

IEEE Trial-Use Recommended Practice for Integrating Power Plant Computer-Aided Engineering (CAE) Applications

Sponsor
Station Design Subcommittee
of the
Energy Development and Power Generation Committee
of the
IEEE Power Engineering Society

Approved September 26, 1991

IEEE Standards Board

Abstract: A data model, called the plant information network, that standardizes categories of generating plant data and data relationships, is presented. Guidelines are provided for using the model to integrate computer-aided engineering (CAE) applications across the spectrum of plant-work activities during the complete cycle of the plant from site selection through decommissioning. Instructions are given to aid the engineering, construction, and operating groups of the utility in specifying integrated CAE applications. The information engineering concepts that are the basis for integrated CAE development are covered.

Keywords: CAE, CAE applications, computer-aided engineering, data models, plant data, plant information networks

The Institute of Electrical and Electronics Engineers, Inc.
345 East 47th Street, New York, NY 10017-2394, USA

Copyright © 1992 by the
Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 1992
Printed in the United States of America

ISBN 1-55937-173-0

*No part of this publication may be reproduced in any form,
in an electronic retrieval system or otherwise,
without the prior written permission of the publisher.*

IEEE Standards documents are developed within the Technical Committees of the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Board. Members of the committees serve voluntarily and without compensation. They are not necessarily members of the Institute. The standards developed within IEEE represent a consensus of the broad expertise on the subject within the Institute as well as those activities outside of IEEE that have expressed an interest in participating in the development of the standard.

Use of an IEEE Standard is wholly voluntary. The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of all concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason IEEE and the members of its technical committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE Standards Board
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
USA

IEEE Standards documents are adopted by the Institute of Electrical and Electronics Engineers without regard to whether their adoption may involve patents on articles, materials, or processes. Such adoption does not assume any liability to any patent owner, nor does it assume any obligation whatever to parties adopting the standards documents.

This recommended practice was prepared by the IEEE with the permission of Electric Power Research Institute, Inc. (EPRI), and is based upon and derived from a report published by EPRI. Neither IEEE, EPRI, members of IEEE or EPRI, nor any person acting on behalf of any of them

- (1) Makes any warranty, express or implied, with respect to the use of any information, apparatus, method, or process disclosed in this report or that such use may not infringe privately owned rights; or
- (2) Assumes any liability with respect to any use, or for damages resulting from any use of any information, apparatus, method, or process disclosed in this report.

Foreword

(This foreword is not a part of IEEE Std 1150-1991, IEEE Trial-Use Recommended Practice for Integrating Power Plant Computer-Aided Engineering (CAE) Applications.)

In May 1987, the Electric Power Research Institute (EPRI) published the results of a two-and-a-half-year project entitled *Guidelines for Specifying Integrated Computer Aided Engineering Applications for Electric Power Plants* (Report NP-5159-Ms, Research Project 2514-3). This project developed a set of guidelines that enabled electric utility engineers to prepare specifications for integrated computer-aided engineering (CAE) applications. This integration is based on a single data model that identifies common data requirements across the spectrum of generating plant activities from site selection through plant decommissioning.

This guideline presents a method for integrating CAE applications specifically for the electric utility industry (hereinafter referred to as the industry). It contains the data model, or Plant Information Network (PIN), and the methodology and procedures to use the PIN for developing CAE application functional specifications.

This recommended practice is based on the EPRI guideline. It advocates the use of a single data model and recommends that the EPRI model be used.

It is generally recognized that better control of data resources greatly contributes to improved efficiency. The lack of access to and control of data, not the lack of data, causes inefficiencies in resource utilization throughout the generating-plant life cycle.

CAE is a development in engineering automation in which the engineering process is modeled within the computer as a progression of interrelated work functions. A significant effort is under way within the industry to develop a wide variety of CAE systems and applications, including plant design applications, construction material and commodity control systems, and plant operations and maintenance applications. However, without a common plant data integration structure, a continuation of the problems that have plagued traditional automation efforts, namely, data redundancies and inconsistencies, duplication of data capture efforts, and information lags, can be expected.

This plant data model will serve as a mapping tool for new applications. It will position a particular application for a given plant activity into the overall picture of the plant life cycle. Integration opportunities will be identified for the developer in the data model without requiring an exhaustive understanding of the entire generating plant process.

