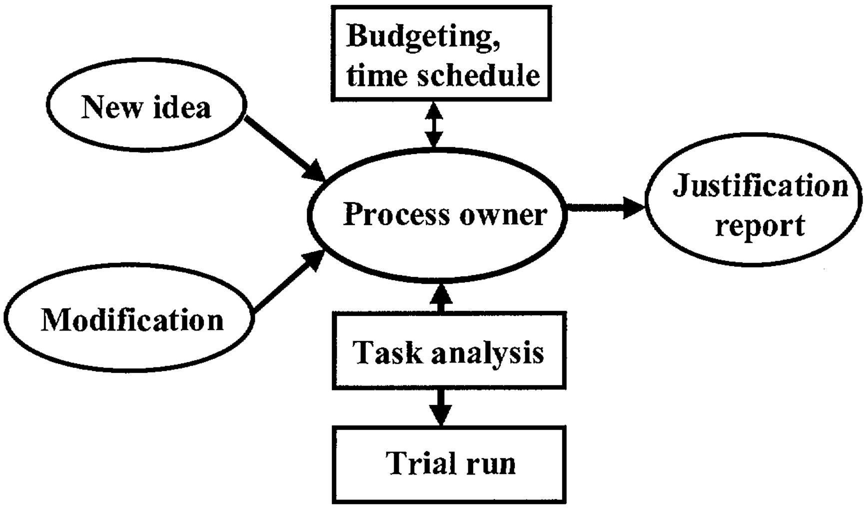

FIG 3. The justification process.

4.6. ORGANIZATION AND MANAGEMENT

Today, many NPPs have a project handbook, which describes the administrative considerations in starting, running and closing a project. The handbook outlines issues connected to the involvement of users and other groups in a project. Typical practices include the appointment of a steering group and a project group in which stakeholders are represented. A senior manager usually chairs the steering group and a project manager to whom the responsibility for the project is given leads the project group. Through interaction, the groups decide the details of the project, time schedules, specific deliverables, and milestones.

In the processes of planning and implementation of an IT system, it is essential to involve all user groups and associated organizational groups. The following is a list of issues to be considered:

(1) **Collecting the needs**
Depending on the scope and size of the documentation project, the collection of needs should be carried out formally. It usually results in a report, which is presented and discussed in project meetings. The user requirements specification is a typical deliverable from the collection of needs.

(2) **Support from management**
The support from the management is typically given through the steering group of the project. Depending on the size and the importance of the project, progress reports should be given to the management of the plant and the company.

(3) **Review of specifications**
The stakeholders in the project should formally review preliminary specifications. Typically, written comments are supplied and discussed in the project meetings.

(4) **Prototyping**
As it may be difficult for the potential users to offer specific feedback to the preliminary designs, the project may decide that a prototype of the system be built to illustrate main

design features. Such a prototype can be realized typically using a design tool to minimize the effort. The prototype is then demonstrated using some typical scenarios involving work processes and interactions between different groups.

(5) **Need of IT professionals**
Depending on the scope of the project, it may be necessary to involve IT professionals who have a clear picture of the domain to ensure that a state of the art design is achieved. For IT systems that build on standard hardware and software platforms, it is evident that specialists have to be involved in the operations and maintenance.

(6) **Planning for project management**
The initial project plan is typically created by a small group of interested people. In the plan, the administrative practices used at the NPP are reflected and divided into subprojects and tasks. Milestones are connected to deliverables for monitoring the progress. To the extend possible, the documentation system should be made independent of the implementation platforms.

(7) **Quality plan**
Procedures for quality assurance and configuration control should be defined during the initial stages of the project. A project handbook typically gives reference to quality assurance procedures and configuration control measures.

The responsibilities and roles of different participants are typically defined in a project handbook and the project description. Major ones are the following:

(1) **Users**
Users should be involved in the early stages for a new system. If the users do not see the system as urgently important, they may not be committed to participate in the specification of the new system. It may be difficult sometimes to combine many diverging views, but a consensus is needed on major design solutions.

(2) **Developers of external systems**
When the requirements for a new system is first defined, it may show that such a system cannot be found on the market or is very expensive to build. This may initiate a need to go back to the requirement specifications and to reconsider whether of not they can be simplified by using standard features, which are available on the market.

(3) **Consultants**
NPPs today do not typically have a large technical staff that can take the whole responsibility of building an IT based documentation project. A special consideration must be placed on finding consultants who have familiarity with the plant and its present documentation.

(4) **Vendors**
A large new documentation system project will most likely build on a standard system supplied by a vendor with some effort of customization or tailoring. It is advantageous if the needs and requirements can be identified before the contract for the whole system is signed with the vendor. It may also be possible that such tailored functions are included in later versions of the documentation system.

(5) **Authorities**
A documentation system using IT technology does not normally require the approval of a licensing authority. However, most NPPs today have adopted a policy of informing the authorities of all major activities, particularly those involved with plant infrastructure and work process. It is advisable for the authorities to understand that such a project improves safety by the capability of reliably tracking and updating plant documentation.

5. DESIGN AND EXECUTION OF INFORMATION TECHNOLOGY PROJECT FOR DOCUMENTATION

5.1. WORK PROCESSES RE-ENGINEERING

Information technology may be used as a tool by designers and plant personnel for improving plant documentation and performance. The information technology and work processes should be developed in parallel and with sufficient interaction between them. The following points should be taken into consideration:

- Current practices should be analyzed to identify problems. This is closely related to the modeling of business processes, including document management;
- Some improvements are possible without information technology through redesign of work processes, changing the organization structure, and better training/motivation/co-operation;
- There should be a synergy for a combination of information technology functions and human tasks. The roles of information technology in performing work processes define the functional requirements for the documentation management system.

Analysing and redesigning the work processes should be a cooperative effort. To start with, a few issues should be clarified to all participants:

- Purpose of the effort;
- Scope, focus and viewpoint;
- Basic concepts (e.g. business processes and work flows);
- Methods and tools;
- Roles of each participant in activities of information management.

The description of work processes may be of concern to the current situation, a realistic new situation, or a future optimal situation. The activities of information management and documentation are a part of the total business processes of a plant or a construction project. The goals and objectives must be clear enough to identify the problems where information technology should be applied to improve the situation. Information technology can make existing processes not only more efficient, but also simpler and more flexible. The analysis may reveal bottlenecks and unnecessary steps. In addition, the introduction of information technology may allow some actions (such as manual checks) to be eliminated.

As people from different backgrounds participate in this work, all should understand the basic concepts. On top level, a few strategic business processes should be defined covering the chains of practical work processes from different types of suppliers to different types of customers. For a nuclear power plant, the three basic business processes are: 1) production of electricity, 2) ensuring plant safety and 3) maintaining and developing the production capacity (asset management). Documentation has an important role in achieving the goals of these processes. On a more detailed level, practical procedures for carrying out specific tasks, the workflows are described.

Several methods can be used for describing and analysing work processes. Commercial tools are available for business process re-engineering. Also, object-oriented analysis and design methods, for example, the Unified Modelling Language, including graphical methods may be used for modelling both work processes and their concepts. Computerized tools are available, as either separate applications or as an integrated parts of larger software products.

In addition to the considerations above, the customers of large commercial software packages are often forced to adapt their working practices to the software products. The reason is that these packages always have some limitations and basic assumptions that can't be fully configured and parameterised to the customer's needs. On the other hand, some suppliers have collected best practices from different users for a long time and integrated them into their products. So, adopting the reference models of a software supplier may be a good solution. Finally, tailoring commercial software product has its inherent risks because implementing and maintaining customer specific solutions lead to increased costs of ownership. It may also cause problems when new versions of the software package must be installed. Besides, the vendor may not be motivated to support any special solutions.

In principle, the business process and work flows at a nuclear power plant should be initially described in a way that is independent of the information technology solutions. The resulting work processes include tasks that must be performed manually, automatically or by a combination. A balanced allocation of roles between humans and computers should be found for each task. In principle, the weaknesses and strengths of each can be used, in combination with technical and economical constraints. The solution is not either manual or automatic, but the computers and humans should cooperate in an optimal way. So, the allocation of tasks describes the roles of each in carrying out the tasks included in work processes. As commercial software is used in most cases, the task analysis and allocation of responsibilities should be kept on a rather general level.

In addition, the allocation of manual tasks between different people should be considered. The goal should be to find an organizational structure and work content. Again, the whole solution should be evaluated iteratively with respect to project goals, resulting job characteristics, and technical and economic constraints. The suggested solution should be evaluated, for example by simulation, scenarios, or talk-through methods together with the users.

5.2. REQUIREMENTS

The detailed analysis and redefinition of the work processes and assessments with users lead to users' needs and requirements. In addition, there are known constraints such as existing systems, company standards and regulatory requirements. The goal of the requirements specification stage is to prioritise and refine these into a well defined set of functional and non-functional requirements, which describe, from the users' point of view, the services to be provided for documentation management. Normally, the customer or consultant is responsible for collecting and documenting the requirements. The resulting user requirements specification can then be used for initial contacts with potential software suppliers and for requesting the actual tenders. This sort of requirement specification must thus be seen as part of the planning phase. In some cases, the supplier of the information technology is also involved in conjunction with the customers for a mutual agreement on what the system is supposed to do. In order to achieve a sound basis, a contract for the requirements specification should be complete, consistent, unambiguous, verifiable and traceable.

To specify the requirements, the following are general issues for consideration:

- Quantifiable business benefits and extra cost that an electronic document management system would bring with respect to the problems and costs of existing solutions;
- Scope and time for implementation as to whether the system should be limited to technical documents or include historical records, maintenance information and meeting notes, and many others;
- Potential impact of such a system on the people and the affected organizations;
- The role of documentation management within the total framework of information technology of the company, which has to deal with other applications that may need to be integrated.

In addition, there are also some high-level technical items to be addressed:

- Amount of existing documents, new documents and updates per year;
- Size of various documents;
- Means of current documents storage;
- Kinds of tools used, for example word-processing, CAD, databases, etc.;
- Amounts and types of users involved;
- Users location in distributed organizations, as well as external users (authorities, outsourced service providers);
- Storage times of different types of documents;
- Management of the relationships between objects and documents;
- Quality requirements and possible licensing considerations;
- Trace ability of documents;
- Security issues with respect to access control, electronic signatures, Internet connections, etc.;
- Configuration control;
- Interfacing with potentially large number of vendors and contractors;
- Existing systems and paper documentation in the plants.

For the definition of the main roles of documentation and information management, the following items need to be considered with respect to workflow activities:

- Design;
- Quality assurance;
- Licensing;
- Construction;
- Training;
- Operations;
- Maintenance;

- Plant management;
- Development, modernizations;
- Decommissioning.

With respect to different types of usage, the following factors should be considered:

- Inserting;
- Modifying;
- Communicating information within design projects and plant operations;
- Generating documents and reports;
- Searching;
- Records management.

With respect to the interaction with different user groups the following are the major interfaces:

- Designers;
- Vendors;
- Component suppliers;
- Authorities;
- Operators;
- Maintenance staff;
- External contractors;
- Plant management.

The above information should be included into a user requirements specification document. To avoid the ambiguity inherent in natural language, structured methods may be used. Common issues should also be addressed in the requirements specification are:

- Required functionality;
- System interfaces (users, existing systems, systems outside the plant);
- Performance (availability, accuracy, response time, etc.);
- Quality attributes (portability, extensibility, security, continued support.);
- Design constraints (standards, legal requirements, company policy, etc.).

To address and reconcile the wide range of issues and factors to be considered in the definition of requirements, limited prototypes are often developed during requirements specification as a vehicle for evaluations and iterations. For example, a few important scenarios can be implemented to evaluate alternative software products or to reach a common understanding of system functionality.

The requirements specification is the basis for the negotiations with the vendors. The document should be well structured to make it easier for the suppliers to write tenders that can be matched with the specification and compared with each other. After the vendor has been selected, the revised requirements specification becomes a contractual document. At this stage the planning phase is completed and the execution of the project starts. Although the requirements specification may be modified later during the design process, a formal change process must be initiated to control and track the mutually agreed changes.

Quality assurance activities should be started during the requirements specification phase. The customer should have a quality and validation plan that defines the quality goals and procedures used during the project as well as the final acceptance criteria. In addition, the supplier should have a detailed plan for design, implementation and testing activities. This must meet the requirements of the customer's quality plan. A task for the customer before signing the contract is to audit the supplier to see if it is capable of producing the required quality. The subject of QA is also addressed in Sections 3.3.3 and 5.3.7.

5.3. SPECIFICATIONS

There are typically two types of specifications required in software production, namely a functional specification and a design specification. As this reports addresses electronic documentation management systems mainly from the NPP owner/operator point of view, the discussions of this section is focused on the functional specification.

A functional specification includes detailed description of system functions in such a way that:

- It is independent of the implementation details;
- It is understandable to the users;
- It forms the basis for detailed designs.

The owner/operator usually prepares the first version. As commercial software is used, a vendor may provide part of the functional specification, which can be refined in cooperation to be a contractual document. Basically, the specification should describe how the supplier's system fulfills the customer's needs and demonstrate that the supplier fully understands the user's requirements. All limitations and deviations from the requirements should be indicated. This creates the need for the items in the specification to be traceable back to the requirements. In general, the requirements are naturally structured according to user's tasks while the specification is concerned with more technical issues.

A functional specification should include the following sections for its report:

- Functions;
- Data structures and storages;
- Interfaces;
- Non-functional attributes;
- Hardware and software implementation.

A functional specification also includes implementation related information. For example, the functions and data can be described in terms of product modules available from the vendor. On the top level, the general structure of the system should be described in a way that allows the owner/operator to understand how well it fits into the company IT strategy. Further, the service and performance attributes of each module should be described and linked back to the requirements specification. Existing technical documentation can be included as background material. The implementation section should define the following issues:

- Operating systems;
- Databases;
- Middleware products;
- Approach to distribution;

- User interface technology;
- Programming;
- Configuration control;
- Testing;
- Maintenance.

As the users may have the needs to integrate documentation management into the overall plant system, the functional specification should describe the process and steps to do the integration.

5.4. VENDORS AND CONSULTANTS

This section discusses the selection process for software and hardware vendors and the strategic use of consultants to assist the owner/operator with the following activities:

- Preparation of functional requirements documents;
- Technology state of the art assessment;
- Preparation of invitation to bid;
- Vendor selection;
- Implementation planning;
- Factory acceptance test plan;
- Site acceptance test plan;
- Prototyping;
- Customisation;
- Integration with other systems;
- Training;
- User support;
- Software support;
- Hardware support;
- Change management.

The decisions about whether to develop in-house applications or buying third party applications and the selection of hardware and software are critical in determining the long term system availability. Because these decisions require a certain level of expertise, the reliance on external consultants is a choice if the expertise is not available within the organization. Another possibility is to build up in-house expertise to manage and control the work done by the consultants.

The selection of consultant should include the following consideration:

- The consultant should possess an established track record in the area of NPP documentation and have a good understanding of NPP related work practices;
- The consultant should have a good understanding of the enabling technologies, the current state of these technologies, knowledge of the leading vendors and prior experience in system implementation;
- The consultant should not be associated with any of the third party organizations that would be invited to bid on the project.

The expectation should be for the consultant to play a major role in defining the scopes and preparing the documents associated with the needs, requirements, or specifications. However, the consultant should not be placed in the position of establishing policies or strategic directions on behalf of the organization. That responsibility should be channeled through the project leader, who has intimate knowledge of the organization, its work practices as well as company goals and objectives.

Some of the key early decisions made with the help of knowledgeable consultants, involve deciding the system components need to purchase relative to those that should be developed in-house as well as those legacy systems, which should be retained. These decisions are often coupled with the vendor selection process and are based on the following factors:

- Information technology currently available on the market;
- Cost to purchase;
- Hardware platform preferences;
- Operating system preferences;
- Database engine preferences;
- Graphic platform preferences;
- System vendor preferences.

