APPLICATION OF INTEGRATED COMPUTER-AIDED ENGINEERING FOR DESIGN, CONSTRUCTION AND OPERATION OF NUCLEAR POWER PLANT: PRACTICE AND PROSPECTS

KYUNG-SHICK MIN and BYUNG-HUN LEE
Korea Power Engineering Company, Inc.
87 Samsung-dong, Kangnam-Gu, Seoul 135, Korea
Telex : KOPEN K22562

ABSTRACT

Computer-aided-engineering (CAE) is an essential tool for modern nuclear power plant engineering. It greatly varies in definition, application, and technology from project to project and company to company. Despite the fast growing technologies and applications of CAE, its complexity and variety have thrown another puzzle to management of a nuclear project. Without due consideration of an integrated CAE system in early planning stage, the overall efficiency of a nuclear project would slow down due to the inefficiency in data flow. In this paper, practices and perspectives of CAE application are discussed under the Korea Power Engineering Company (KOPEC) philosophy in CAE approach.

I. INTRODUCTION

The computer technology is an essential tool for nearly all kinds of advanced engineering at the present time. It is especially true when nuclear power plant engineering is concerned, which is an aggregate of the most advanced technologies.

The computer technology, applied for the engineering area, is frequently called as computer-aided-engineering (CAE). CAE is widely used throughout the whole life span of nuclear power plant. In this paper, the following topics will be discussed in a relatively liberal way:

- o Definition and general usage of CAE
- o Life span of nuclear power plant and CAE application
- o Current practices and obstacles in CAE application
- o Perspectives of CAE application

II. DEFINITION AND GENERAL USAGE OF CAE

A. Definition of CAE

The term "CAE" could be defined narrowly and broadly. The narrow definition of CAE is computer aided engineering computation. In this paper, the broad definition of CAE, computer aided engineering environment, would be accepted.

The comprehensive CAE system should cover the following broad spectra of modern engineering aspects in a form of total integration: (See Figure 1)

- o Computer aided design and drafting (CAdd)
- o Computer aided engineering computation (CAec)
- o Computer aided administration (CAa)
- o Computer aided information retrieval (CAir)

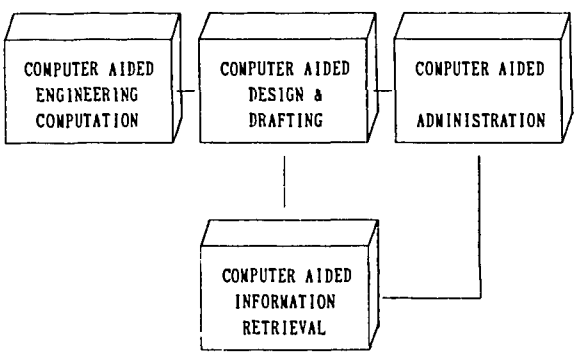

Figure 1. Concept of Integrated CAE

CAdd is the design/drafting arm of the integrated CAE system. CAec is the computational arm of the system. CAa is the control center of the system which comprises both organization and project administrative activities and communication. CAir serves the system as a data bank for both current and historical records.

To put in a clear sense, the integration means that any design/drafting activity performed by CAdd and CAec should be directed and monitored by CAa and that the results of design and drafting should be stored or registered at CAir database.

B. General Usage of CAE

1. Computer Aided Design and Drafting

CAdd is a genre of computer graphics system specialized in engineering design and drafting. The principle of computer graphics system is converting drawing into digital form which computer can understand.

CAdd is utilized by various engineering disciplines as follows: (See Figure 2)

- o Civil: Site plan
  Structural design
- o Architectural:
  Building plan
- o Mechanical:
  Process flow diagram (PFD)
  Piping and instrumentation diagram (P&ID)
  Heating, ventilating, and air conditioning system (HVAC) duct design
  HVAC hanger/support (H/S) design
- o Piping: Equipment plan
  Pipe design
  Pipe H/S design
- o Electrical:
  Single line diagram
  Wiring diagram
  Electrical raceway design
  Electrical raceway H/S design
- o Instrumentation & Control (I&C):
  Control logic diagram
  Instrument loop diagram
- o Common: Interference check/resolution

The database of CAdd should consist of:

- o Reference database: A repository of job specifications, company practices, industrial design codes, vendor's catalog data, commodity libraries, and past design references
- o Master database: The overall approved version of the plant design which is the main source for extraction of final drawings and reports for construction
- o Task database: A working database created by each discipline

These three databases contribute to orderly integration of plant design data from project to project, discipline to discipline, and design to operation.