A single data model

- Facilitates the development of additional CAE applications
- Supports the integration of existing CAE applications
- Improves the transfer and sharing of data between organizations and work activities
- Helps make information exchanges more accurate, timely, and consistent
- Furnishes a common view of the data requirements of an organization
- Improves data and software integration to reduce redundancy and thereby improves data consistency and increases efficiency

The PIN methodology and procedures have been developed and defined to provide a data model of plant-related information for the entire plant life cycle. This recommended practice is defined in such a way as to encourage utilities and suppliers to support and implement the PIN.

This recommended practice offers utilities and their suppliers a standard that can be used to model the information flow through the plant life-cycle activities. In this way, plant information integration will be brought to CAE development for the power industry so that communications are facilitated within a utility and among the utility, the A/E, and the suppliers. Standardization can lead to CAE implementation that promotes efficient re-

source utilization and that takes advantage of the whole knowledge base of the generating plant processes.

This IEEE working group would like to thank EPRI, Palo Alto, CA, and especially Dr. John J. Carey, the project manager, for its efforts and funding of the original development project. This project was primarily performed by Duke Power Company, Charlotte, NC.

The report described earlier is the copyrighted material of the Electric Power Research Institute, which has licensed it to the IEEE for use in the development of this recommended practice.

This recommended practice was prepared by the Working Group for Integrating Computer-Aided Applications Using a Single Data Model, Station Design Subcommittee of the Energy Development and Power Generation Committee. At the time this recommended practice was approved, the members of the working group were:

Robert A. Esterbrook, Chair

Kevin R. Andersen
David C. Atkins
John J. Carey
Kenneth F. Cooper
Leslie D. Davison

Erika B. Donahue
David W. Gilbert
DeLynden Lersch
Samuel Martinovich
Albert C. Merkel

Terry Molloy
Peter A. Phaneuf
David M. Rhodes
Edwin P. Rothong
Thomas J. Talley

The following persons were members of the balloting group that approved this document for submission to the IEEE Standards Board as a trial-use recommended practice:

I. B. Berezowsky
L. D. Boydstun
S. R. Brockschink
R. L. Castleberry
E. F. Chelotti
R. S. Coleman
R. E. Cotta
M. L. Crenshaw
D. J. Damsker
D. Diamant
G. Engmann
A. H. Ferber

N. R. Friedman
D. I. Gorden
R. K. Gupta
J. H. Gurney
T. J. Hammons
M. E. Jackowski
J. H. Jones
P. R. H. Landrieu
J. E. LeClair
G. L. Luri
J. T. Madill

O. S. Mazzoni
D. R. McCabe
G. R. Meloy
M. W. Migliaro
P. A. Nevins
C. R. Pope
E. P. Rothong
G. Stillman
J. E. Stoner
R. E. Strasser
T. R. Whittemore
J. P. Whooley

When the IEEE Standards Board approved this standard on September 26, 1991, it had the following membership:

Marco W. Migliaro, Chair

Donald C. Loughry, Vice Chair

Andrew G. Salem, Secretary

Dennis Bodson
Paul L. Borrill
Clyde Camp
James M. Daly
Donald C. Fleckenstein
Jay Forster*
David F. Franklin
Ingrid Fromm

Thomas L. Hannan
Donald N. Heirman
Kenneth D. Hendrix
John W. Horch
Ben C. Johnson
Ivor N. Knight
Joseph Koepfinger*
Irving Kolodny
Michael A. Lawler

John E. May, Jr.
Lawrence V. McCall
T. Don Michael*
Stig L. Nilsson
John L. Rankine
Ronald H. Reimer
Gary S. Robinson
Terrance R. Whittemore

*Member Emeritus

Also included are the following nonvoting IEEE Standards Board liaisons:

Fernando Aldana
Satish K. Aggarwal
James Beall
Richard B. Engelman
Stanley Warshaw