Other equally important, factors that should also be taken into account are:

- Impact on the overall system architecture leading to the rationalized information base.
- Long term availability without the need of major modifications.
- Proven track record of the product.
- Proven long term support record by the vendor.
- Vendor migration policies and track record in relation to:
  - Major Operating System upgrades;
  - Hardware upgrades and migration;
  - Database engine upgrades and migrations;
  - Graphic platform upgrades and migrations.
- Vendor's product upgrades and migrations that guaranties continued operation while recognizing the reality of technological changes.
- Adherence to recognized industry standards with the best chances of being supported long term.

The decision to select a system that combines the acquisition of commercially available software, in-house development of some applications and the use of legacy programs and databases, must therefore deliver a system that meets the functional requirements. Recognizing that the rapid changes in information technology will continue, vendors whose products are able to handle these changes with the least impact to the operation, should be given high marks in the selection process.

5.5. SYSTEM MAINTENANCE AND OPERATION

Within the NPP organization, the owner/operator who deals with the plant infrastructure and handles individual workstations should have the responsibility of the new system as follows:

- Provide the daily support to the users;
- Update manuals and procedures;
- Evaluate the system in order to recommend improvements;
- Recommend improvements in the working processes of the end users;
- Recommend improvements in the plant computer infra structure.

Normally there exist an IT board for the whole organization. The main responsibility for the board is to coordinate the various activities in the different groups responsible for the individual tools and to supervise the infrastructure in the plant. Important issues are discussed and decided by this board. This board will also identify new or existing workflow processes where the use for new IT tools may be needed. The maintenance and operations for the individual IT tools remains with the group responsible for the tools. The work should be carried out in accordance to the QA procedures as described in Section 3.3.3.

The owner/operator normally selects a responsible group for the software maintenance. It can be an internal organization, but the work may also be outsourced to an external consultant or vendor. Typical maintenance activities are:

- Correction of software;
- Periodical tests in accordance with procedures;
- Modifications ordered by the owner/operator;
- Modifications caused by changes in plant infrastructure or human machine interface;
- Modifications caused by changes in workflows that provide or receive information;
- Regular activities as backup of databases;
- Purchasing and evaluation of standard software;
- Modifications of standard software and adaptation to the working processes;
- Following up of software market.

The operations of the IT tools are normally done through a help desk or to assign a focal person in the owner/operator group who has the responsibility for a workflow process. The help desk or the focal person interacts directly with end users. Examples of operational activities are:

- Modification of existing users manuals;
- Production of new users manuals;
- Training of end users;
- Support to daily problem solving;
- Collection of users' recommendations;
- Analysis of users' feedback.

5.6. CHANGE OF PLANT INFRASTRUCTURE

The issues and concerns associated with major changes in plant infrastructure are referred to Section 8.5. This section only addresses minor modifications in plant infrastructure, in which there should be a long term development plan for information technology. The plan should be prepared to deal with the changes in required functions and in technology with the following issues:

- Basic platforms such as operating systems;
- Communication standards and databases;
- Middleware software;
- Multi-tier architectures;
- Applications;
- Integration of applications.

All changes will thus be related to the long term development plan. The resultant changes in documentation management may affect several computer functions as well as human tasks, which may be distributed to or interacted with different applications of documentation management. For changes that deal with legacy systems, there are different strategies for handling existing legacy systems. The solutions may be considered are replacement, modification, or development of a "wrapper" to enable interfacing with new systems. (See Section 8.1.)

6. EXAMPLES OF INFORMATION TECHNOLOGY IMPLEMENTATION

According to IAEA statistics at the end of 1999, there are 433 operating nuclear reactors and additional 37 reactors are under construction. There are a number of reactors designed and constructed in the 1970s and 1980s when the information technology, along with computers, communications and Internet, underwent great stride in progress. As far as documentation for NPPs are concerned, the range varies from NPPs designed in the 1960s in which documents are all papers and hand-drawings to a modern French Chooz-B plant in which the plant was completely designed by CAD. For those reactors currently under design, either for power production or for research, they have totally embraced impressive state-of-the-art information and automation technology. On the other hands, many existing older plants have endeavoured certain degrees of modernization effort. In this section, several examples are given to demonstrate the advantages of using modern information technology for documentation in the design, construction, and retrofitting of nuclear reactors.

6.1. FRENCH CHOOZ-B PRESSURIZED WATER REACTOR

The nuclear power station Chooz-B constructed and erected by EdF in France is the first plant to be completely designed with CAD. Thousands of P&IDs were produced using a 2D CAD system. The data of these P&IDs were stored in a database system that was fed into a 3D system. Several hundred engineers worked on the construction of the 3D model, which was demonstrated as a pre-construction of the real plant. The 3D model itself contained all disciplines such as civil structures, steel structures, equipment, piping systems etc. This also allowed the detection and elimination of clashes before the real construction work started. The system was further coupled to stress analysis tools so that the effects of design changes could be studied [7].

All installation drawings of the Chooz-B plant were drawn from the CAD model. The item lists generated by the computer were consistent with the drawings so that the procurement of material had a basis that was much more sound than the methods used in the past. Regarding the cost/benefit, the quality of the deliverables during design and construction was remarkably improved due to the use of the CAD model. The number of clashes during the erection was reduced by a factor of 5 compared to the previous EdF plants.

The 3D-CAD model can support the whole plant life-cycle, as it is used not only for design and construction, but also for operations and maintenance as well as decommissioning. Huge amounts of valuable and qualified information in electronic form have been transferred from the design phase to the operations phase, building the nucleus for a consistent information model. The use of electronic document management especially helps in the important task of configuration management during the operation of NPPs for forty or more years in their lifetime.

Regarding the adaptation of the electronic document system to the maintenance work, a special system to support the lockout of valves during the outage has been developed. Further applications, measures and procedures are established for the reduction of radiation dose during maintenance. In summary, the success of applying information technology at the French Chooz-B plant demonstrates that the CAD models and the associated data can be used for the whole plant life-cycle starting with the design process through the operation and maintenance process till the final decommissioning phase.

6.2. EUROPEAN PRESSURIZED WATER REACTOR DESIGN

The European Pressurized Water Reactor, which is designated as EPR, now under design with the most up-to-date information technology, is completely modelled using 3D and 2D CAD tools [2, 3]. The major advantages of using the CAD tools are the following:

- Consistency of data;
- Designs free of interference;
- Consistency between drawings and item lists;
- Easy revision of design work.

The planning procedures are described in Figs 4 and 5. Additionally, all relevant engineering data are stored in one single database, called PEDB (Project Engineering Data Base). The design work has been further improved by using document management systems and workflow systems. As all information created is in electronic form, the document management system can be fully applied. The document management system fulfils the basic functions as listed below:

- Classify, store and retrieve;
- Complete integration of office Software;
- Activity planning and control;
- Workflow;
- Reports in the form of listings.

The work process has to be analyzed first in detail to set up the workflows that support administration. The introduction of all these tools namely PEDB, the 3D CAD tool and the EDM (Engineering Data Management) together with a workflow have remarkably reduced the effort during the design work.

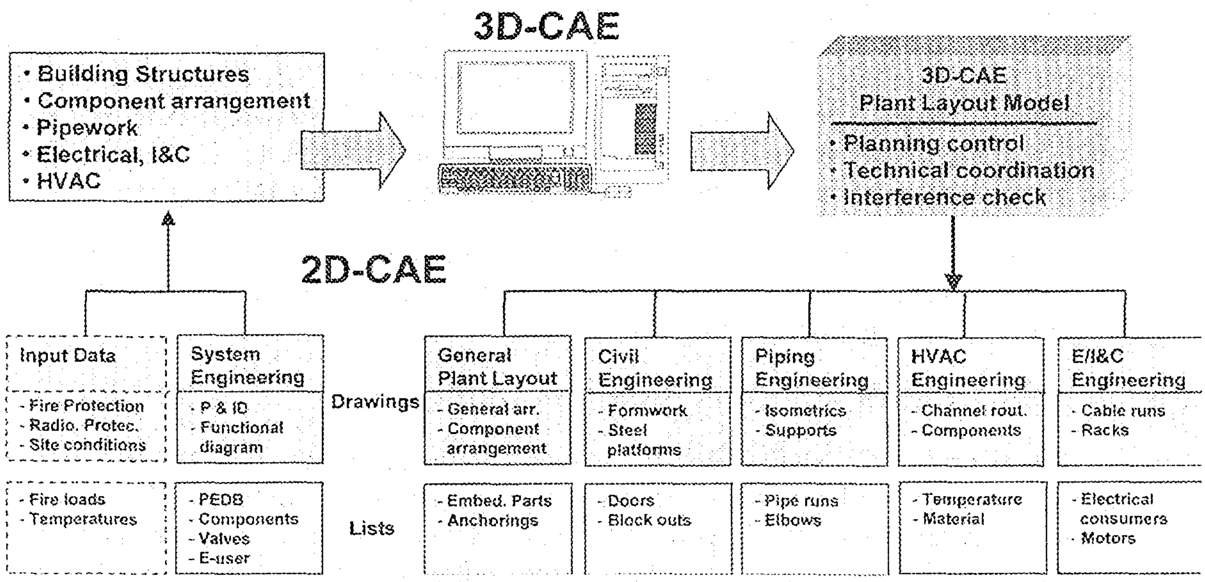

FIG 4. General plant layout CAE production for the several disciplines (3D-CAE).

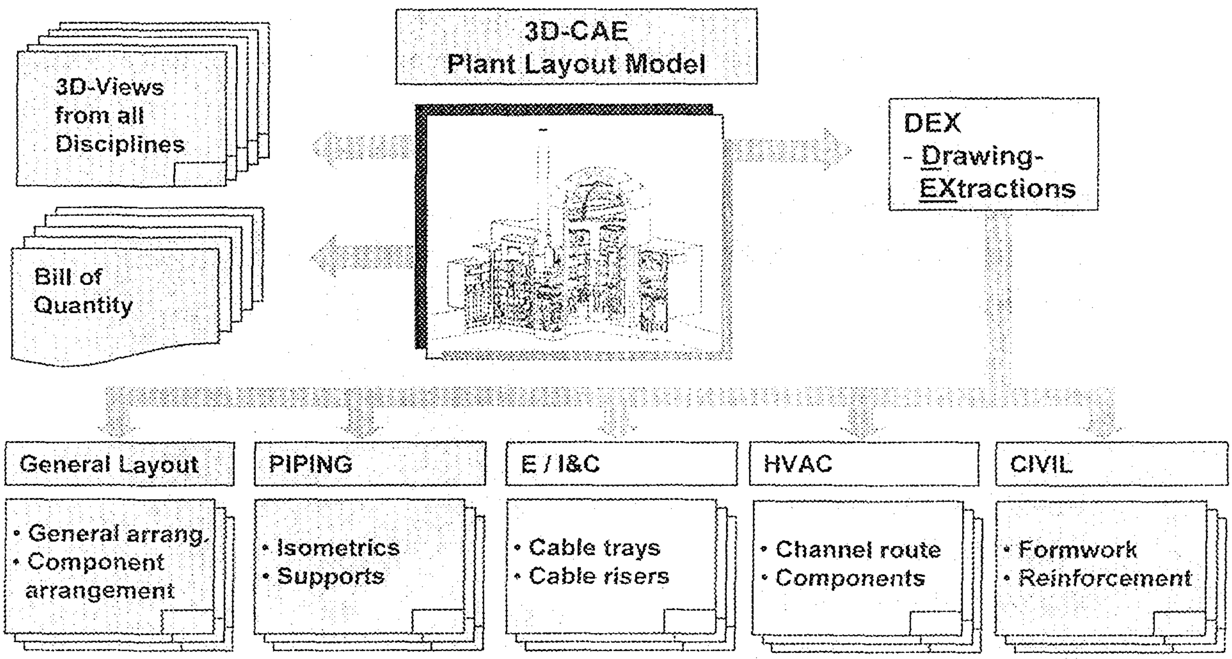

FIG 5. 2D-CAD drawing extraction.

6.3. DESIGN AND CONSTRUCTION OF RESEARCH REACTOR OF MUNICH

The research reactor of Munich (FRMII) in Germany has been designed using a 3D CAD model for all the disciplines. The 3D CAD model represents the virtual "erection" of the designed facility. The model of the mechanical and the electrical equipment without the civil structure can be seen in Fig. 6. The bulk of the construction drawings are directly derived from the model with little post preparation. Fig. 7 shows the isometric drawings that are directly generated from the model. In Fig. 8, additional information that is circled in black is shown. The post preparation comprises an additional cut with references to the building axis.

These references are needed for the erection of the piping system. During the design process, a lot of changes occurred. These changes have been handled effectively due to the flexibility of the planning process with 3D CAD tools.

6.4. CANADIAN CANDU-6 DESIGN AND PROCUREMENT

In the effort of CANDU-6 design and procurement, formal deliverables, such as documents, drawings, work packages, etc. are managed with the aid of an EDMS, which is a commercial software tool called AIM. The AIM system has been implemented at the construction site. It is used to manage and deliver to contractors, documents received from the design offices as well as those produced by local contractor and suppliers, etc [4]. A product developed by AECL tightly integrated with AIM, provides the following additional functions:

- Assists with the packaging, delivery, tracking and control activities associated with documents;
- Managing the material and procurement processes to facilitate the generation of material demand and other design and site activities associated with material management;
- Wiring and cabling applications that are integrated with the equipment data and the digital control computer I/O points.

The next objective is to extend the application as described above, to provide connections to be used in conjunction with the work management applications that are needed for the operations of the plant.

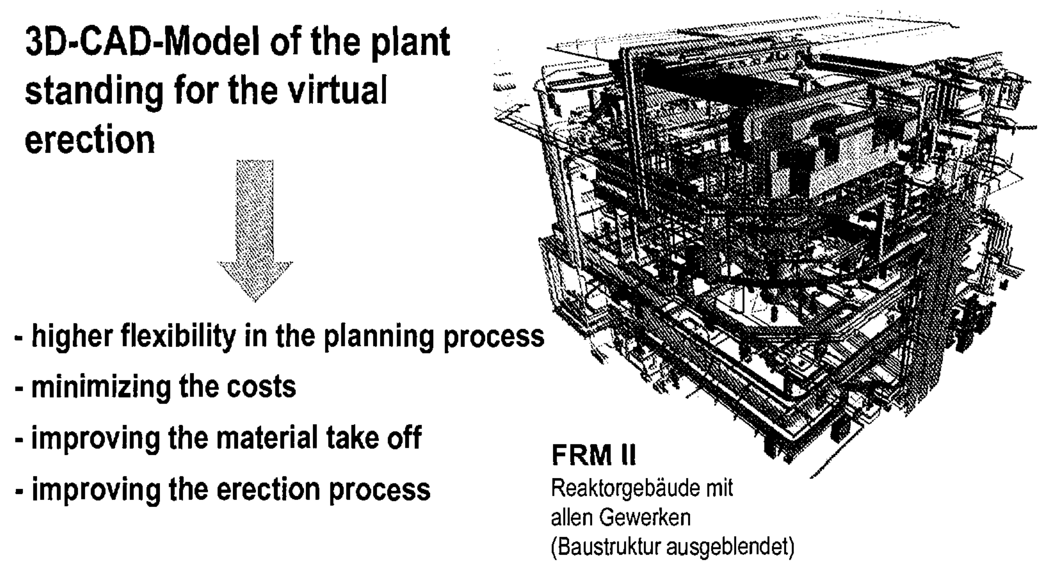

FIG 6. The use of 3D CAD modelling method for the plant design and construction.