2. Computer Aided Engineering Computation

CAec is the computational arm of CAE for design support and verification/validation of design. CAec requires capabilities of fast numeric processing and of interacting with CAdd system to transfer data from/to it, and it does not need any database.

CAec is utilized by various engineering disciplines as follows:

- o Civil: Seismic analysis
  Structural analysis
- o Mechanical: Thermohydraulic analysis
- o Piping: Pipe stress analysis
  Pipe H/S analysis
- o Electrical: Electric load analysis
- o Nuclear: Safety analysis
  Licensing review

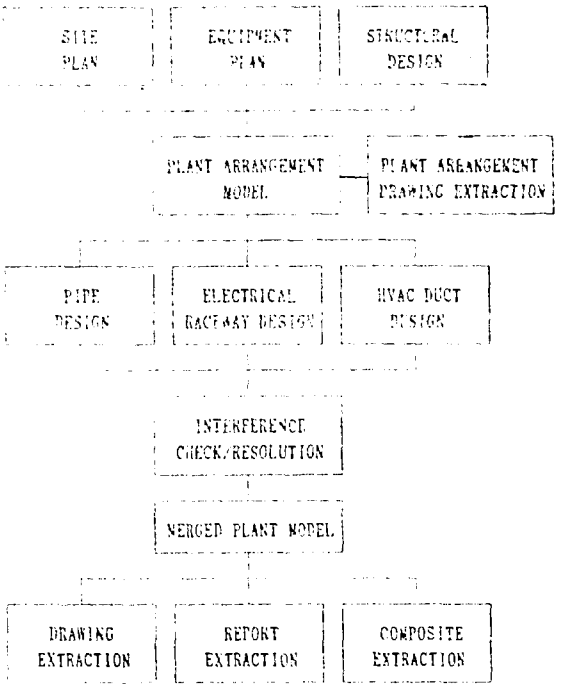

Figure 2. Flow of CAdd System

3. Computer Aided Administration

CAa is an administration tool to manage an engineering project and interacts with corporate management information system (MIS). CAa includes planning and control methods which provide a time-phased plan of manpower and resources allocation and a feed back procedure for comparison of actual expenditures against budgets or forecasts.

CAa should cover the following areas of project control: (See Figure 3)

- o Planning and scheduling
- o Resources control
- o Estimating
- o Procurement
- o Project accounting
- o Cost and performance measurement

4. Computer Aided Information Retrieval

CAir is a repository bank of all the data generated during the life span of a nuclear power plant. It is more than a pure data

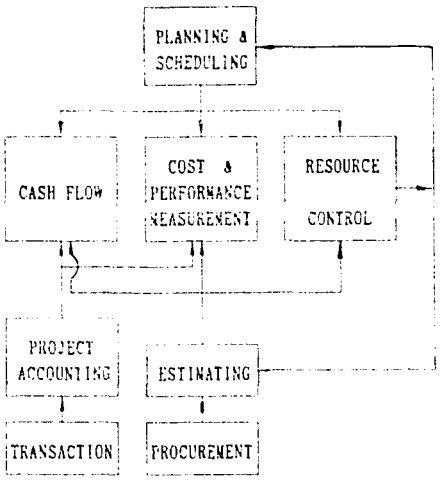

Figure 3. Flow of CAa System

storage, it should provide adequate search tools to retrieve data in variegated types and formats from the database.

The data bank could consist of the following databases: (See Figure 4)

- o Equipment and component
- o Documentation
- o Correspondence
- o Event
- o Activity
- o Procurement

These databases are closely linked and indexed by each other based on the following concept. An event is a certain engineering process or incident which triggers an engineering activity via correspondence. Equipment/component data and related documentation are required to perform a certain engineering activity that would normally require procurement. These are a set of unit history.