Mary Lynne Nielsen
IEEE Standards Department Project Editor

Contents

SECTION	PAGE
1. Introduction	7
1.1 Scope.....	7
1.2 Recommendation.....	7
2. References.....	7
3. Definitions.....	8
4. Recommended Methodology	10
4.1 Basic Concepts of CAE Application Integration.....	10
4.1.1 Information Engineering	10
4.1.2 Plant Information Network.....	11
4.1.3 CAE Application Development Practices.....	12
4.1.4 Functional Specification	12
4.1.5 Common Plant Data Model	13
4.2 Description of the PIN.....	14
4.2.1 Definition and Structure of the PIN	14
4.2.2 Activity List.....	16
4.2.3 Activity Documentation Package	17
4.2.4 Plant Data Model	28
4.2.5 Plant Data Flowpaths	30
4.2.6 Special Techniques Used in the PIN	34
4.3 Instructions for Using the PIN.....	37
4.3.1 Finding Activity Information	38
4.3.2 Finding Plant Information	39
4.3.3 Customizing the Data Model	41
4.3.4 Adding/Investigating Activities.....	44
4.4 CAE Application Development and Integration	46
4.4.1 Data Issues	47
4.4.2 System and Interface Issues	48
5. Development of a Functional Specification Based on the PIN.....	49
5.1 Using the PIN in the Development of a CAE Functional Specification.....	49
5.1.1 CAE Application-Specification Procedure.....	49
5.1.2 Completion of the Functional Specification	51
5.1.3 Summary.....	52
Appendix A An Example of CAE Application Specification Procedure	53
A1. Introduction	53
A2. Step 1: Define the Scope of the CAE Application.....	53
A3. Step 2: Identify Relevant PIN Activities	53
A4. Step 3: Initiate Development of the Application Data Model.....	54
A5. Step 4: Identify Related Activities.....	56
A6. Step 5: Revise the Scope of the Application.....	57
A7. Step 6: Economic Analysis	57
A8. Step 7: Customize the Application Data Model	57
A9. Step 8: Describe the Detailed Functional Requirements	58

TABLES

Table 1	Tabulation of Data Flowpaths.....	34
Table 2	Example of Subset Entities From the PIN.....	36
Table 3	Activities Using Data Item CABLE ESTIMATED LENGTH (Data Usage List).....	41
Table 4	Entity Attributes After Customization	42
Table 5	Splitting the Attribute LOCATION	42
Table 6	New Relationships for an Entity	43

APPENDIX TABLES

Table A1	Entity/Attribute List for a Motor Control Circuit Tracing Application (Before Customization)	54
Table A2	Entity/Attribute Table for a Motor Control Circuit Tracing Application	56
Table A3	Customized Attributes for Device/Instrument Location	57
Table A4	Customized Attributes for Electrical Equipment Location	58
Table A5	Entity/Attribute List for a Motor Control Circuit Tracing Application (After Customization)	59

FIGURES

Fig 1	Concept Diagram of the Plant Information Network (PIN).....	13
Fig 2	Hierarchy of the Plant Life Cycle	14
Fig 3	Plant Life-Cycle Phases	15
Fig 4	Numbering System for the Plant Activities	17
Fig 5	Sample Page From the Activity List.....	18
Fig 6	Sample Page From the Activity Short Descriptions	19
Fig 7	Sample Activity Description of the Fire Protection Zones	20
Fig 8	Sample Activity Process Diagram for the Fire Protection Zones Activity.....	22
Fig 9	Sample of the Input Data for the Fire Protection Zones Activity.....	23
Fig 10	Sample of the Output and Internal Data for the Fire Protection Zones Activity.....	24
Fig 11	Example of the Data Item Numbering System for the Entity/Attribute Format.....	25
Fig 12	Sample E-R Diagram for the Fire Protection Zones Activity.....	26
Fig 13	Sample Activity E-R Table for the Fire Protection Zones Activity.....	28
Fig 14	Example of a Portion of an E-R Diagram and Table.....	29
Fig 15	Sample of the Activity Support Modules for the Fire Protection Zones Activity.....	30
Fig 16	Sample Page From the PIN Data List	31
Fig 17	Sample Page From the E-R Report	32
Fig 18	Sample Page From the Data Usage List for the Fire Protection Zones Activity.....	33

APPENDIX FIGURES

Fig A1	E-R Diagram for an Example Application.....	55
Fig A2	Activity Flow Diagram for an Example Application	56

IEEE Trial-Use Recommended Practice for Integrating Power Plant Computer-Aided Engineering (CAE) Applications

1. Introduction

1.1 Scope. This recommended practice presents a data model that standardizes categories of generating plant data and data relationships. It provides guidelines for using this data model to integrate computer-aided engineering (CAE) applications across the spectrum of plant work activities during the complete life cycle of the plant from site selection through decommissioning. It contains a description of the plant data model and instructions for the engineering, construction, and operating groups of the utility for specifying integrated CAE applications.

The purpose of this recommended practice is

- (1) To introduce the information engineering concepts that are the basis for integrated CAE development
- (2) To present a data model that represents the data and data relationships supporting the plant work activities; this model is known as the Plant Information Network (PIN)
- (3) To define guidelines for applying CAE system technology to the generating-plant life cycle, based on the PIN
- (4) To describe methods for developing functional specifications for CAE applications based on this model

The goal of this recommended practice is to show how to use the PIN as a reference when developing a functional specification for a CAE application. It is directed to both CAE application users and developers. A common data model should be adopted, and existing procedures and organizational structures relative to the data model should be evaluated to successfully integrate CAE applications in the work environment.