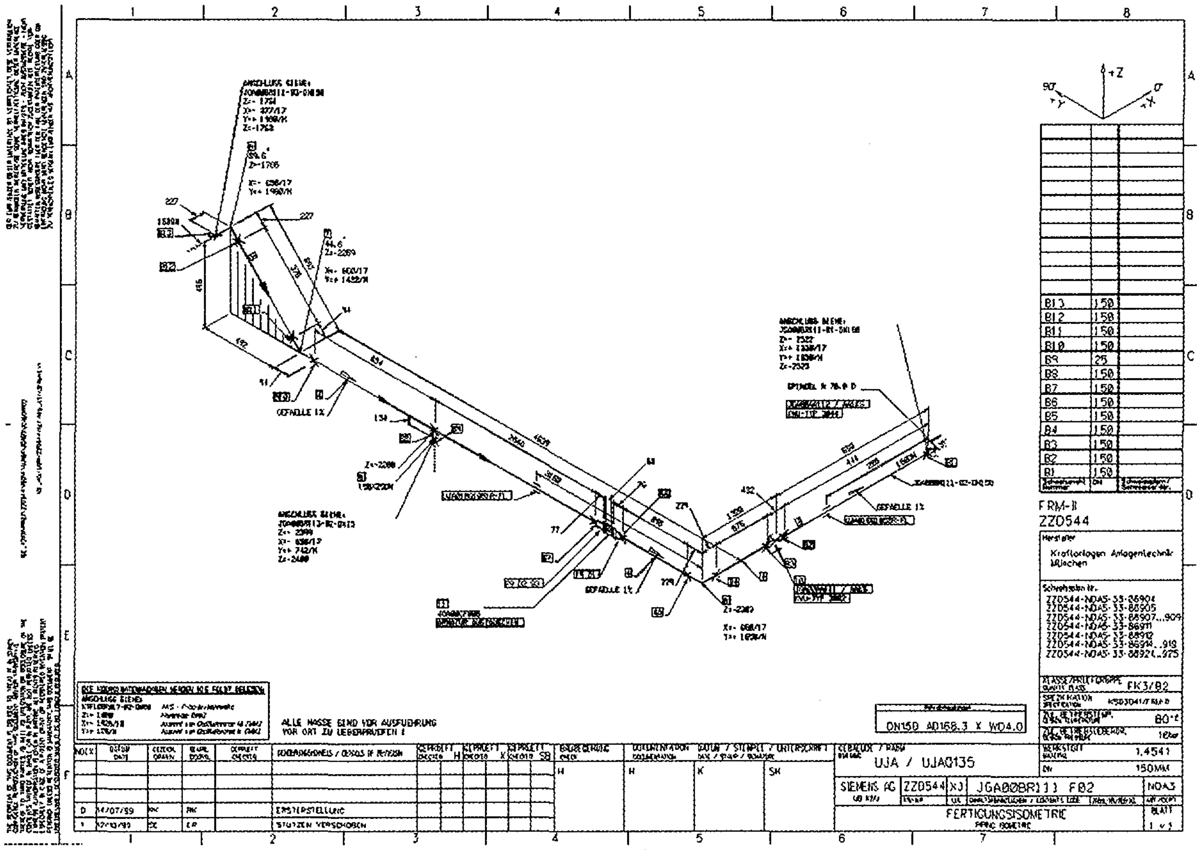

FIG 7. Isometric 1 generated by ISOGEN with post processing.

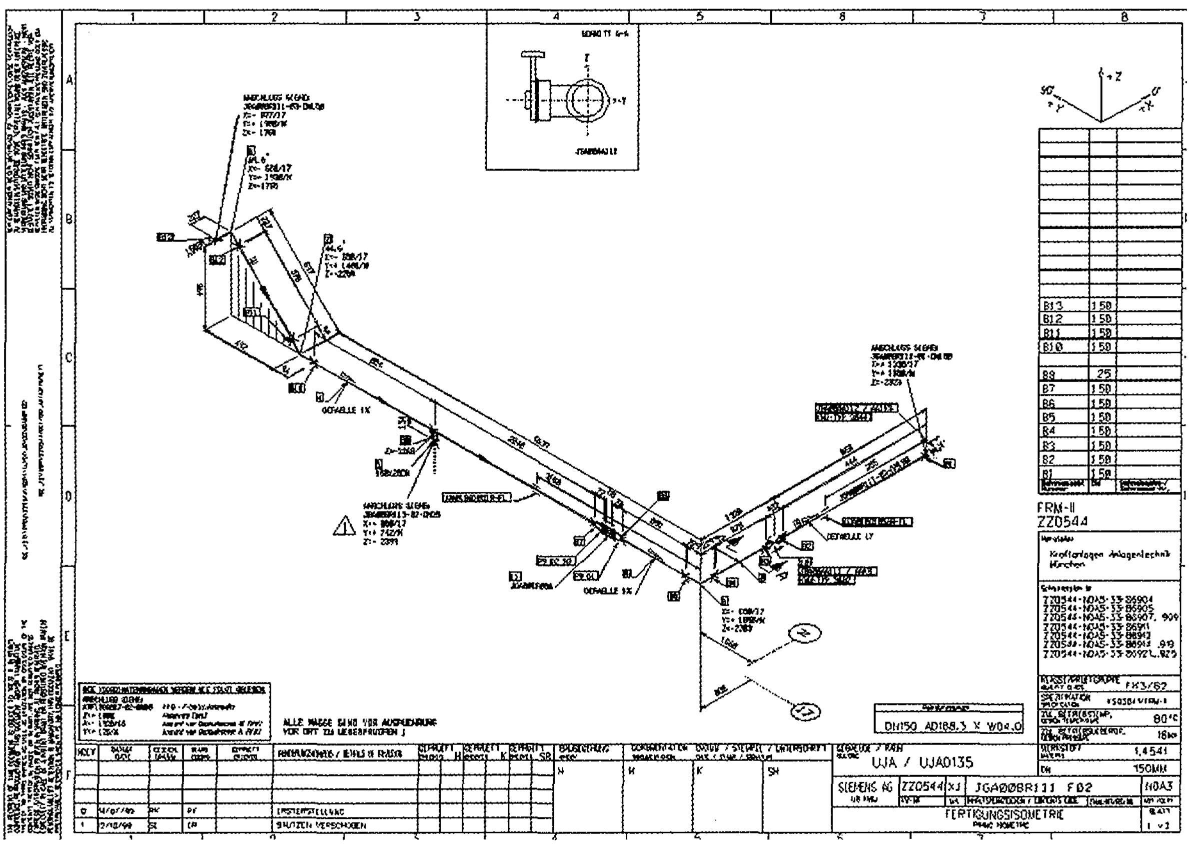

FIG 8. Isometric 1 generated by ISOGEN.

6.5. WORK ORDER AND PROCEDURE SYSTEMS AT BROWNS FERRY NUCLEAR POWER PLANT

The Browns Ferry nuclear power plant, which is owned and operated by the Tennessee Valley Authority (TVA) in the State of Tennessee of the USA, consists of three units of 1065 MW Boiling Water Reactors. The first BWR started commercial operation in 1974, while the second and the third BWR started production of electricity in 1975 and 1977, respectively. At the Browns Ferry NPP, two information technology systems were developed and implemented recently to improve the efficiency and effectiveness of the procedures and work order processes. The systems were operational in 1995 [6].

At the U.S. nuclear power plants, the procedures and work planning processes had become extremely inefficient and costly. At the Browns Ferry NPP, a procedure revision took an average of 24.6 hours to accomplish because of the required technical review, management reviews, filing, documentation, and comment resolution before the implementation of the information system. There are approximately 2500 procedure changes per year in average at the Browns Ferry NPP. With associated materials cost, this leads to an annual cost of US $4.8 million to the NPP site. One computerized system known as Curator, which has been developed to improve the situation allows for electronic development, storage, revision, routing, and documentation of procedures.

At the Brown Ferry NPP, a work order used to take an average of 37.4 hours from identification of work items to completion of work during normal operations and outages. This result in an average annual price tag of US$ 48.7 million including the maintenance work, US $ 14 million which is associated with administrative work, such as writing, reviewing, scheduling, planning, and closure, versus actual work in the field. The information technology system, called EMPAC, allows for access to information including financial, personnel, asset, and inventory. EMPAC provides electronic development, distribution, documentation, and control of plant maintenance work.

The new computer system using information technology provides capabilities for instantaneous, parallel routing of procedures during the revision process. The work order process also benefits from the same review routing improvements as the procedures. The improvement to the work order process allows a planner to assemble a plant work order electronically, including processing work instructions, associated surveillance instructions, technical guidance, and other references. The package is then put in electronic storage, which may be retrieved easily for review by reviewers or by work order planners.

The application of information technology to the Browns Ferry NPP demonstrated that unnecessary steps have been eliminated in the workflow process and plant infrastructure is thus simplified. They also simplified the problem that numerous software tools, databases, and different hardware were used to manage information on site prior to the improvement. The systems achieved performance improvement and cost savings of more than US $ 2.2 million in the first year, with the promise of considerably more in the future.

6.6. COMPUTERIZED DOCUMENTATION SYSTEM AT SWEDISH FORSMARK NUCLEAR POWER PLANT

The Forsmark nuclear power plant, located at north of Stockholm in Sweden, comprises three BWRs. The first one started operation in 1981 and the last one in 1985. From the beginning a site-wide computer system was developed to support the management of the process systems, the operation, the maintenance and the general administration. Later, other computer systems were installed and connected to the site system that was largely based on the available software and hardware technology around 1980. This system became rather complex with many computers including those for process control, human resources, IAEA safeguard of the fuel, plant access control, and dosimetry. The system has been modernized with both hardware and software. (See Appendix C.)

For the modernization, a model has been developed called Forsmark Network Application Architecture, the FNAA. The model includes two parts as IT and IS. The interface between the two parts and the general principles for the man-machine interface are well defined. The IT part includes the hardware and software platform with network and database services. The IS parts contains the applications and end user interfaces. The IS part has been installed on many workstations around the plant. Within this model, each application has an owner. Each owner of an application has a well defined responsibility for the development and the operations of the application, which is adapted to a working process that is specified in the plant QA handbook. Therefore, the development or modification of an application is always started with a study of a working process. One of the applications is a document management system.

The document management system, which has a central system called FEDHa for the plant site, provides an advanced capability for text and document searching as well as compiling local and virtual archives. The goal of the system is to improve the quality of the documents and to increase the effectiveness of its production, storage and distribution.

Another important aspect of the development project is to reduce the number of different document types and to introduce a common standard for identification of documents. The project started in 1995 and the system was in operation during 1999. It was divided into four phases namely:

(1) During the first phase, the pre-project, the existing system and way of working was evaluated and new ideas were proposed. A report was prepared for justification to start the main project. The decision to start the project was accepted by the IT steering committee in 1996.

(2) During the next phase, more requirements were described and a market study was performed. The project members visited several users of comparable installations for learning their experiences. The phase was concluded with a recommendation for selection of the contractor for a standard software platform.

(3) During the third phase, a platform was purchased and modifications were made to adapt it to the working model of the Forsmark staff. The system was put in operation on site for validation testing. Fifty-five end-users were trained to use the system in their normal work for a period of time. The results of this validation were the basis for eventual acceptance for modification and for the decision to put it in operation.

(4) The fourth phase was to develop all necessary manuals, standard templates, and working models for operation of the system. Furthermore, strategies were developed for transfer of existing information to the new system and to integrate the documentation system with others as for maintenance, operations, and intranet. The system was handed over to the owner.

The system is used by members of Forsmark staff as well as by external personnel who have an access control. Different working models are available for documents, letters, and drawings, meeting protocols. The models are used both for material generated within and outside the Forsmark organization. A system for feedback of operation experiences is developed and in use. Besides integration with other systems, FEDHa is expanded further to include an electronic signature method. In addition, scanning of many old or external documents is going on routinely for eventual feeding into the information system for the Forsmark NPP.

6.7. KOREAN STANDARD NUCLEAR POWER PLANT DESIGN

The Republic of Korea has 8 units of Korean Standard Nuclear Power Plant (KSNP). Among them, 4 units are in operations and the rest are under construction. All the design drawings for the operating 4 units have been produced by KOPEC (Korea Power Engineering Company) using Intergraph 2D CAD programs in MicroStation based CAD environment since 1984. KOPEC has introduced IPIMS (Integrated Plant Information Management System) in 1998, which brought new concept to power plant design and engineering works.

Introduction to IPIMS

IPIMS is an integrated computerization system for power plant design and engineering. The system is composed of four main functional application tools as the following:

- Intelligent 2D System;
- 3D CAD System;
- DDMS (Drawing & Document Management System);
- EDB System (Engineering Database System).

Users can access design drawings, equipment data, 3D models, technical specifications, and other design information, such as vendor documents on their desktop PC through IPIMS as shown in the Fig. 9. This kind of IPIMS function meets the configuration management requirement specified in EPRI Utility Requirements Document (URD) for advanced reactors.

IPIMS can also provide plant constructors and owners with the following benefits:

- Comprehensive plant information database for construction planning and project controls;
- Enhanced plant visualization and animated applications for constructibility reviews, construction sequencing, and training aids;
- Integrated design, operation, and maintenance information used in many applications for plant life-cycle support.

Project Experiences with IPIMS

To verify and validate IPIMS, a legacy database of KSNP has been built by using the as-built drawings and other design information of an operating KSNP, Ulchin NPP unit 3. The content of the legacy database is as follows:

- 3D CAD model for power block buildings such as containment building, fuel building, primary auxiliary building, secondary auxiliary building, and turbine building;
- Drawings produced from 3D CAD model and Intelligent 2D CAD system;
- Engineering database from engineering material index and system design drawings.

IPIMS with the legacy database is being used in the current KSNP construction projects, the KNGR (Korean Next Generation Reactor) project, and the Korea Peninsula Energy Development Organization (KEDO) NPP project.

Future Plan

Now a 4D CAD system, which adds a time dimension to the 3D CAD system, is being developed to utilize 3D model for construction schedule simulation and work order optimization, including the construction equipment resources allocations. The final goal of IPIMS is to be a system to support NPP full life-cycle from planning to decommissioning.

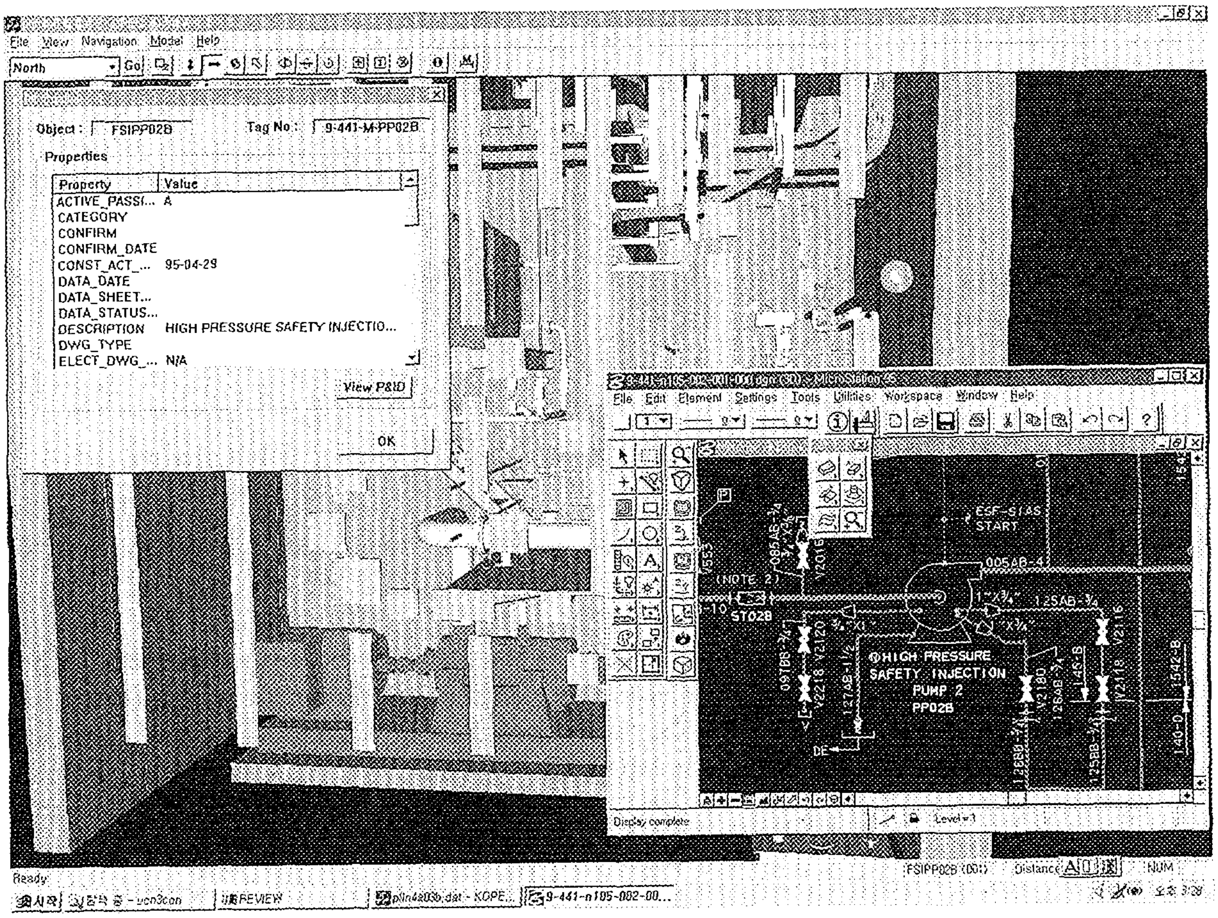

FIG 9. Plant information on a PC monitor through IPIMS.