CAir data bank needs to be searched in several convenient ways by engineering phases, activity groups, plant equipments, or event groups. CAir can be utilized by engineers to design a new nuclear power plant, to improve existing plant facilities, or to aid problem solving at the time of plant anomaly.

III. LIFE SPAN OF NUCLEAR POWER PLANT AND CAE APPLICATION

The life span of a nuclear power plant consists of: (See Figure 5)

- o Development phase
- o Design phase
- o Construction phase
- o Start-up phase
- o Operation phase
- o Decommissioning/Life extension phase

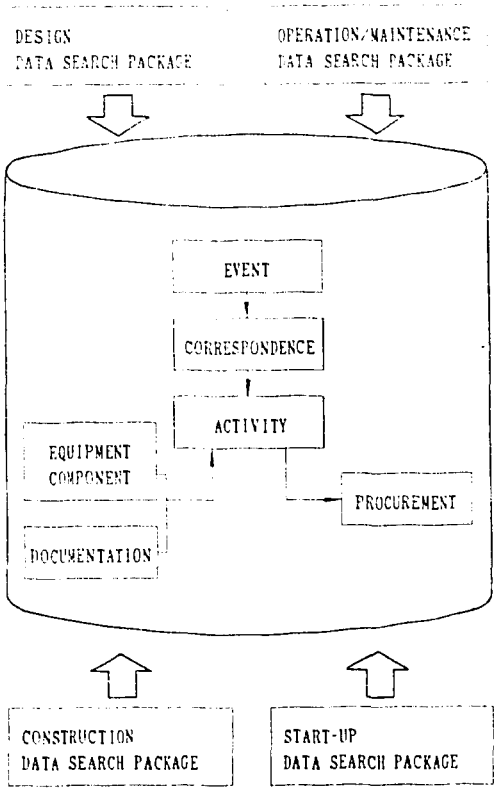

Figure 4. CAir Database

The design and construction phases are heavily overlapped.

In this section, the activities and CAE applications in each phase are briefly discussed.

A. Development Phase

The development phase is generally performed by a utility company to define:

- o Required electricity amount
- o Plant type and size
- o Number of units
- o Required plant performance

During this phase, CAec is normally required for planning of power system, estimation of generation cost, and others.

B. Design Phase

The design phase is generally performed by an architect/engineering (A/E) firm and divided into:

- o Conceptual design
- o Basic design
- o Detail design

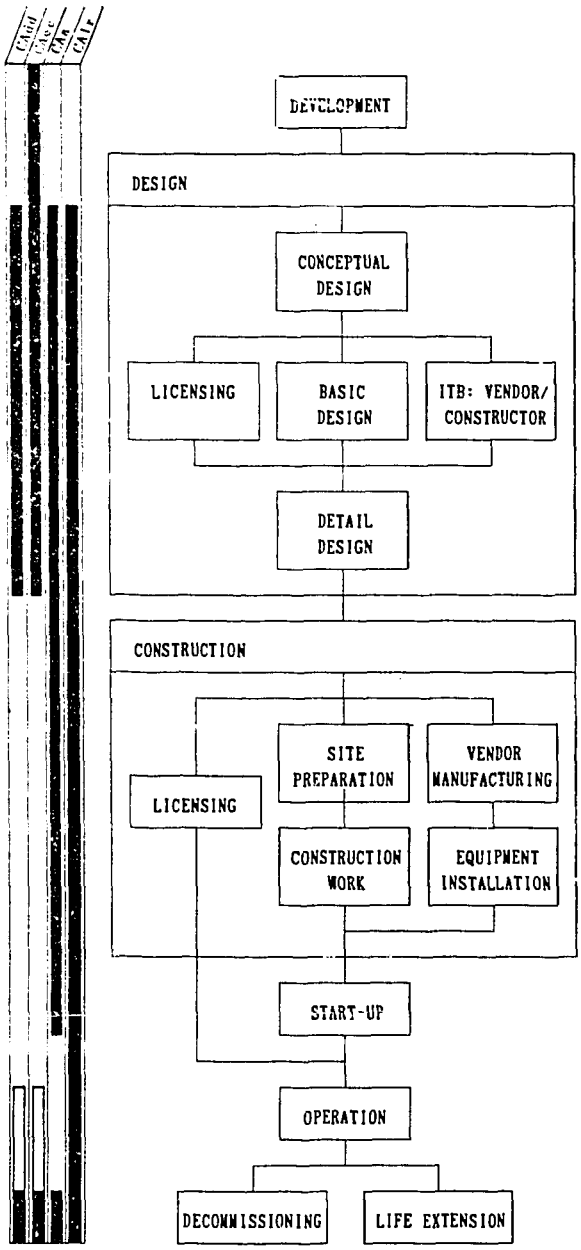

Figure 5. Life Span of a Nuclear Power Plant

During the conceptual design, the A/E firm assesses the problems and establishes engineering approach of the project. These activities require CAec and CAdd.

During the basic design, the specific engineering parameters are developed and set in accordance with the engineering approach. In this phase, CAec and CAdd are required.

During the detail design, a massive quantity of engineering details are generated and sent out to the site for construction. In this phase, the most precise manipulation of data is required, and an error will result in not only magnified loss of money but also unrecoverable delay of the project. In this context, the detail design requires CAec and CAdd. CAdd is extensively utilized to generate actual drawings and reports.

Throughout these three subphases, CAa is required for project control, and CAir is also required to accumulate the historical records of valuable experiences that will be retrieved and utilized in next phases.

C. Construction Phase

The construction is performed by a construction firm with the assistance of an A/E firm and equipment vendors. The construction phase may be divided into the following three categorical works:

- o Site preparation
- o Construction work
- o Equipment installation

During this phase, CAa is definitely required to administrate the construction, and CAir is required for the data accumulation for next phases.

D. Start-up Phase

The start-up phase is led by a utility company with assistance of equipment vendors and an A/E firm. This phase requires CAir, because the historical records of start-up are essential for trouble-shooting during the operation phase.

E. Operation Phase

During the operation phase, CAir, which ties to the plant MIS, is strongly required for effective plant maintenance. CAdd and CAec are also required for the facility modification, but a utility may not have to own them.

F. Decommissioning/Life Extension Phase

When a nuclear power plant reaches the end of the predetermined lifetime, the plant will be decommissioned or extended in its life by intensive modification. CAec, CAdd, and CAa can be utilized either for decommissioning or life extension. If the plant may go under life extension, the historical document and data in CAir will be the most valuable things.

IV. CURRENT PRACTICES AND OBSTACLES IN CAE APPLICATION

As indicated in the foregoing sections, the integrated CAE system is intended for multiplant or multiorganizational entity applications that need to exchange data on a regular basis.

In an ideal case, there could be a certain network of computer hardwares and softwares among different entities such as a utility, an A/E, a constructor, and equipment vendors. In such an ideal network, all the arms of the integrated CAE system are able to function properly by sharing a single or at least a common database.

In reality, however, those entities in both advanced and developing nuclear nations happened to use different computer systems, eventually different CAE philosophies and systems including their arms. Moreover, even in one entity, different computer systems are applied for different arms of CAE. This situation is quite surely an unhappy thing to a utility who wants to build at less cost and take good and long-term care of its nuclear power plants through effective data flow.

A. Current Practices

In advanced nuclear nations, they seem to be losing the opportunity of realizing a full-fledged and integrated CAE system due to the recession in the nuclear power industry. The consequential effect would be just partial application of the CAE in operation and maintenance of the existing nuclear power plants, in which some parts of the CAE arms such as CAdd, CAec, CAa, and CAir may be loosely bundled.

In developing nuclear nations, however, there is possibility to have such an integrated CAE system, because they in general have new nuclear projects under plan and most entities are relatively newly formed and flexibly adjustable to a new system environment.

In Korea, for an example of the developing nuclear nations, a computer system network is being seriously discussed among the Electric Power Group which consists of the utility, Korea Electric Power Corporation (KEPCO), the A/E, Korea Power Engineering Company (KOPEC), Korea Heavy Industries and Construction Company (KHIC), Korea Advanced Energy Research Institute (KAERI), and others.