1.2 Recommendation. This recommended practice

- (1) Advocates the use of a single data model for integrating CAE applications
- (2) Recommends that the EPRI PIN be used as the single data model (see [1])

2. References

[1] Electric Power Research Institute, *Guidelines for Specifying Integrated Computer-Aided Engineering Applications for Electric Power Plants* (EPRI Report NP-5159-Ms).¹

¹EPRI documents are available from the Electric Power Research Institute, 3412 Hillview Avenue, P. O. Box 10412, Palo Alto, CA 94303, USA.

[2] IEEE Std 610.12-1990, IEEE Standard Glossary of Software Engineering Terminology (ANSI).²

[3] IEEE Std 730-1989, IEEE Standard for Software Quality Assurance Plans (ANSI).

[4] IEEE Std 830-1984, IEEE Guide for Software Requirements Specifications (ANSI).

[5] Downs, H. R., *Software Development and Maintenance Guidelines, volume 3*. Palo Alto, CA: Electric Power Research Institute, 1984.

3. Definitions

activity. A set of tasks that relate to the performance of a specific function in a plant phase. Information is compiled throughout the Plant Information Network (PIN) at the activity level.

activity coordinator. A person who is an expert in the methodology and development of the activity documentation packages and who is responsible for coordination and development of the activity documentation packages with the activity technical contacts.

activity data list. A list that itemizes the major data items used by the activity, gives a brief description of each data item, and lists other activities that provide or receive each data item.

activity description. An overview of the activity that briefly describes the activity and its scope, and delineates the boundaries and major tasks of the activity.

activity documentation package. A summary of the results of the activity investigation which includes the activity description, activity process diagram, activity data list, activity entity-relationship diagram, and the activity support modules.

activity entity-relationship (E-R) diagram. A diagram that defines the data contents of the activity by identifying its data entities, associated data attributes, and the relationships among data entities.

activity list. A list containing names of activities that define the work processes of a generating plant from conception to decommissioning. There are approximately 400 such activities that comprise the power-plant life cycle and are mainline activities that are common throughout the industry. The list also separately contains brief descriptions of the activities.

activity process diagram. A diagram that shows the relationships and flow of tasks within an activity and represents the process required to complete an activity.

activity support modules. Procedures or computer programs that operate on the data associated with the activity.

activity technical contact. A person who is knowledgeable about the functions, tasks, data, and details related to an activity.

²IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

attribute. A property or fact about the entities in an entity set.

automation. Computerization of data or of a process that uses that data.

cardinality. The numeric relationship between entity sets, labeled as one to one (1-1), many to one (M-1), or many to many (M-N), which indicates the number of items in one entity set that could possibly be associated with the items in another entity set.

computer-aided engineering (CAE). The application of computers to the engineering process. The term now commonly applies to any computer system or program that manipulates data for the purpose of assisting engineering, design, procurement, maintenance, etc.

concurrency. The process of multiple users accessing and manipulating a data item simultaneously, with the data-base management system linking the transaction of each user so that the access appears to be sequential.

customizing. Modifying, or adding to, the structure of data in the PIN to tailor the general data requirements to an needs of an organization. Customizing can result in an organization-specific data model that should be cross-referenced to the PIN.

data flowpath. A segment of the overall plant data flow that represents one attribute sent from a providing activity to a receiving activity.

data model. A conceptual representation of the information requirements, data flows, and data relationships for an organization, facility, activity, or process.

entity. A group of like items or subjects that can be individually identified and about which information is recorded. Examples include cable, drawing, modification, and system
Syn: **entity set.**

entity-relationship (E-R) diagram. See **activity entity-relationship diagram.**

functional specification. A formal description of the essential requirements of a software product. It specifies the objectives of the software application, the functions that will meet those objectives, the information requirements, the internal data flows, and the external interfaces.

hierarchical data base. A data-base system that uses tree structures to represent the data.

integration. Providing a single set of data for use between multiple activities or departments (multiple application data base).

key (relational data base). A field or group of fields in a relational data-base table that uniquely defines each row within that table. A composite key is made up of more than one field in the table.

network data base. A data-base system that uses directed graphs to represent the data.

normalization. The decomposition of more complex data structures according to a set of rules designed to give simpler, more stable structures.

parent entity. An entity set that has other entities dependent on and related to it called subset entities. The subset entities are linked and related to other entity sets through the parent entity set.

phase. A major stage within the generating-plant life cycle. See **plant life cycle**.

plant information network (PIN). A representation of both the flow and the structure of the information that supports the discrete activities occurring during the life cycle of the plant.

plant life cycle. The life of a power plant from conception to decommissioning. In this model, the cycle consists of five phases: site selection and plant concepts, design, construction, operation, and decommissioning.