7. ISSUES AND CONCERNS FOR APPLICATION OF INFORMATION TECHNOLOGY IN NPP

7.1. LEGACY SYSTEMS

Most EPC and utility organizations have introduced, over the years, computerized tools and databases that are used to manage important information. These systems may be considered obsolete by today's technology. In many cases, they were developed using proprietary platforms not lending themselves to be rationalized and integrated with the rest of the information base or plant infrastructure. Nevertheless, they are used by different groups within the organization and have become a part of their activities and practices.

When defining the system architecture of the NPP EDMS and redesigning the associated work processes, decisions must be made about the legacy systems and how they should be positioned within the context of the rationalized information base. The decision process should take into consideration the following factors about every legacy system:

- Is the legacy system performing a vital function within the context of an EDMS?
- Is the functionality of the legacy application adequately covered by the proposed EDMS system, or if not, can it be easily added at later stage of the implementation?
- What is the cost of retaining the legacy application?
- Could the legacy application conflict with the new EDMS and create confusion at the working level?
- Will there be data redundancy requiring additional effort to keep the systems synchronized?

Depending on the results of analysis that addresses these factors, the following options could be considered:

- Terminate the legacy application and the function it was serving;
- Phase out the legacy application and replace it with similar functionality available within the EDMS;
- Modify the legacy application to fit the proposed architecture of the rationalized information base and work in conjunction with the EDMS.

The importance of dealing with legacy systems cannot be overemphasized when implementing EDMS in NPPs. Unattended legacy systems that do not fit within the overall architecture become the "Rogue" applications as described in Section 4.2.1 that eventually will hurt the plant life-cycle activities in the long run.

7.2. DESIGN BASIS RECONSTITUTION FOR AS-BUILT PLANT CONFIGURATION

The design basis for a structure, system, or component identifies their specific functions, the controlling design parameters, and specific values and ranges for these parameters. From a licensing point of view, NPP staff and government regulators use the design basis to judge the acceptability of the design and its modifications with respect to the health and safety of the public. The design basis stipulates the following:

- Regulatory requirements and acceptance criteria;
- Applicability of industry codes and standards;
- Function of the structures, systems and components (SSC);
- Fundamental process that satisfies the function;
- Essential SSC parameters of the stated functions and processes;
- Basic safety margins to be included in the design;
- Interfaces with other SSC, including mutual dependencies;
- Accident and fault scenario expectations;
- Environmental considerations and impacts.

Design basis is typically established at the plant level, which is divided into the system and structure levels. As such, they form the foundation for the specification of subsystems, system components, and substructures. Typically, a complete set of design basis for a given system or structure would be contained in a document with comprehensive reference to the source documents. Design basis documentation can be affected not only by design changes, but also by the evolutions of safety standards, periodic safety re-evaluations, and generic issue evaluations, even if no physical modification is initiated.

In each occasion when a new or modified document that affects the document configuration is prepared, it is necessary to assure that all related documents are modified as appropriate. It should be noted that a document management system that includes computerized links among documents is a valuable tool for consistency and connectivity checking. Nevertheless, it is not always possible to rely totally on such a system, especially when a new document is originated. Preferably, all new documents should be generated in an electronic data management system to avoid future deviations.

For older plants, the information for the design basis is typically in the paper forms that are inflexible, difficult and costly to update. Sometimes, it can be hard to verify if the plant systems still fulfil the design basis for the original design. For this reason, many NPPs have initiated projects to re-construct the original design data basis in order to identify modification requirements and to verify the existing plant designs. The main output is normally a great volume of new documentation. It is highly recommended that such projects should be coordinated and integrated with EDMS in order to provide long-term support to the NPP life-cycle activities.

7.3. LICENSING AND REGULATIONS

The licensing and regulation processes can be divided into two main parts:

- Licensing of the digital infrastructure, which is used for the different phases in the life-cycle;
- Licensing of the individual applications "tools".

In order to define a licensing process, the experiences gained from previous processes for software can be studied as a guide, such as licensing the applications for the software used for the loss of coolant accident (LOCA) calculation or for fuel management. In those cases, licensing is primary done by verification of the results using experiments and review of the data input to the software for each calculation. While the software are largely engineering tools for safety analysis and design calculations, in recent years important work has been carried out to license on-line and real-time digital I&C. Such licensing work includes both the infrastructure and the applications. For this licensing, a special process has been developed for software that can be bought as standard from the market. The IT technology used for plant documentation also adopts such standard software for both the infrastructure and the applications. For this reason, experiences gained during such a process for standard software can be very useful. (Also see Sections 2.3, 4.3.7 and Appendix A)

The licensing procedure for new design as well as for major changes should as a minimum include following steps for important safety functions:

1. Risk and hazard analysis.
   The analysis will identify in the first place the safety functions of the IT applications. It will further define the environment where such applications are used and on which infrastructure they are executed. The analysis will result in an estimation of the impact on plant safety by failures in the design, operation and maintenance of the software and hardware;
2. Based on the risk and hazard analysis, different part of the infrastructure and application are classified into different safety categories as explained in Section 3.3;
3. For the infrastructure and each application requirements, acceptance criteria should be described. Requirements are best described for the highest safety category. These can be of different kind of requirements as the following:
   - Life cycle planning;
   - Functions;
   - Performance;
   - Installation, power supply, and environmental conditions;
   - Reliability;
   - Quality assurance and quality control;
   - Operations and maintenance as well as experiences feedback;
   - Conformance to applicable codes and standards;
   - Documentation;
   - Interfaces between individual software or hardware modules.
4. The infrastructure and applications are described in safety reports (see Fig. 10) and evaluated against requirements and acceptance criteria.
5. The licensing process shall be completed by a description of the resolution of open items.

There are several typical aspects for IT applications that can be important for licensing. These include the standard software and hardware, infrastructure, and special applications, which are addressed below.

Standard software and hardware

Most of the hardware and software are bought as a standard on the market. The purchased modules are tailored and integrated into the infrastructure for the site. For this reason, the purchasing control of suppliers and the integration work on the site are important aspects. Purchased items can be qualified in accordance to the principles of "tool qualification" as described in Section 5.3.7. Integration must be done by using approved procedures for design, changes and verification.

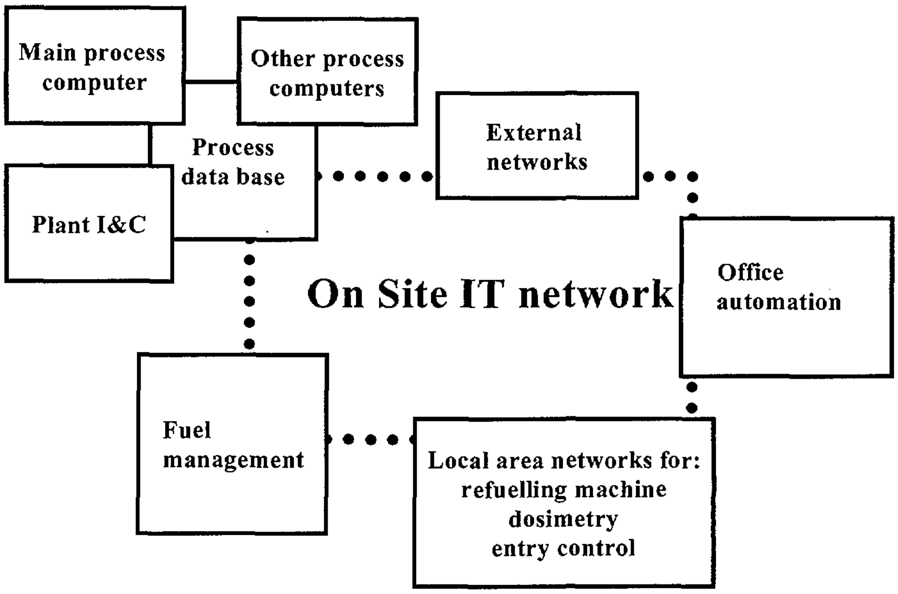

FIG 10. A typical package of safety analysis reports for the IT system.

Infrastructure

The individual hardware and software modules must be integrated into an infrastructure for the whole plant. Typical nuclear requirements for the infrastructure are:

- Long term storage/backup of operation, maintenance and QA documentation during the plant lifetime
- Access control of important information
- Data and software security
- Environmental conditions as for electro-magnetic control
- Firewalls between internal networks and external ones
- Facilities for service and development
- Redundancy and protection against external events
- Links to regulatory authority

Information technology applications

Special nuclear applications of IT technology can be used for:

- Support to the SAR as for LOCA calculations, transients analysis, seismic verification;
- Fuel management;
- Man dose radiation monitoring and reporting;
- Planning and data storage for inspections and periodical surveillance;
- Reporting of events relevant to the technical specifications;
- Surveillance in accordance to IAEA rules;
- Entry control to critical plant areas;
- Calculation of calibration for plant instrumentation
- New design or changes in safety systems.

7.4. MANAGEMENT OF RAPID CHANGES OF INFORMATION TECHNOLOGY

Nuclear power plants have a long lifetime and a need for extensive documentation and traceability. Therefore, critical information should be kept traceable even after an operating period of sixty years. This is clearly a challenge to the pace of changes in information technology. The most up-to-date technology solution currently available may become obsolete within a few years. A careful analysis is needed for strategic decisions concerning how IT technology should be applied. Issues to be addressed include:

- Where should computers be applied and what could be left manual?
- Which hardware, operating systems and other basic software should be selected?
- What are the best application software solutions?
- How should the applications be integrated?
- What kind of document formats would be the most stable and portable?

In the current competitive energy market, the implementation of information technology includes cost and risk that may not contribute to the bottom line. To reduce the effects of the impact of information technology, a power plant might be conservative in applying computers in the following way:

- Rely on competent, flexible and motivated personnel where appropriate;
- Select proven products and technologies (e.g. relation databases) instead of the newest ones;
- Use outsourcing for non-critical functions and computer applications.

The high quality requirements, the rapid change and the cost of software development may mean that the nuclear plant does not build and maintain in-house solutions. As the total number of plants and applications are not large from market standpoint, experiences from other industrial sectors are helpful. This leads to the use of commercial off-the-shelf packages (COTS). Fortunately, a major part of information technology functions at a nuclear power plant is similar to those found in the process industry. The expected lifetime of products and technologies to be used should be considered. The solutions should be supported by a wide industry, which would guarantee the availability of vendors, the portability of database to new applications and the capability of transformation of existing applications to fit into new software environments.

In a nuclear power plant, the documentation and information management function must be integrated with other information systems. One possible solution is the commitment to a single vendor, which may solve a big share of integration problems but not all. The existing software modules may not cover all needs, in particular those that are specific to nuclear power. Another approach is to select 'best-of-breed' products for each purpose and to interface them with each other. In either case, IT products should be complying with widely used interface standards.

Existing legacy systems are a common issue in application integration. These systems may contain valuable company specific solutions and still be operational and vital for the business. Corresponding products may not be available and rewriting the whole application to substitute the legacy systems may be too expensive. A "wrapper" that implements a new interface around the old application and allows a standardized integration with the rest of the system may be a solution.

The emerging Internet technology and component based software development (CBSD) might provide some solutions for IT applications in nuclear plants although it is difficult to say when they will be replaced by more advanced techniques. In IT technology today, software components are often developed based on standardized interfaces between distributed modules . This will make it possible for a customer, such as nuclear power plant, to purchase these components from different sources and integrate them by using graphical tools and simple scripting languages.

Several standardization efforts are active around documentation. For example, the Document Management Alliance (DMA) is a task force of the Association for Information and Image Management (AIIM) International (www.aiim.org/industry/standards). It is made up of more than fifty commercial and government organizations. The DMA specification defines a programming interface that allows document management products from different vendors to work together. Specification defines a set of client-to-service-provider interfaces applicable to both client-server and Internet/intranet-based architectures. DMA complements other standards initiatives, such as the Open Document Management API (ODMA), Web Distributed Authoring and Versioning (WebDAV), and the Workflow Management Coalition (WfMC).

A further issue closely related to documentation and information management is the format for document storage and exchange. ISO 10303 is an international standard for the computer-interpretable representation and exchange of product data [23] (www.nist.gov/sc4/ www/stepdocs. htm). The development of the ISO standard has been a long and extensive effort that has produced very extensive international standards that are widely used. The objective is to provide a mechanism that is capable of describing product data throughout the life-cycle of a product that is independent of any particular CAD system. The nature of this description makes it suitable not only for neutral file exchange, but also as a basis for implementing and sharing product databases and archiving. Several application protocols are underway that may have relevance to nuclear power plants, as well. These include, for example,

- Part 208 (CD): Life cycle management — change process;
- Part 212 (CD): Electro-technical design and installation;
- Part 221 (CD): Functional data and their schematic representation for process plant;
- Part 231 (CD): Process engineering data: Process design and process specification of major equipment.

7.5. CHANGE OF PLANT INFRASTRUCTURE

Today, every nuclear power plant has some type of digital infrastructure, which is mostly a result of continuous upgrading throughout many years. In the late 1970s when computers began to appear in nuclear power plants, there were no related infrastructures. Installed computers were largely stand-alone systems with the peripherals directly connected. Typical examples are the process computers that were interfaced with process data, the administration mainframe computers and many black and white text terminals. Later on, autonomous networks with simple serial links were installed for the process computer in connection with other process-oriented computers, different kinds of administration or maintenance computers and for gathering radiation emission from different sampling points.

A trend during the recent years was to integrate the stand-alone systems into a common site management system. In this way information stored in different subsystems can be made available for many users. Simultaneously and in contrary to this integration process, another trend for decentralization of computer application was going on due to the availability of powerful workstations, which made it possible for users to have their own programs installed on their own computers. Therefore, today the site wide network is integrated with individual workstations, but the idea to have users keep their individual software installed on workstations remains. Updating of software and standardization requirements is easier for software available on central servers and not on individual workstations. For some countries, links are provided for users outside the nuclear site including the headquarters of the utility and the office of the regulatory authority. However, after virus and hackers attacks within several networks, the regulatory authorities became more and more concerned about this problem.

In spite of the continuous updating of infrastructures, the existing databases are still used in many plants with the component databases obtained from the designers, which were developed many years ago. Experiences with the operation of plant infrastructures have shown that changes are mostly motivated by user requirements and technology development, while some are driven by the regulatory authorities. As the infrastructure is continuously changed, flexibility for different aspects is an important design requirement. A typical infrastructure for a site with several reactor plants is given in Fig. 11.