The utility, KEPCO, has the prime role in effective data exchange through the network for construction of Korea Nuclear Units (KNU) 11 & 12 that started in early 1987.

The designated A/E, KOPEC, has been operating the CAE system as follows: (See Figure 6)

- o Intergraph (IG) system on IG VAX for CAdd
- o Gilbert Commonwealth (GC) Cue system on Hewlett Packard (HP) for CAa
- o Bundles of engineering departmental programs on Unisys UNIVAC and Control Data Corp. (CDC) CYBER for CAec
- o CAir partially developed and still being discussed with KEPCO

Many application programs have been written,

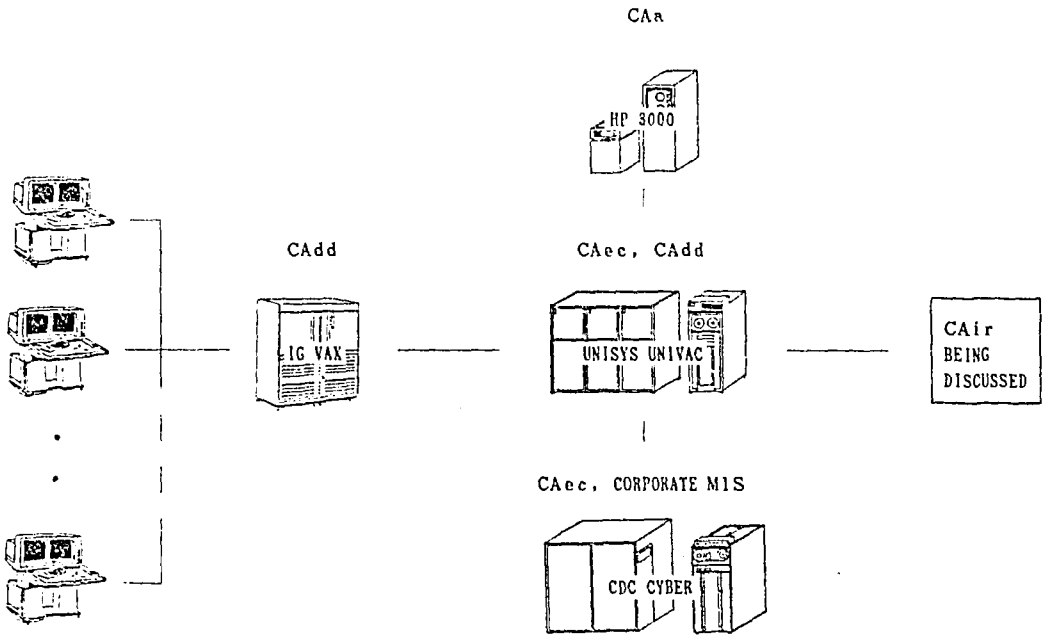

Figure 6. Current Configuration of KOPEC CAE

modified, and run for production of actual drawings, calculations, and reports.

B. Current Obstacles

In Korea, as earlier pointed out, the members of Electric Power Group are strongly tied around KEPCO. Since the power-related policies and plans are determined for the benefits of group rather than individual entities of group, there are less hindrance to synchronize CAE philosophy among entities related to the nuclear project.

The current obstacle to the intergrated CAE system originates from the diversification of computer software and hardware vendors of CAE parts. KOPEC's case for example, CAdd has been developed by IG and running on IG VAX hardware, CAec and a part of CAdd have been developed by KOPEC and Sargent and Lundy (KNU 11 & 12 subcontractor) running on CYBER and UNIVAC hardwares, CAa has been developed by GC running on HP hardware, and corporate MIS has been developed by KOPEC and running on CYBER hardware. These packages are loosely bundled and are only interfaced by intersystem data file exchange and human interference.

The importance of CAir has been earlier recognized in the Electric Power Group. CAir would not be so effective without consideration of such an integrated CAE concept which can be shared by various entities involved in the nuclear project. The main hindrance in establishment of a CAir is the matter of cost bearing.