RAM. Reliability, availability, and maintainability of the plant. In economic analysis, the increase in RAM due to data integration or automation is sometimes quantified as a benefit. In computer applications, this refers to random access memory, which is not used in this text.

relational data base. A data base that represents data as a collection of tables linked through common entries.

relationship. A specific association that exists between entity sets or entities of a set that can be described by a single word or phrase.

software life cycle. The various phases for software development from initial conception to final release and maintenance.

subset entity. Entities that are related to and dependent on other primary entity sets called parent entity sets.

4. Recommended Methodology

4.1 Basic Concepts of CAE Application Integration. This section describes the basic concepts for integrating CAE applications. These include

- Information engineering
- Plant information network
- CAE application development practices
- Functional specification
- Common plant data model

These ideas and techniques combine to provide the user with a standard guideline for CAE application development, focusing on the data requirements of the functional specification, to achieve integrated CAE applications. A basic understanding of these concepts is necessary to implement these guidelines.

4.1.1 Information Engineering. Information engineering is an approach to analyzing and representing data that maximizes integration and allows the data to be used for a variety of purposes. A central idea in information engineering is the development of a generic description of the data requirements of the organization, called the data model. A

data model consists of primary data items (entities), associations between these entities (relationships), and pertinent descriptive properties of the entities (attributes).

The principles of information engineering were used to generate the plant data model described in 4.2. In applying these concepts to a plant-specific application, one should adhere to the principles discussed in 4.1.1.1 through 4.1.1.5.

4.1.1.1 Focus the Data Model on Data Rather Than Procedures. By concentrating on the data involving plant activities rather than on the procedures that actually operate on that data, a more stable model can be developed. This is because the kinds of data involved in plant activities remain mostly constant with time, although the procedures (whether manually performed or computerized) operating on the data may change frequently.

4.1.1.2 Represent the Data Generically. Generalized data structures are flexible, maximizing data sharing, so that many applications may create separate logical paths to use the data. For example, a data item such as cable is preferred over power cable or instrument cable, since many activities such as routing, pulling, and termination will be common.

4.1.1.3 Reduce or Eliminate Redundant Data Storage. Typically, many different activities support separate versions of the same data. In each activity, data is organized in a distinct data-base structure, whether the data is computerized or not, and then that data is transferred (manually or by computer) to other activities. This redundancy often causes data inconsistencies among activities, errors in data transfer, time delays while the information is communicated between activities, and poor decision making due to conflicting or untimely information.

The plant data model makes it possible to consolidate data used in different plant activities in one place so that a single copy is available to all activities using that data. In this manner, the need for duplicate storage and communication of data among activities is reduced, and the information is up-to-date, manageable, and auditable. Using the plant data model permits a conscious decision about retaining redundancy.

4.1.1.4 Use the Model When Developing New Procedures. Currently, procedures are often developed independently in each functional area, and the necessary data are then communicated to other areas. Using the integrated plant data model, new procedures can be developed that may cross functional boundaries in the plant. These new procedures can recognize and anticipate other uses of the data. This type of procedure development can improve productivity if the data exists in one place and is simultaneously shared by all users. The errors and time lags involved in data transfer are eliminated.

4.1.1.5 Use the Model for Both Manual and Computerized Tasks. The plant data model should be used to design and modify either manual or computerized tasks. It should also be used to facilitate communication among diverse tasks. In addition, the plant data model is readily adaptable to any computerized or manual data management system.

4.1.2 Plant Information Network. The PIN is a concept that applies information-engineering principles to the generating-plant life cycle. It combines a common plant data model with the activities that use the data represented by the model and provides a foundation on which to build integrated CAE applications.

Applying information-engineering principles to an electric power generating plant results in the type of structure shown in Fig 1. Conceptually, the structure has four major components: activities, a common plant data base, data flowpaths, and interfaces between the activities and the data base. Together, these components depict the basic elements of the PIN, which encompasses plant-related information for the entire life of the plant. A set of discrete activities, A_N , which occur during the life of a plant, are along the time line. An activity is defined as any work function performed in support of the plant: A_1 can be site se-

lection, A_2 can be architectural design, A_3 can be piping design, A_4 can be piping erection, A_5 can be plant chemistry control, and so forth. When combined, these activities ideally define all functions needed to support a plant from conception to decommissioning.