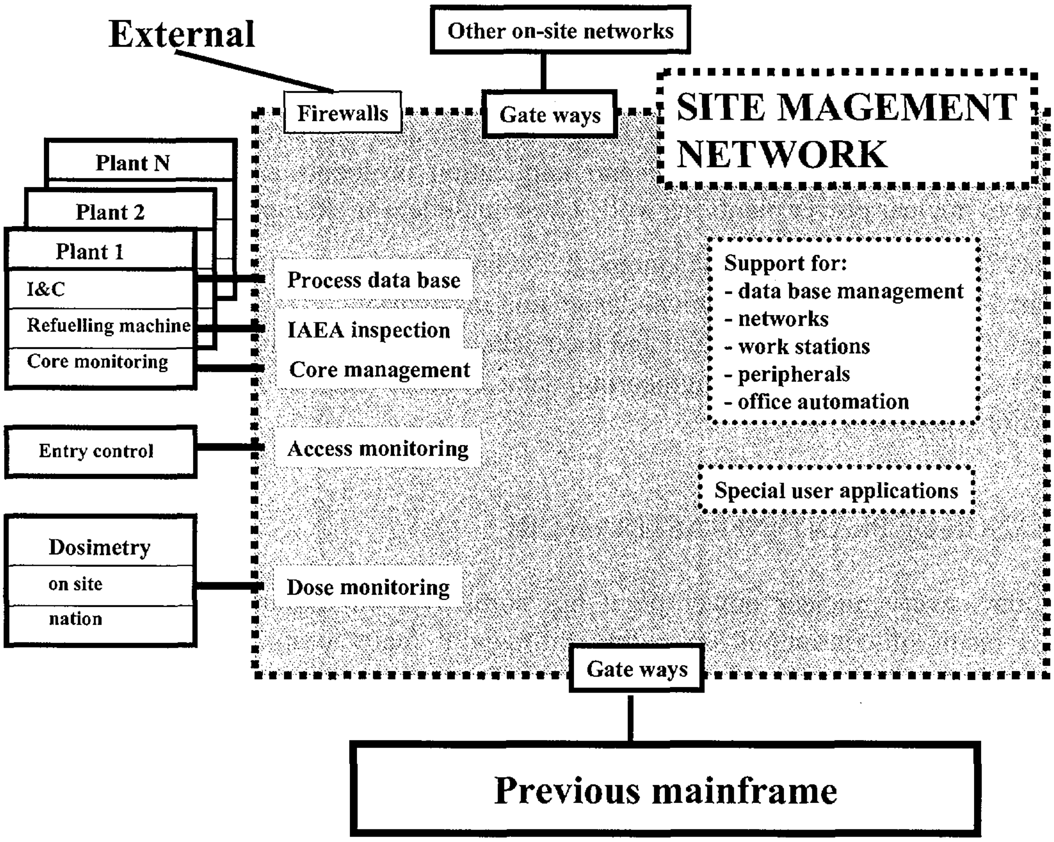

FIG 11. Typical infrastructure for an existing nuclear power plant site.

For plant infrastructures, the nuclear requirements can make significant influence on all parts of the infrastructure as indicated in the following examples:

- Databases required for permanent storage include information for documents, plants components information, etc.;
- Interface with process part for real-time sampling of dynamical information;
- Computer platforms with servers and networks to make information available to the users;
- User applications based on different types of workstations;
- Connections to external systems for communications.

As the infrastructure is used more and more for critical nuclear application, it is expected that more nuclear requirements will be defined. Some have been already defined as a spin-off of the licensing of the digital I&C equipment. Other ones are a result of conversion of paper documentation to a electronic document management system. Typical examples, which can result in special nuclear requirements for the infrastructure are:

- Reliable and storage of information about the operation, maintenance and QA /QC;
- Storage of the information in the SAR;
- Reporting to the regulatory authority as required including, periodical surveillance, abnormal events and release of radioactivity to the environment, etc.;
- Monitoring and reporting of man doses;
- Monitoring and reporting of fissionable material to the IAEA;
- Design for Electromagnetic Control (EMC);
- Data and software security, especially for attacks through external connections;
- Access control for entry to critical plant areas;
- The use of design tools for safety equipment.

7.6. TRAINING

Training is an important element of work in a NPP when a new system is implemented or when a new procedure or practice is introduced. In the case of implementing a new information technology on documentation, it is inevitable that in the work flow process some steps and manual functions are eliminated and some automated systems are added and training becomes essential. For new information systems, it is sometimes difficult for users to find the most appropriate way to achieve a given objective, as the system may represent a large field of activity and it may include many subsystems. Besides, even the best systems can be completely ineffective if users do not know how to use them. Therefore, systematic training programs need to be established for users to get familiar with the new information systems, to get used to the new infrastructure, and the modified work flow process.

The systematic approach to training may be considered. This approach provides a logical progression from the identification of the competencies required to perform a job to the development and implementation of training to achieve these competencies, and subsequent evaluation of this training. As an internationally recognized practice for training and qualification to ensure the competence of NPP personnel, the approach to training provides a comprehensive method to ensure the completeness and effectiveness of training.

The training associated with a new information technology system should consist of two major elements:

(1) Training acquiring the skills for using and maintaining the new system;
(2) Instructions and training for adapting the new working practices, environment, and culture as a result of introducing the new information technology.

Since the information technology system generally does not deal with direct and on-line plant monitoring, control or protection, the training may emphasize on-the-computer and on-the-job training to provide trainee the first-hand experience and benefit. To ensure the success of training, a training program for new information technology system should address the following items:

- A part of the operating organization training policy;
- Plant management support and monitoring;
- Management involvement in establishing training needs;
- Adequate resources and training skills.

In addition, training programs should have different level of training courses to provide users with the proper knowledge to use the newly developed IT systems for their own purposes. Typically, users may be classified as top management, management, and document preparers. The following training courses could be prepared and provided to users:

- Introduction Courses: Top management or prerequisite for other users;
- Basic Courses: Management or prerequisite for document preparer;
- Detailed Courses: Document preparer.

To enhance the user training more effectively, the diversity of training method may also be required. Some examples of training method are listed as follows:

- Classroom training by instructors or video tapes;
- Computer aided training through network or electronic media;
- Individual user's on site training.

8. FUTURE TRENDS

8.1. TRENDS OF INFORMATION TECHNOLOGY

8.1.1. Software intelligence for information management

Information management may be an area for serious consideration if nuclear power plant documentation is given a wider scope to deal with all plant information throughout its life-cycle. This may consist of various kind of comprehensible human documents on papers or in electronic forms, including for example drawings, specifications, minutes of meetings, personal notes, measurement results, video tapes, etc. A further expansion of this idea would include Knowledge Management (KM), which is the collection of processes that govern the creation, dissemination, and utilization of knowledge. KM is not only a technological issue, but also covers organizational structures, facilitation of organizational members, putting IT-instruments with emphasis on teamwork and diffusion of knowledge, etc. (see for example, www.km-forum.org/what_is.htm).

Because of the specific safety and reliability requirements and the large investment costs, knowledge management is a key issue at a NPP for plant wide optimization. That is, information should be effectively documented, maintained according to systematic regulations and rules (e.g. change control), and utilized for the safe operation, maintenance and management of the plant.

There exist vast amounts of information in various formats and of different ages, which are stored in diverse computer systems, manual archives and human minds. Most of the information is located at the plant, while others are stored externally in various sites and organizations. Advanced information technology may be used to coordinate and integrate distributed knowledge repository. The following are examples of technical areas that are worthy of learning for possible future applications of knowledge management to the NPPs:

- Software agents;
- Automatic configuration of systems;
- Natural language treatment/formalizing design and management of design knowledge;
- Ubi- computing and wearable computers;
- Wireless communication;
- Component based software development;
- Intelligent search methods and data mining;
- Multimedia;
- Speech and pattern recognition as an input method;
- Computer supported cooperative work;
- Teleconferencing, document sharing, etc.

8.1.2. Virtual reality

Virtual reality (VR) is a technology, which is being developed and continuous refined with more information from VR industries and research institutions. The VR technology that are considered to be relevant to NPP documentation applications include graphic data file compression technology and I/O technology for VR, e.g. sensors and display devices.

VR technology is a useful tool for the NPPs as the 3D CAD model may be considered a virtual construction. As the CAD models are linked to a database with all the reference information, the models can be used for a walkthrough or virtual reality evaluation. In the design phase, designer, plant operator and vendor are able to review the accessibility in plant general arrangement drawings by using the walkthrough functions. Human machine interface study of control room design through operator action simulation is another application in the design phase. Simulation of equipment installation for checking and removing difficulties prior to transport it to sites, and construction schedule simulation linking schedule information to 3D CAD models are examples of applications in construction phase.

In addition to its applications to design and construction, a virtual model can also be a tool for maintenance and operational tasks, which can be simulated together with the owner/operators. The simulation of equipment replacement or modification in operating plant, for example, for the replacement of a turbine condenser, the transport of the condenser may be simulated for the whole path as to find bottlenecks or obstacles that must be removed. Also with VR technology, the maintenance and operational aspects can be implemented in the plant design in the early stage of conceptual design, without causing any hardware changes. For example, the accessibility of a pump can be studied long before the plant is erected. Thus, virtual reality can be a useful tool for communication between the owner/operator and the vendor.

To facilitate effectiveness and productivity of maintenance activities, VR can also be used in training of the operator and maintenance staff, and in preparing the job to be performed in hazardous areas or under time constraints.

8.1.3. Advanced simulation

Advanced simulation may be considered as the combination and integration of human-machine interface techniques and mathematical models, which describe the detailed behavior of the simulated subject to help the human operator to understand the static and dynamic behaviour of the plant. Advanced simulation may be used as a tool for management of a variety of information and knowledge. For example, a modification of I&C-system can be verified not only in the test field, but also against the mathematical models of the plant. Using advanced simulation techniques, I&C system may be tested for the required functionality, technical characteristics, and human-machine interface. Thus, most of the I&C errors may be detected and eliminated before installation. The mathematical models for the systems and the plant may further be used for the validation of operational procedures that are developed or modified.

There are other examples on the use of advanced simulation. The seismic re-qualification of existing plants could be done on site by the use of the mathematical models for the stress calculations. The effect of changing piping support could immediately be studied on site. For this purpose, advanced simulation with a user-friendly interface may allow users to observe the "virtual" change of the pipe support. Therefore, the superposition of a virtual reality generated by a 3D CAD model with advanced simulation techniques provides extended possibilities for future information and documentation management.

8.1.4. Pattern recognition for documents & drawings

As NPP staffs strive to convert paper documents into electronic forms for effective management of documentation, they encounter laborious and costly manual effort to deal with old papers and drawings, which make many conversion projects prohibitively expensive. Technology development has been in progress in the past years to automate the conversion process using pattern recognition techniques. Today, for the text documents efficient object code recognition (OCR) tools are available.

Development has been in progress to automate conversion from raster drawings to vector representation. The different CAD vendors have developed various systems to superimpose raster and vector graphics as to speed up the victimization process. So far, diagrams that use vector representation are open for full text retrieval. For NPP applications, much work has been accomplished to convert the P&ID and I&C diagrams into formats acceptable to CAD systems. In addition, some effort has been made to digitise the prints i.e. setting up parts of buildings including the equipment. Overall, to accomplish electronic documentation management, automation of conversion of paper documents into digital forms is an essential need from economic point of view.

8.1.5. Data driven graphics and documents

Data driven graphics and documents are technologies that can produce and update CAD' files or word processor files automatically from the textual information stored in non-graphic databases such as those using RDBMS platforms. The technology follows the gradual migration from a "document centric" approach to one referred to as a "data centric" approach. When the approach is completed, the CAD files or the word processor files can be used as the interface for recording additional information in their native database. Once the task is completed, the files may be discarded as it can be reconstructed readily at any time from the native database.

In the "document centric" approach, the component information is recorded manually on every document. For example, a pump would be manually placed on a P&ID drawing together with some pertinent information about its operational parameters. The same pump would also be defined on a component specification sheet with some of the same information from the P&ID being repeated again. The same pump would also appear on general arrangement drawings and on piping isometric drawings, which are all prepared and maintained independently. Changes to information common to some of these, would require each document be modified manually. Whereas, applications that follow the "data centric" approach provide the means to store the information about the pump in a common or rationalized set of databases, through interfaces that are familiar to the user. This interface could be a P&ID drawing, a word processor document, a 3D graphical environment or a database form. Regardless through which interface the information is entered, it can be retrieved through any of the others as appropriate.

For data centric approaches, the applications are also able to store spatial information in a way that the graphical representation can be recreated without the need of manual intervention. In the 3D environment, different views of the same object can be retrieved and used to best suit the particular task. As a result, there is only limited needs to preserve the CAD files or the word processor files, as these would be recreated readily as required. The document-oriented files would be retained when there is a need to issue them to external organizations, such as manufacturers, partners and regulators or, for cases to preserve a snapshot of the information when certain milestones are reached, or for QA audit trail purposes, etc. The "data centric' approach is currently being implemented by a number of solution providers in the computer aided design field. It is expected that the technology will be widely used for effective and productive management of documentation.

8.2. TRENDS OF INFORMATION TECHNOLOGY APPLICATIONS AT NPP

8.2.1. Preventive maintenance

Preventive maintenance becomes more and more important for the existing operating nuclear power plants. As the components in the plants are aging and more maintenance is required in the future, a documentation management system for planning of cost effective maintenance is not only important for safe and reliable operations, but also essential in the deregulated market today.

Each plant generally keeps a stored record for evaluation of the operations of the components and planning the maintenance of the specific component. The first step for preventive maintenance is to list all components in the plant and classify them according to the requirements of safety and operations. This will provide the background material for prioritising of the preventive maintenance activities. In addition, the asset database must be designed for storage of historical data of component maintenance as most of the evaluation is based on the study of trends.

The inputs to the database used for preventive maintenance are provided by different sources as the following:

- Process information from sensors;
- Periodical testing where the performance of components is recorded;
- Component operational time;
- Transients as number of switching, starts, thermal changes, etc.;
- Reporting of repairs;
- Component manuals where preventive maintenance is described;
- Component adjustments or calibrations.

The main tool for prediction of preventive maintenance is evaluation of trends. Such trends are extrapolated and compared with acceptance criteria. Sometimes, the condition of components is not measurable and must be calculated from a number of process values. If there is a risk that the condition of components will violate the acceptance criteria, an alert is generated. This approach is used as input for planning of preventive maintenance. In many cases, this method may save costs by replacing a current maintenance system, which is based on periodical maintenance regardless of the condition of the components. With the predictive maintenance approach, it is also possible that work orders are automatically generated for service or replacement. A special system may be established to evaluate the costs for service and repairs. If the cost for component maintenance is comparatively high compared to replacement, a decision may be taken to replace the component with a higher quality component.

8.2.2. Capture of physical layout

During the plant life-cycle, a nuclear power plant will undergo many modifications due to many reasons including such as, regulatory requirements, operational experiences, effect of aging, technological advances and research results. During this modification process, it is often recognized that differences between physical layout and documentation exist. When the differences between the physical layout and the documentation are too large, the capture of the physical layout may be recommended. Two methods are known for the capture of the physical layout:

(1) **Laser capture technique**
Using a laser scanning technique, a cloud of points is generated from different positions to find a surface of the plant equipment. The different positions are combined and a next step approximated by a CAD shape. This method gives results for the surface modelling but has some disadvantages for the recognition of the equipment. This means that for a simple CAD model this method may be suitable, while for a refined model a lot of work remains to be done.

(2) **Photogrammetry**

A large volume of pictures is taken for the specific plant to perform the so called "orientation" using three-dimensional coordinates. From the 3D coordinates, a 3D model is generated, in which the pictures, the annotation of the pipelines and equipment can be displayed.

8.2.3. Improvement of information processing

Modernization activities are going on in many NPPs around the world. An important input for the modernization effort is the information of the original design and its basis. As major modernization project is planned, it is recommended to evaluate the IT tools used during the planning and execution of the systems. An important application of electronic document management for a power plant is the management of the maintenance. The application includes the failure reporting system, preventive maintenance database, work permit, work order system and verification of lining up of the process systems, etc. Another typical NPP application is the analysis of transients and incidents for reporting to the regulatory body, which contains records of transient recording, event lists and calculations for comparing with the licensing SAR. (Also see Section 3.7).