However, since most of the KOPEC programs for technological self-reliance have been aiming at building a firm foundation of an integrated CAE system with its sound arms, it is firmly believed that series of these efforts will fructify in KNU 11 & 12 project. Through this project, the KOPEC's CAE resources in hardware and software will be expanded upto or surpass the levels of the advanced A/E firms.

Nobody can expect any panacea or radical improvement in CAE system, but one should try to get close to it by effective and efficient coordination among the concerned organizations.

In short, the most important thing in an attempt to reach a successful CAE is unisolated effort in each arm of the CAE system throughout the whole life span of nuclear power plant, and the role of a utility to achieve this is more highly required than ever.

V. PERSPECTIVES OF CAE APPLICATION

Regardless the fact that from nation to nation and company to company there will be differences in intentions and driving forces toward an integrated CAE system, the total integrity of CAE system will be improved due to the advancement in computer hardware and software technologies.

The most notable improvements of computer technologies will be:

- o Micro trend of hardware
- o Automation in software engineering

The micro trend of computer hardware could allow the individual CAdd workstation to have local standalone capabilities. The current practice of CAdd to have its own host computer will be revolutionized. The CAdd workstation itself can be considered as host, and the CAec mainframe computer could act as a direct file server of CAdd workstations. The software engineering

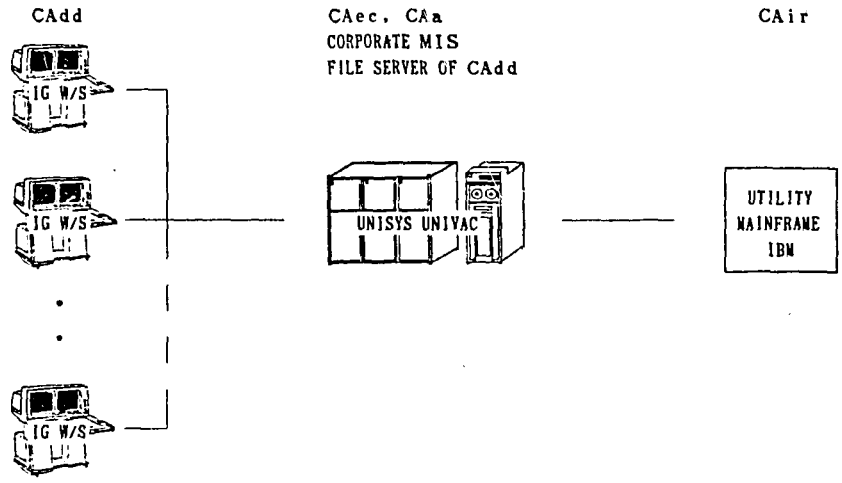

Figure 7. Future Configuration of KOPEC CAE

technologies, such computer-aided-software-engineering, could increase the productivity of software design/programming by approximately 200 folds. Such technique enables one to develop or rewrite softwares with less effort and in shorter period.

KOPEC's plans for the next generation CAE are: (See Figure 7)

- o Substitution of current IG CAdd on IG VAX with standalone IG CAdd workstations
- o Utilization of CAec UNIVAC mainframe as a file server of CAdd
- o Rewriting of own CAa based on current system on UNIVAC totally tied to corporate MIS
- o Development of CAir on KEPCO's mainframe which is tied to KOPEC's UNIVAC

The technical push together with demand pull by utility companies will provoke various entities in nuclear power industries to exchange and share valuable data and experiences. Under the circumstances, Korea will be a precious case to test an integrated CAE system including not only computer hardware and software but also total entities and their personnels.

VI. CONCLUSION

Throughout all the phases in the life span of a nuclear power plant, the information flow should be made smoothly among the concerned entities.

Since the CAE systems are complicatedly interwoven among the entities such as utility A/E, constructor, and other contractors, early consideration of an integrated CAE system is important for successful accomplishment of a total nuclear power program. The integration here means the functional integration of the system and the organizational integration. In this consideration, the role of a utility is more highly required than ever. The developing countries, such as Korea, are in better position to establish the totally integrated CAE under the circumstances.

New nuclear project, new CAE approach, and new resolution to achieve these will be essential to new era of nuclear power industry.