Although Fig 1 presents these activities as discrete and sequentially processed, many frequently overlap on the time line and are actually processed iteratively. However, for the purpose of these guidelines, this figure accurately represents the intended concepts.

Associated with each activity is a data base, DB_n , that contains all the information required to support that activity. A data base consists of computer data files, DF_n , manual filing systems, and the like, which contain various parts of the information. Also associated with each activity are support modules, M_n , which operate on the activity data to perform a specific task within the process. Examples of support modules are computer programs, procedures, and calculations.

An integrated plant data base is established by first organizing all plant activities, their data, and their interrelationships into a common plant data model. The data model provides a plan for the structure of the data base, which can then be implemented in whole or in part as needed. This common plant data model and its subsequent data base are illustrated in Fig 1 by the large box containing the data files. Each activity simply stores data in, or receives data from, the integrated data base. The interfaces between the activities and the integrated plant data base are illustrated in the figure by the vertical lines between the activity boxes and the large box representing the integrated plant data base.

When an activity begins, certain data from previous activities is sometimes a required part of the data base of that later activity. To provide this required data flow, individual activities must be interconnected by an architecture that will associate an activity with any related activities in the PIN by the flow of data between them. This flow of data among activities, referred to as data flowpaths, provides a commonality among the activities and allows an exchange of information. The flowpaths, which link the activities together, are represented in the figure by the time line (lines with arrowheads) and the lines joining the data files (squares) to the end of data use (shown as circles) in the various activity databases. The exchange of information between activities is actually accomplished via interaction with the integrated plant data base.

4.1.3 CAE Application Development Practices. To implement CAE applications based on the PIN, sound software development practices must be followed. These concepts, known collectively as the software life cycle, address the techniques for software development from conception to the final release and maintenance of the software. Generally, a CAE application development project consists of six phases:

- (1) Preliminary project evaluation
- (2) Functional specification
- (3) Software design
- (4) Software implementation
- (5) Software verification and release
- (6) Project management

More information about the software life cycle can be found in IEEE Std 610.12-1990 [2].

4.1.4 Functional Specification. The functional specification is a formal description of the essential requirements for the application, including the information flow with other activities. It specifies the objectives of the application and the functions that will meet those objectives. The functional specification details the data model requirements and all functions, performance, inputs/outputs, and the like, so that the system design can be developed directly from it. This detail helps to ensure that interfaces with existing software, hardware, and manual systems are planned before coding begins.