As described in Sections 8.1 and 8.5, a common situation for operating nuclear power plant is that only a limited amount of the information is captured in the electronic form from the beginning of the plant life-cycle and the documentation is largely on paper. Today, most of the working activities are supported electronically but the input for the work is still based on the original paper documentation. Effective method for scanning such documentation is desirable. Another observation is that information is produced by different organizations in different formats. A typical step in the workflow is using information from different sources. Thus, some type of standard format is required for easy information distribution and integration.

In the workflow process, the traditional way to combine a set of information is to use a binder with paper copies. In the future, paper copies will be replaced by electronic files and links to the original files through a virtual library. However, inconsistency problems may occur if the links are not checked whenever information is changed. Linking of information is also necessary if responsibility for the maintenance of sources is changed. Nevertheless, the concept of virtual library is a viable future technology for NPP applications.

8.2.4. Plant infrastructure

The issues and concerns of the change of plant infrastructure have been addressed in Section 8.4. It is recognized that as a NPP proceeds through its life-cycle, the plant infrastructure will continue to change, which inevitably will impact on its information and document management systems. As the degree of office automation is increased, more users will be connected and the number of application is increased along with the data stored inside the infrastructure. For these reasons, continuous upgrading of the structure must be flexible during the operation of the plant. The upgrading is also driven by the development of the IT technology. It is expected that the use of IT tools will help reduce the costs for operation and maintenance. In order to prepare for such upgrading and to have a flexible infrastructure, the NPPs need to define a long term plan.

Process information

The part of the infrastructure for the process information is growing. The I&C equipment will continue to be modernized with computers and as a result, more process information is available through the network. This type of information will be available to the operators as well as staff members within the technical and maintenance organization. To protect the data in the I&C network from access, there are utilities that forbid transfer of information outside the control building or are using "read only" memories as an interface to the site network. In addition, to rationalize the maintenance work more administrative tools may be used in the control room to improve administrative management as well as co-ordination among the various departments including maintenance planning, supervision, testing, local control activities, and access control.

Network loads and reliability

As more IT technology is used in the NPPs, the network becomes more important and the load will increase year by year. Increasing the capacity of servers is today done regularly. Typical actions which increase the load on the network in existing plants is the replacement of paper based documentation to electronic management systems and the increased volume of documentation for licensing. The increased use of electronic tools for design, maintenance or operation will also increase the load on networks. The need for changes to increase the reliability and the performance has introduced many modifications of the network. The requirements about reliability and the resulting need for redundancy will be similar as for the plant I&C. An important issue to increase the reliability is the quality assurance for critical platform software and the applications.

External communication

In recent years, internal company networks were connected to external ones. Examples are the Internet with related e-mail, mobile telephones or the use of bar code readers in the plant. Other examples are the information networks about plant operation and accident management to authorities and emergency organizations. However, the connection of external networks and devices can be a threat to data security. In order to reduce the risk for unauthorized access, the regulators as well as the management of the company are putting stringent requirements for security protection. Some regulators or utilities require the separation of the internal networks from external ones by allowing only one way communications. The use of password, ID cards will be increased. Some more requirements about data security coming from the regulatory body or from the international standard society can be found in Refs [5, 16]. These references cover mostly the requirements for data security within the infrastructure for the I&C. However several requirements can be found regarding the connections between the I&C network, the site network and external networks.

Mobile devices

A future network will have facilities to gather information from mobile devices. Such devices may be used for gathering process information if permanent sensors are too expensive to install. Typical examples are:

- Bar code readers for position indication of manually controlled valves;
- Gathering of information for component conditioning monitoring;
- Verification of the correct line-up of the plant by using portable procedures.

9. CONCLUSIONS AND RECOMMENDATIONS

The report addresses all aspects of documentation associated with various life-cycle phases of nuclear power plants and the information technologies that are relevant to the documentation process. The report also provides a guide for planning, designing, and executing an information technology project for documentation. Examples are given to demonstrate successful implementations at plants. Finally, it discusses the issues related to the application of information technology in nuclear power plants and the trends for applications of information technology at plants as well as the technology itself. The following conclusions and recommendations are made as a result of preparing the report:

9.1. CONCLUSIONS

(1) The rapid advancement of the information technology as well as the needs of efficiency and effectiveness in nuclear power plant performance and safety lead to wide applications of information technology for the documentation process throughout the utilities and reactor designers around the world.

(2) As the bulk of the nuclear power stations were built in the years 1970–1990, their documentation are largely paper-oriented. The trend has been to move away from paper-centric documentation towards data-centric documentation where documents can be automatically generated from information stored in databases like the Rationalized Database. The hardware and software technology available today provides the capability for electronic recording, storage, retrieval, processing, and distribution of information related to a nuclear power plant.

(3) The information technology today has been used in many phases of the plant life-cycle, such as design, construction, operation, maintenance, and decommissioning. However, the applications within a phase or interfaces among the different phases are in general not well coordinated and integrated to achieve maximum effectiveness.

(4) Information technology tools have been used increasingly for all phases in a nuclear power plant life-cycle. The use of tools is inevitably related to safety and regulation of the plant. For this reason, special regulatory and safety requirements are important for both the individual applications and for the infrastructure.

(5) The benefits for installation of new information technology systems include making the work process more efficient, improving quality of the documentation, and reducing costs. A rationalized information base will facilitate the update of the complete set of documentation, maintain the design basis of the plant and asserts overall consistency. Work process and flow as well as organizations may therefore be re-engineered and changed. Participation by users to specify requirements and training of end users are important parts of the development of the new system. Such user involvement can lead to better definition and acceptance of the new system at plant site.

(6) Continuing advancement of functionality and complexity of the information technology solutions has made in-house development of total solutions impractical. This situation promotes the use of existing and well-qualified commercial off the shelf (COTS) tools. Nevertheless, plant in-house expertise should be retained for controlling the configuration and quality assurance of the applications.

(7) The specification of an information technology system for electronic data documentation can be divided in two parts, a functional specification and a design specification. The functional specification should be independent of the implementation and understandable to the users, while the design specification may be dependant on certain commercial tools. The selection of tool vendors and consultants is important in cases where outsourcing is desired for the execution of the project.

(8) A new feature of information technology called virtual reality (VR) has been adopted by the nuclear industry to facilitate planning and evaluation of certain operation and maintenance tasks. The technology enables the users of the system to simulate the tasks before they are implemented in the plant, thus reducing the risks and maximizing the effectiveness and efficiency.

9.2. RECOMMENDATIONS

(1) As progress has been made to implement information technology in the nuclear power plants, the trend has been the replacement of processing capability from large mainframe computers to smaller distributed workstations and personal computers. This development has led to sets of stand-alone legacy systems and solutions. The legacy systems that exist in various parts of the nuclear power plant for different applications may be included, deleted or modified when the plant is planning to implement a new electronic document management system using advanced information technology. A strategy for such process should be developed for the project to facilitate coordination, merger and integration between the old and new systems.

(2) The Design and implementation of information technology software or system for electronic document management should be based on an integrated approach for the whole nuclear power plant. This shall be valid not only for the part of technology such as the infrastructure, but also for standard plant practices, for example, using standard templates for documents, users interface menus, tagging system for components, and human-machine interfaces in general.

(3) To implement information technology for nuclear power plant documentation, quality assurance procedures must be established to ensure compliance with specifications, regulations, security and quality requirements for the plant life-cycle that include design, construction, operation, maintenance, and decommissioning. A guideline for the quality assurance procedure should be developed to facilitate both the development and the implementation processes.

(4) Further studies and evaluations are needed to develop criteria for regulation and licensing acceptance of information technology that includes rationalized information bases in an electronic document management system for nuclear power plant life-cycle applications. The criteria may facilitate planning and implementation of the system as well as the scheduling and cost estimation of the project.

(5) There are a whole series of techniques and methods being developed rapidly in the information technology industry that may be relevant to the nuclear power plant applications. It is recommended that the nuclear establishment should evaluate the development and application of these techniques and methods and recommend solutions for enhancing the performance and safety of nuclear power plants.

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ABBREVIATIONS

AIIM	Association for Information and Imaging Management
API-ODM	Application Program Interface for Open Document Management
CAD	computer aided design
CADD	computer aided design and drafting
CAE	computer aided engineering
CALS	continuous acquisition and life-cycle support
CBSD	component based software development
COTS	commercial off the shelf
DMA	Document Management Alliance
EAI	enterprise application integration
EdF	Electricité de France
EDM	engineering data management
EDMS	electronic document management system
EMC	electro magnetic compatibility
EPC	Engineering, Procurement, and Construction Company
ERP	enterprise resource planning
FAT	factory acceptance test
HMI	Human–machine interface
IB	information base
I&C	instrumentation and control
IDEF	integration definition for function
IEC	International Electrotechnical Commission
IEEE	Institute of Electric and Electronics Engineers
I/O	input and output
ISO	International Organization for Standardization
IT	information technology
ITB	invitation to bid
KM	knowledge management
LOCA	loss of coolant accident

OCR	object code recognition
O&M	operation and maintenance
O/O	owner/operator
P&ID	piping and instrumentation diagram
PDM	product data management
PEDB	project engineering data base
QA	quality assurance
QC	quality control
RDBMS	rationalized data base management system
SAR	safety analysis report
SAT	site acceptance test
SSC	structures, systems, components
TCO	total cost of ownership
TIF	the image film
UML	unified modeling language
VR	virtual reality
V&V	verification and validation
Web DAV	web distributed authoring and versioning
2D	two-dimensional
3D	three-dimensional

GLOSSARY

build projects	Projects involving the design and construction of a new nuclear power plant.
compound document	A document composed of a variety of data types and formats. Each data type is linked to the application that creates it.
content search	The ability of a system to search through text to match a group of characters.
criticality index	A classification to indicate the importance of an information technology tool for safety. It is used to evaluate how errors in information technology tools can propagate to the design, operation or maintenance.
data centric	An information system managing and storing the information at the object level, independent of the documents depicting the object, able to reconstruct documents based on the data stored with each object in a unified database.
decisions	The result of an activity leading to the generation of information that can be used to produce formal deliverables or to initiate other activities, or to relate the state of physical plant object.
document	A document is any container of coherent information that is assembled for human understanding.
document centric	An information system managing documents separate from the objects contained within each document.
document management	Process of managing documents through their life-cycle, from inception through creation, review, storage and dissemination to their destruction.
document management system (DMS)	Also referred to as Electronic Document Management System (EDMS): typically refers to a computerized environment which enables the creation, capture, organization, storage, retrieval, manipulation and controlled circulation of documents in an electronic format.
enterprise application integration (EAI)	A common term for modernizing and linking together the computer applications of an enterprise.
enterprise resource planning (ERP)	Refers to the broad set of activities supported by application software that help a manufacturer or other business manager the important parts of its business, including product planning, parts purchasing, maintaining inventories, interacting with suppliers, proving customer service, and tracking orders.

information consumers	Individuals, groups of individual or organizations whose activities rely on data supplied by others.
information object	A collection of information which contributes to the definition of a plant object, its current state as well as its history, a documentation of specific design base decisions that might relate to system design parameters, configuration, licensing issues.
information providers	Individuals, groups of individual or organizations, responsible to generate and to record information as part of project or plant setting.
knowledge management	The process of capturing value, knowledge and understanding of corporate information, using IT systems, in order to maintain, re-use and re-deploy that knowledge.
metadata	Information used to describe stored documents or data, such as "creation date", "author", "department", etc. Also called attributes or control fields.
plant object	The physical nuclear power plant assets such as buildings, equipment, pipe lines, cables, etc.
process re-engineering	Activities associated with the optimization of a work processes in view of a changing working environment and/or the implementation of new tools as part of the associated tasks.
product data management (PDM)	A broad-scope approach of data management that relates to all the data associated with a particular product.
publishing	Making information publicly available, usually through print media, but also through electronic media such as design database or World Wide Web (WWW).
rationalized information base	The collection of all information sources describing the state of the NPP, re-structured in a way that optimizes the recording of information and facilitates the retrieval and use of the information.
"rogue" applications	Applications created by individuals to automate certain portions of their work. In many cases, they are adopted by a group to fill gaps in the NPP's information base. They become a problem when they compete with the main information system being adopted by the organization.
work flow	A description of the information transmitted among the participants of a work process.
work process	A description of the organization of a task and the responsibility of the involved groups and departments.

Appendix A

INFORMATION FOR LICENSING

During the different life-cycle phases of a nuclear power plant, there are requirements about certain type of information that must be made available to the regulators or the licensing authorities. Different countries have different requirements [1–10]. A typical example is outlined herewith in this Appendix.

For information technology projects, the typical milestones for submitting information packages to the regulators are at the beginning of the project before investments are committed and near the end before official operation of the IT system. The purpose of the submittal in the beginning of the project is to inform the regulators for potential impact on the safety and reliability of the plant, if any, or to obtain a preliminary acceptance. The type of information is similar for new systems as for modifications of existing ones.

For preliminary acceptance, the information is related to the following:

- Background for the proposed modification or new development
- Risk analysis for potential safety impact
- Safety classification of software and hardware
- Design and acceptance criteria
- Influences to existing hardware, software or work processes
- Influences to the current plant safety analysis reports and technical specifications
- Quality assurance (OA) manual for the project
- Verification and validation (V&V) plans
- Time schedules
- Description of the new system or proposed modifications
- Schedules for information submittals to the regulator.

For final acceptance before handing over the new system or modification for applications in a work process, it must be subjected to a formal acceptance or licensing procedure. The input for the information requirements is related to following:

- Test result and verification reports for hardware and software
- Evaluation of the V&V results with identification of open items and corrective actions
- An approved site acceptance test report
- Evaluation of the training for the end users
- Human machine interface evaluation
- Reliability assessment for the hardware and data
- Verification of dismantled hardware or deleted software
- Security plan
- Operation and maintenance manuals
- Procedures that are required by the plant QA program
- Detailed descriptions
- Modifications to the plant SAR and technical specifications.

For the operations and maintenance of the IT systems that are relevant to safety, information should be made available to the operators for safety critical items. Such information can be related to following subjects:

- Operational, event, incident and error reports;
- Human factors analysis;
- Audit reports for the work process and related activities;
- Proposals for changes or modifications;
- Violation of data security.

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Appendix B

DEVELOPMENT OF METHODS AND TOOLS FOR CONFIGURATION MANAGEMENT

The method that deals with the control of changes in documentation must be capable to handle the relational structure of the plant objects and the reconstitution of the database. As depicted in Fig. 1, the relationship between design requirements, physical configuration and the facility configuration information must be kept under control using administrative measures together with tools. Generally, a plant management system can support most of the administrative aspects with a variety of tools. However, without an integral approach, a typical administrative system mainly addresses intensive control at the interfaces between the different tools. Extensive man-hours can be saved with the assistance of computer programs that enable engineering data management (EDM) capabilities. There are tools on the market that can perform the following tasks:

B1. Document Management

A document in electronic form is described by additional data — so called "meta-data" for storage and easy retrieval. The tool provides a revision and version management capability, which can store all changes and modifications of a document when needed and the history of a document can be traced back. The retrieval mechanism can include full text retrieval capabilities. Thus whole document content can be searched for a specific word or word string.

B2. Communication

For the purpose of communication, the tools should provide viewing and redlining features. A viewing tool can typically view dozens of different formats. Therefore, special care should be taken so that the viewer can handle the specific formats of the nuclear plants and the utility company. For communication among departments or individuals, redlining features can replace the traditional notes on the report or drawing. With this feature, comments are transferred without changing the original document. This is achieved by adding specific layers to the original document where remarks, comments and clarifications are stored.

Concerning the distribution of the documents to participants within the EDM system, the pointer to the documents should be transferred. So, the huge amount of data generated by the E-Mail or other systems can be avoided. Furthermore, the system should be able to select the participants of the system and automatically provide the information by E-Mail.