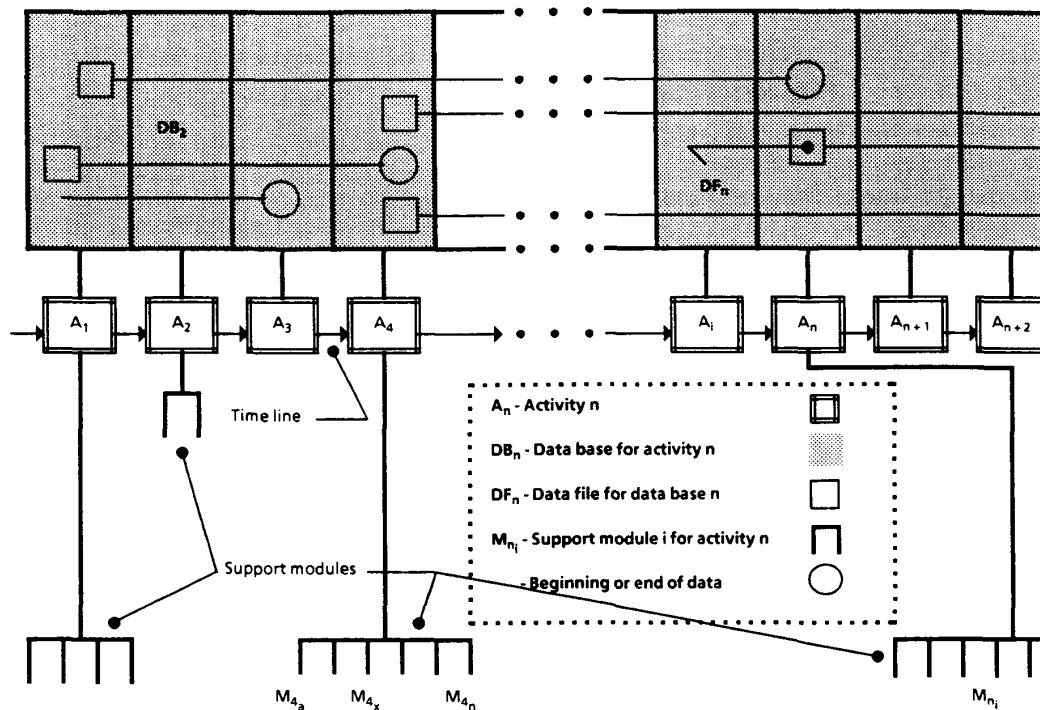


Fig 1
Concept Diagram of the Plant Information Network (PIN)

Although the functional specification concentrates on the functions that must be incorporated into the system, it may also specify growth and expansion requirements. The software can be designed with future requirements of the application in mind, thereby eliminating the need to perform a costly redesign of the application later. More information on functional specification guidelines can be found in IEEE Std 830-1984 [4].

4.1.5 Common Plant Data Model. Applying these existing functional specification guidelines to CAE application development will result in good stand-alone applications, but they do not address the concept of application integration. When limited to a single activity, CAE applications cannot provide maximum benefits; only through integration with other activities can benefits be maximized. The key element for integrating CAE application is the use of a single, comprehensive plant data model that consolidates the types and structures of information used by the work activities performed over the life of the plant. This data model, combined with the various activities that use and exchange its data, forms the PIN that provides a foundation on which to build integrated CAE applications. The PIN serves as a mapping tool to integrate a particular application into the overall picture of the plant life cycle.

Using the PIN when designing and implementing CAE applications will give the designers the ability to make conscious decisions about data duplication and other implementation alternatives before implementing those interfacing applications. Given the number of activities involved in a generating plant, modular implementation of CAE ap-

plications maybe the only feasible course of action for a utility to follow. Therefore, the integration aspects of the PIN are best used during application development, not after.

4.2 Description of the PIN. This section explains the definition and structure of the PIN, tells how the PIN was formed, and outlines the scope and level of detail in the PIN.

4.2.1 Definition and Structure of the PIN. The PIN is a structure of plant information that integrates common data requirements across the generating plant life cycle, from site selection to decommissioning. This structure is based on the concepts presented in 4.1 and illustrated in Fig 1. The PIN consolidates the types and the structure of information used in activities performed throughout all phases of the life of a plant into a single, comprehensive plant data model. This data model, combined with a definition of the data requirements for each activity and the flow of data among activities, results in a network that clearly defines the flow of information throughout all phases of the life of a plant.

The PIN contains the following four major components:

- (1) *Activity list*—A list of all activities occurring throughout the life of a plant. A short description of each activity is included.
- (2) *Activity documentation packages*—Documentation that contains the activity scope, major data items, data relationships, interfaces to other activities, and a conceptual data model for the activity.
- (3) *Plant data model*—A compilation of all activity data models into one comprehensive model of plant data. It includes a list of all data names and definitions and the relationships among the data.
- (4) *Plant data flowpaths*—A list of activities sending and receiving each data item to show the flow of data between the activities.

These PIN components are presented in Appendixes C through H of EPRI Report NP-5159-Ms [1] and are described in detail in 4.2.2 through 4.2.5. These appendixes are listed here for convenience and are referred to in the remaining sections simply by the appendix name or letter.

4.2.1.1 Formation of the PIN. The generating-plant life cycle is divided into activities, the data used by individual activities is established, and these results are merged into a single network of plant data and plant activities called the PIN.

To determine a list of activities for a typical generating plant, the plant life cycle is divided according to the hierarchy shown in Fig 2.