The communication among the users not having an EDM installation may be supported using web-based technology that can access the EDM system. It helps to convince the internal users to abandon the private information platforms as they see the advantage of a common platform that is kept up-to-date. The same is true for communication with external partners as suppliers, architect engineers, vendors etc. In this case, an extranet approach is helpful providing the central information to the partners. This can be done using a viewer on the information available that may be restricted according to the access rights.

B3. Representation of Plant Structure

For the purpose of plant configuration management, the document, data and information should be tied together to the plant structure. The following structure may assist to visualize the information mechanisms needed:

As indicated in Fig. 1, the plant object structure should be represented in the system following the identification system of the plant. Therefore, an easy navigation over the information is possible especially for the users working in the plant environment. The plant object structure and the project document structure must be reconciled including all revisions. As the EDM method links documents with plant objects, any deviation occurring during installation or operation can be noticed so that countermeasures and corrective actions are taken. For example, the EDM system should be capable of providing all information concerning a specific valve including the P&ID, wiring diagram, isometric of the pipe where the valve is located, cut-through figures of the valve, item list of the valve, etc.

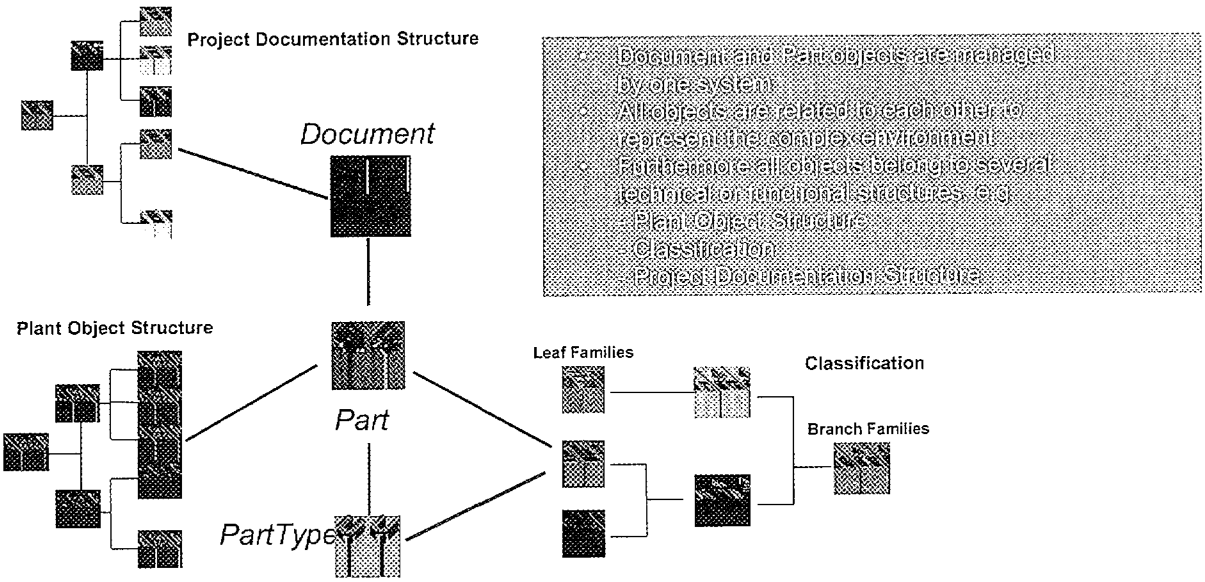

FIG 1. Relations for configuration management.

B4. Workflow Management

As shown among the relationships in Fig.1, changes in the documentation can be followed regarding the time of the change and the author of the change to enable trace back complying with the demands. The workflow should be modeled in the EDM system following the work process, which can replace administrative measures. So, the release of a drawing can be channeled automatically to the person who has the right to release this drawing. In the case of reconciliation of documentation with as-built situations after the modification, the workflow automatically transfers the documents to the "electronic desks" of the persons who are in charge of the different tasks. As this transfer is registered by the system, persons having the specific rights can see the status and the position of the documents.

B5. Customization of EDM Tool

To select an EDM system, special attention should be paid to the fact that the system must work and represent a power plant situation and documentation. EDM systems should be customized in advance for the representation of a power plant with its identification system and corresponding document types, so that less customization is applied in this field. As the EDM system covers a lot of administrative and organizational aspects, it must be customized to fit into the individual organization to represent the workflow.

Appendix C

MODERNIZATION OF THE PLANT COMPUTERIZED DOCUMENTATION SYSTEM

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C1. Introduction

The Forsmark nuclear power plant, located at the north of Stockholm, comprises three BWRs. The first unit started commercial operation in 1981 and the last one in 1985. The three units are operated by the Forsmarks Kraftgrupp AB, which is a subsidiary of Vattenfall AB. The power plant has a total net capacity of 3300 MW. A site-wide computer system was developed for support of the management of the process systems, the operations, the maintenance and the general administration. The system, or rather a complex of different systems, has been in operation from the beginning, but has since been in the progress of modernization, which includes both hardware and software functions. This paper provides an overview of the integrated system with especial focus on the modernization of the documentation system.

C2. Background

The nuclear island and the balance of plant for all three units were delivered by ABB. A well-structured and integrated computer-based support system was established for each unit and the whole power plant. Each support system is based on fundamental principles that must be used for the whole organization. Examples of such principles are:

- A system for identification of all plant systems and components
- A structure for plant documentation for systems, operational and maintenance manuals and other information
- A well structured database for all components in the power plant.

By having the same contractor for all process systems, it was possible to use the available design database and expand it for operations and maintenance. The different types of computer systems were designed from the beginning as autonomous ones. However, during the years they were modified and integrated into the digital highway for the whole plant. Some typical modernization projects were:

- The introduction of a new I&C network infrastructure for the two oldest units
- The integration of each unit I&C network and connection to the site network
- The change over from a mainframe computer concept to one with workstations.

C3. Site Infrastructure

The infrastructure of the Forsmark NPP consists of a communication system to which all computers or workstations on the site are connected, including the administration network. Originally, the administration system was based on a mainframe computer with terminals. The system has since been substituted by a network with servers and workstations. The old terminals are emulated, which makes it possible to exchange and modernize the functions performed by the old mainframe system one-by-one. The following subsystems or functions are connected to the administrative network through gateways and firewalls:

- Process control and instrumentation
- On line core supervision
- Safeguard
- Plant access control
- Dosimetry
- Waste handling
- Plant simulation
- Human resources.

The software and hardware infrastructure for the administration system is based on the Forsmark Network Application Architecture (FNAA) model. The architecture is divided into two groups as shown in Fig. 1.

In Fig. 1, the IT part includes the main platform with related database and communication services, while the IS part contains all the individual application programs and the interfaces to the end users. The information exchange between the two groups is managed by a well defined "information interface". The different parts of the site infrastructure are described and analyzed in the safety analysis report (SAR) for the Forsmark site.

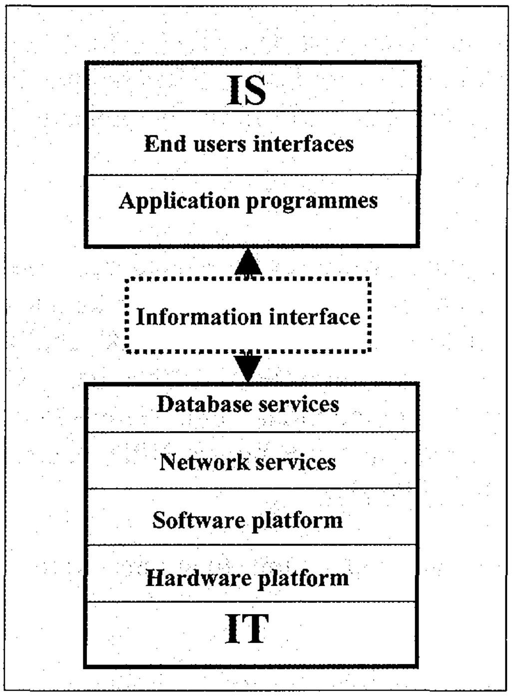

FIG 1. The "Forsmark network application architecture" (FNAA).

C4. Organizations

Many organizational units are using their own typical computer functions. All the functions are integrated into the FNAA model (See Fig. 2). For each computer function, it is associated with an "application owner" who has the responsibility for the whole life-cycle for the application, the IS part, while the "IT" part is the responsibility of the site computer department.

An important responsibility for the owner is to design the application so that it is suitable for the applicable working method of the end user; that is the "working process". Development for a new application or modification of an existing one is normally initiated with an analysis of the working process.

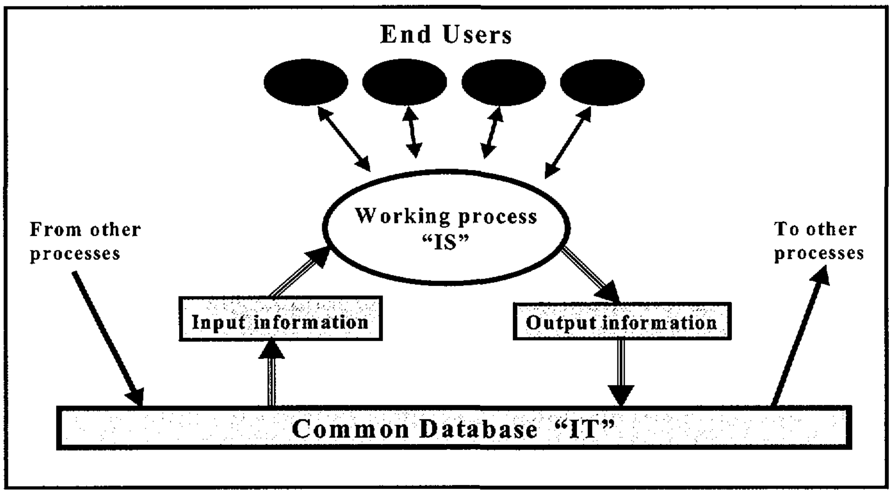

FIG 2. The "ownership" of IS applications.

For co-ordination and decision-making, a site IT/IS group is available where personnel from the production units, technical support and IT/IS security are represented. An important responsibility for the group is to supervise that standard solutions are being used, e.g. menus, colour coding and that access control is uniform for all applications.

C5. Modifications

All IS/IT activities are periodically reviewed and decisions are made to develop new hardware or software functions to modify existing ones or to delete obsolete functions. Today, the IS/IT system for the whole site includes about 200 applications. About 40 of these applications are common for all the three units. The other applications are related to the operations and maintenance of an individual unit. The administrative functions used at Forsmark are similar to those used at the Ringhals NPP. The functions are described in an appendix to the IAEA-TECDOC-808 [1].

During a 1999 review, all application functions were divided into the following categories:

- Existing functions without requirements for modification
- Existing functions that must be modified within 1–2 years
- Existing functions that must be modified within one year

- Functions used by many other users or functions
- Obsolete functions that must be deleted.
- Not used functions
- Functions under development
- Functions in another computer system with information exchange.

Based on this review, a plan was established, which encompassed activities for development or modifications in about 30 areas. The plan is continuously updated. One important decision was to develop a new system for document management. This project was called FEDHa, which stands for Forsmark Electronic Document Management.

C6. The FEDHa Project

C6.1. Objectives

The main objectives for a common documentation system for the whole Forsmark site were:

1. To reduce the time for production, storage, access and distribution of documents and to increase the quality for information treatment
2. To make information available to all Forsmark staff members with minimum limitations
3. To reduce the time for document acquisition and distribution by using simple and effective tools
4. To increase the quality of the management of documentation by common procedures for uniform document design, QA, registering and storage
5. To reduce the need and volume for local or private archiving.

C6.2. Project planning

The project was started at the end of 1995 and was divided into four phases (see Fig. 3)

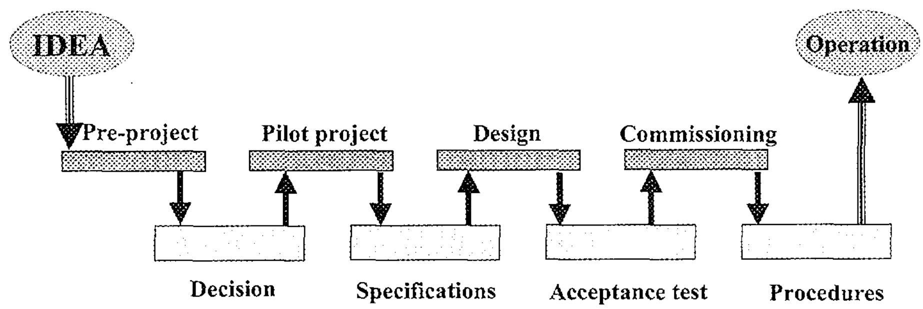

FIG 3. The FEDHa time schedule.

Phase 1
The first phase was a pre-project, during which the existing document system for Forsmark was assessed. Based on the result of the assessment it was recommended to continue with a main project in 1996 and for operation in 1998. The pre-study included not only the assessment of software functions, but also necessary modifications to the existing plant computer system.

Phase 2
One important recommendation of the pre-project was to install a pilot system for validation before installing the main system. During this phase, the following main activities were performed:

- Development of detailed specifications for a pilot function
- Planning for installation
- Market study
- Selection of a contractor.

Phase 3
Phase three included the following steps:

- Purchasing of the main document software platform
- Description and approval of specification of functions
- Adaptation of the main software platform by the contractor
- Factory acceptance test
- Site acceptance test
- Validation of the pilot project
- Training of staff members and production of user manuals.

The validation was carried out by a group of 55 end-users at Forsmark unit 1. The result of the pilot project was analysed and specifications were modified for installation of the final system. This phase was concluded in the beginning of 1997.

Phase 4
The last phase in the FEDHa project was the installation, commissioning of the system and the turnover to the owner during the years 1998 and 1999. The detailed steps were:
- Installation, commissioning and testing of the system for the whole Forsmark site
- Production of technical and performances requirements for the hardware
- Recommendation of a life-cycle organization for the development and maintenance of the system
- Implementation of an uniform treatment of documentation produced internally and externally
- Specification of a strategy for transfer of information from existing system to FEDHa
- Production of standard templates for all documentation within the Forsmark organization
- Recommendation of a strategy for the integration of the FEDHa system with other functions e.g. maintenance, intranet and other functions
- Training of end users.

Since the new FEDHa system has an impact on the currently used working practices, it is therefore important during the training of the end users to explain carefully all changes and to motivate the involved personnel. The FEDHa system includes tools to handle existing documentation as for registration, scanning and interpretation. However, transfer of such information to the new system is decided case by case.

C6.3. Document survey

The FEDHa project was started with a survey of all documents types that were in use within the Forsmark organization. The goal for the survey was to reduce the number of different document types, to improve registration and the access for the users of the system. Identification of documents was not uniform for the whole site and it was a responsibility for each different organizational unit. As a result, different types of documents exist and it has sometimes been difficult to find the information required.

It was observed that two main document classes were used; one for administration and the other for technical documentation and that documents are not only produced within the own organization, but also by outside contractors, e.g. drawings. Each one has its own procedures for registration and storage. The existing system was in principle a registration of documents. Storage was done in paper form, while the registration was done by "cards" in the existing mainframe computer. The number of cards was about 170,000. This number increased every year with about 15,000 for all types of documentation. Examples of documents are shown in Table I.

Table I. Examples of documents

Letters	**Minutes**	**Notes**
Procedures	**Reports**	**Drawings**
Fax	**Operating procedures**	**Maintenance procedures**
QC procedures	**FSAR**	**Technical specifications**
Operational orders	**Working permits**	**Decisions**
Overheads		

The project was started with the text documents. Next, all drawings produced on site shall be included. Furthermore, development is ongoing between main contractors and the Forsmark organization to standardize the format for drawings. It is also planned to include other external documentation by scanning.

C6.4. Work process

Two types of work processes were identified. The first one was the process to produce documentation, to identify and register each document and make it available. The second process is for the end users to retrieve information. Once a document can be retrieved, it is possible for the end-user to use the information. The first work process includes such elements as:

- Production of a draft by using an approved template
- Assignation of an identity and storage as a draft
- Review of the draft in accordance with QA procedures
- Modifications according to review comments
- Approval in accordance with QA procedures
- Final registration, storage and release for distribution
- First page with signature stored as a paper.

Fig. 4 gives an overview of the responsibility of the staff members involved and shows the process how the documents are approved and signed. The work process includes a method to keep track of all versions of each document.

Many documents are referred to enclosures. Such enclosures can be in another format than the base documents. The FEDHa has the possibility to include in the text, embedded links to enclosures and to other references. Today, all documents are approved and signed as paper-documents that are stored in an archive. The paper-document function is verification for the users that the document, which was registered in FEDHa, is approved and can be used. The FEDHa system does not yet support functions for electronic signature of documents. Development for this kind of support is planned for the near future.

C6.5 Retrieval of information

The end users retrieve the information by using a standard menu on his workstation. The menu is designed with the same principles as those used in the operating system such as the Windows, but modified in accordance with a common Forsmark standard. (See Fig. 5)

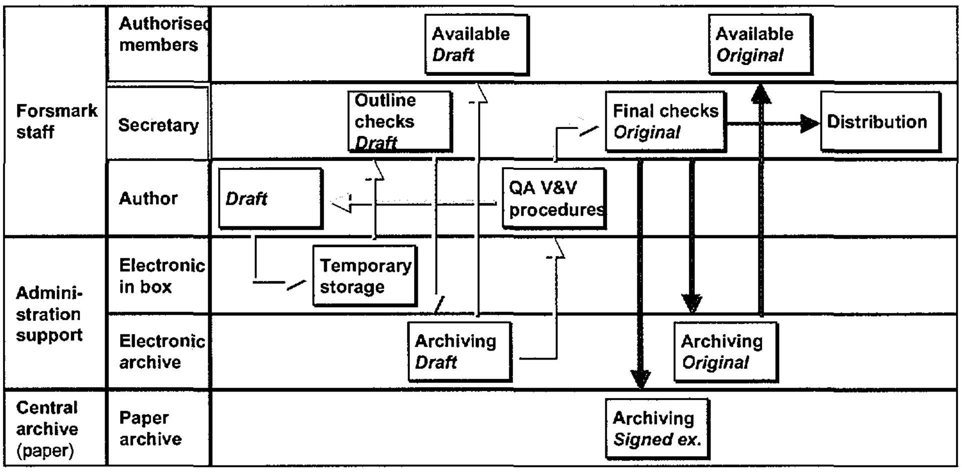

FIG 4. The work process to produce a document.

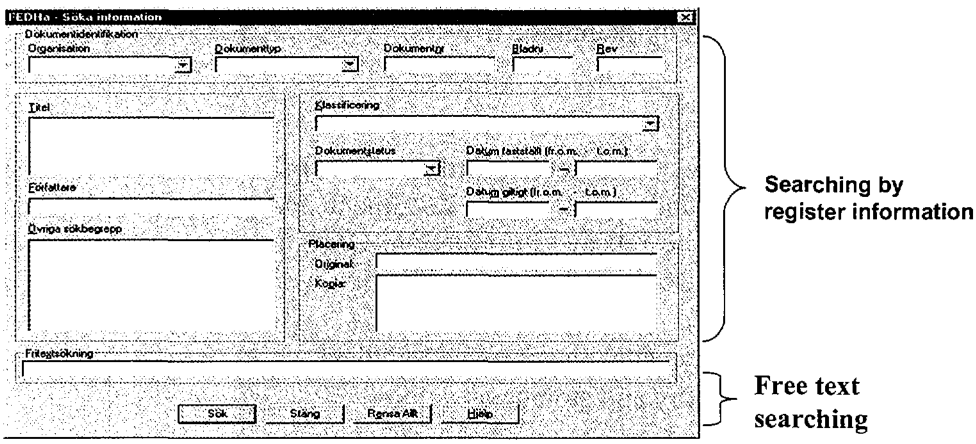

FIG 5. Standard menu for information retrieval.

By using the menu, the following features are available:

a) The basic function is the search of database for documents by using key words or their combinations.

b) The context-search allows users to perform search for specified data or text in the register or in text documents at the same time.

c) The searching process can be a combination on the register-information (database) for documents and the text in documents (context-search).
d) To create different categories such as personal, a project, or a technical issue, the files can be arranged by composing links to stored documents.
e) Documents can be stored or printed out for local use.

C6.6. Training

During the design of the prototype, a training was arrange for following categories of actions:

- Administration of the system
- Registration of information
- Using of information.

The training during the pilot project was done in cooperation with the contractor with 55 end users participated. Similar training was also arranged for the final full scope system.

C6.7. Experiences

The first feedback of operation experience was obtained during the validation of the prototype. The feedback was gathered in a systematic way by letting the end users fill in forms. Many important comments were received and modifications where included in the final system as a result of the comments. A similar feedback system is used for the final installed system. (See Fig. 6)

The system has been in operation since June 1999. The system meets the requirements although the lack of uniform naming conventions make searching of documents difficult. The system is now used by all of the staff at the site and the number of stored document is growing rapidly. The system has been well received by the users and lots of changes are suggested and ideas are proposed for integration of FEDHa with other systems. A development project to integrate FEDHa with other systems (for example, maintenance and intranet) has been started. The integration will make the system more powerful and increase the use of the system. It is also planned to increase the number of external and scanned documents.

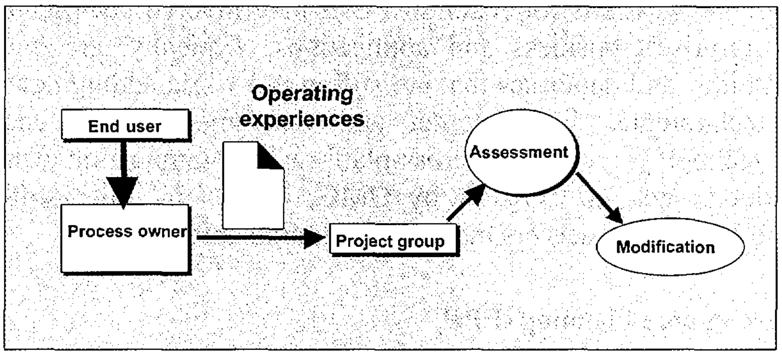

FIG 6. The feedback of operating experiences.

REFERENCE TO APPENDIX C

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Appendix D

SOFTWARE TECHNOLOGIES TO SUPPORT DOCUMENTATION AND INFORMATION MANAGEMENT

D1. Current Problems in Documentation and Information Management

The role of the appendix is to provide a view of computer based techniques and software products that can be used for or may have some impact on the design processes and the electronic documentation in nuclear power plants.

As problems have been solved one at a time, a set of isolated information systems of different ages and technologies has been developed at nuclear power plants. As a result, the increasing number of interfaces among the isolated systems have led to high maintenance costs. A clear trend for the nuclear industry is toward using commercial off-the-shelf (COTS) components. The key issues for the IT professionals of a utility include, for example:

- What sort of IT architecture and technological basis would be the best guarantee for performance and long-term maintainability?
- Would it be wise to rely on a single primary IT supplier or to use multiple suppliers and try to solve the integration problems with in-house expertise?
- How to combine users' own specific needs with the capabilities and parameterization possibilities of commercial software products?
- What to do with the existing systems?

A number of approaches have been developed for addressing these problems. A short overview is given below. Many of these techniques are related to the management of plant information during the different phases of a plant's life-cycle.

D2. Enterprise Application Integration (EAI)

EAI is a common term for modernizing and linking computer applications of an enterprise (http://www.whatis.com/eai.htm). EAI may involve developing a completely new view of an enterprise's business and applications. Typically, an enterprise has existing "legacy" applications and databases that are still in use while adding new applications, which exploit new technologies like Internet and e-commerce. EAI encompasses different "middleware" technologies such as cross-platform communication using message brokers (currently products such as CORBA by OMG, COM+ by Microsoft), message queuing approaches, and application servers managing common databases.

D3. Enterprise Resource Planning (ERP)

ERP is an industry term for the broad set of activities that are supported by application software to help a manufacturer or other business manage the important parts of its business, including the following: (see for example, www.whatis.com/erp.htm)

- Product planning
- Parts purchasing

- Maintaining inventories
- Interacting with suppliers
- Providing customer service
- Tracking orders.

ERP can also include application modules for finance, maintenance and management of human resources to cover and integrate a major part of business processes. The deployment of an ERP system can involve considerable business process analysis, employee retraining, and new work procedures. Typically, an ERP system uses, or is integrated with, a relational database system. So far, ERP applications have usually covered a single enterprise including one or perhaps several locations. The emergence of networks of enterprises (or extended enterprises) has created the need to integrate the different ERP systems of the partners leading to what is often called supply chain management (SCM). This calls for a common model for data and documents, operations and work processes.

D4. Electronic Commerce (EC)

EC is the buying and selling of goods and services on the Internet, especially the World Wide Web. In practice, this term and a new term, "e-business," are often used interchangeably. EC can be divided into the following (see for example, **www.whatis.com/** ecommerc.htm):

- E-tailing or "virtual storefronts" on websites with on-line catalogues, sometimes gathered into a "virtual shopping center"
- The gathering and use of demographic data through Web contacts.

D5. Electronic Data Interchange (EDI)

EDI is the business-to-business exchange of data, which includes the following:

- E-mail and fax and their use as media for reaching prospects and established customers (for example, with newsletters)
- Business-to-business buying and selling
- The security of business transactions.

D6. Electronic Document Management (EDM)

EDM refers to the management of documents using computers and mass storage. (See for example, http://whatis.com/edm.htm) There typically are many kinds of documents such as specifications, CAD-drawings, invoices, sales orders, photographs, phone interviews, or video news clips. An EDM system allows its users to create, store, edit, print, process, and otherwise manages (e.g. version control) documents in image, video, and audio, as well as in text form. An EDM system usually provides a single view of multiple databases and may include scanners for document capture, external tools for editing the documents and printers for creating hard copies. Server computers are typically managing the relational databases that contain data and links to the documents, or the actual documents themselves.

Traditional EDM systems have a document or image centered focus. Product data management (PDM) has a broader scope. It relates all, not just part, of the data relevant to a particular product (see for example, www.pdmic.com/articles/whatspdm.html). Using a product point of view, the approach to product data enhances a company's ability to perform tasks related to using the information. A PDM system covers, for example:

- Definition of the product structures (decomposition), product families and variations
- Documents (specifications, manuals) and historical data
- Configuration management and version control
- Computerized work processes

In conclusion, the electronic documentation in a nuclear power plant is not a separate single issue. Many types of documents and other pieces of information exist. They are affected by many work processes and user groups during different life-cycle phases, and document management can be included in different information systems. As a result, an EDM system could be combined with a PDM of ERP system or a workflow management approach to maximize NPP effectiveness and efficiency.

Appendix E

INTERNET APPROACH TO PLANT DOCUMENTATION

E1. Need of Standardization for Information Model and Work Process

It is a trend that the commercial off-the-shelf software (COTS) is playing an increasingly more prominent role in plant documentation. As software becomes more complex, it will be less and less feasible for the utilities and even some system vendors and consulting firms to maintain their own software and their information base. COTS may provide more functionality for less cost in the long run. However, there is a serious drawback with COTS. The end users whether it is the plant vendor, consultant or utility may easily become dependent on the software tool providers. When the commercial support is no longer available from software vendors, the left-along users will not be able to upgrade their system to reflect innovations in hardware and software technology.

One way to deal with the situation would be for the end users to build their database updating system from scratch, using a new tool provider, and trying to excavate as much information from the old system as possible. Thus, it makes sense for the end users to plan their software systems as to avoid this situation. Using a standard approach seems to be a legitimate solution. Still some problems persist as there are no standards applicable to the actual domain and the relevant standards do not always address the problem at a suitable level. A suitable level would enable the users to move the utility specific information used by one application to another application without manual intervention. For example, the data that have been stored in the database may be easily transferred, but may not necessarily following the rules that update and maintain the data in the database. The rules of update may be still implicitly embedded in the original IT tools. Thus, even though a popular commercial tool may be seen as a de facto standard, the system as such is not based on a standard at a suitable level. If changes in the environment should make update of the rules desirable, this presupposes that expertise would be available to change the IT tools that provides the updating capability.

The situation is being recognized by more and more industries. Standardization efforts have been started to represent information independent from the application in which it is being used. In order to deal with this problem one need to have a terminology that is common to the enterprise. A terminology common to the trade is even better because it enables the industry to share information. The terminology should also have an associated qualification that restrains how the individual concepts can be used. Such a formal system can be denoted an information model.

In the NPP industry, standards that deal with the working processes are needed. If a utility or a vendor should decide to reengineer its business process for their working processes today, they would not be able to use a terminology that is certified and widely accepted by the community at large. The industry should therefore look at the possibility and desirability of investing in such a standardization effort. It might be a problem to arrive at a common set of concepts that would be useful to describe the work processes, as this is different from one plant to the other. Irrespective of the outcome of standardization involving several utilities, each single utility should strive to establish and maintain an information model that could be used to describe all data in the information base.

Separate tools are often used for maintaining the information model vs. the information that are encoded by the information model. If the tool uses a proprietary format to encode the information, the end users will again be vulnerable to the dispositions of the tool provider for the information model. Consequently, it is important that the tool provider uses a representation language that is open and as general as possible. A good strategy to achieve this could be to look for formalisms that have a large community of users, such as the Internet and intranet.

E2. Emergence of Internet Technology

With the introduction of Internet and intranet technologies, a large community of users has really come into existence. Dealing with such a large community of users a wide variety of COTS will naturally evolve. Obviously, the present state of Internet browsers is not adequate enough to serve the needs of computerized plant documentation in NPPs. Still there is a development in the software industry for Internet applications.

The evolution of Internet may serve an example to illustrate the point. The first formalism for presenting web pages was the Hyper Text Mark-Up language (HTML). A lot of information could be presented only by means of this formalism. However, as the information available on Internet increased rapidly, a problem occurred to the users that searching on Internet often rendered many possibilities. The problem has spawned worldwide activities on making more intelligent search engines for Internet.

One of the problems relating to Internet information retrieval is the involvement of natural language recognition. HTML only defines the rendering of the information, not the content. In observance of this, a new standard has been proposed, which is the Extendible Mark Up Language (XML). XML helps the WEB page creators or designers to define the content of their WEB pages. So far, the web designers can freely select the tags that describe the content. This means that there are no common information models that information can be structured accordingly. However, for a smaller community, like an enterprise, it is possible to agree on a set of XML tags to describe the content of the WEB pages. This will facilitate the search for WEB page information within that community.

Once the content has been described by XML, the rendering of the page will be described by another formalism called Extendible Stylesheet Language (XSL)[1]. This leads to a separation of content and presentation that can be exploited to create many different outlooks on the same information content. This is a desirable feature, because it enables the enterprise to tailor the information according to user types and situations for which the information is to be used.

The example of retrospect illustrates the development that is provoked by a large group of users, resulting in something that maybe relevant to NPP documentation. It is interesting to note that this has happened without the involvement of the NPP industry. It is thus recommended, that the NPP industry closely watch the possibilities of integrating their systems with the solutions evolving in the Internet domain.

The future development of the Internet is difficult to predict. Nonetheless, it is reasonable that future systems will be downward compatible. Without this quality, a lot of information already available could not be used in future versions of the Internet.

The NPP industry might not adopt the Internet approach straight away because of the requirements on safety. It is reasonable to observe the evolution until the Internet solution development further matures and high reliability can be achieved. Besides, there are legacy systems that cannot easily be transcribed to the Internet format. Still, it is technically viable to start integrating legacy systems by means of Internet. This activity would be in line with activities around EAI (Enterprise Application Integration). Such a solution is already attempted in the iEMPAC system [2] that extract legacy data from an Oracle database in terms of XML tagged data.

REFERENCES TO APPENDIX E

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