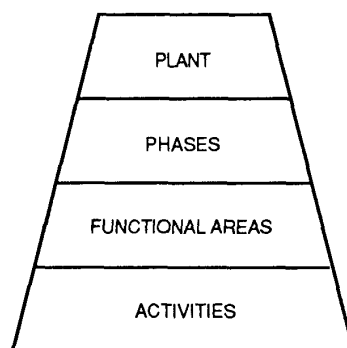


Fig 2
Hierarchy of the Plant Life Cycle

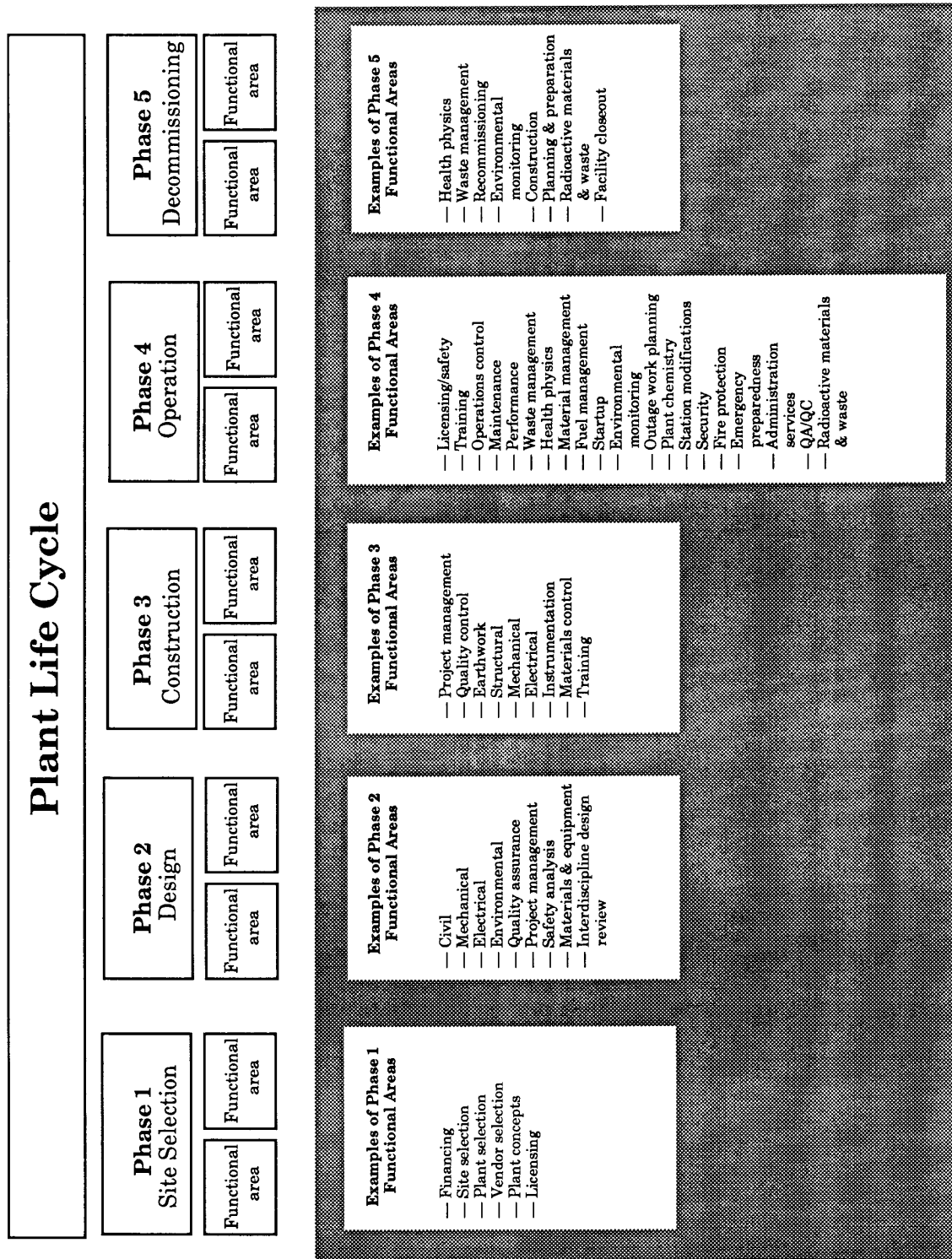


Fig 3
Plant Life-Cycle Phases

Fig 3 shows this hierarchy and includes the phases and examples of functional areas of this structure. The plant work processes are divided into five phases that represent the major stages of a generating-plant life cycle. The five phases are site selection, design, construction, operation, and decommissioning. This separation into phases implies movement along a time line. Each phase is divided into functional areas that organize the plant activities into broad functions. Within each functional area are the discrete activities that occur (and may occur) during the life cycle of the plant.

In general, each plant phase contains activities that are performed in a common time frame within the plant life cycle. Frequently, however, an activity can be active during a subsequent plant phase, as in a design activity performed for a modification to an operating plant. For this reason, the phase that an activity is listed under should not be taken as a strict time frame for performing the activity.

This division resulted in the identification of over 400 activities. The names and scopes of these activities were chosen according to various utility procedures, organizational structures, US Department of Energy and utility workflow studies, and guidance from several utilities and architect/engineer firms. A list of these activities is presented in Appendix C of EPRI Report NP-5159-Ms [1].

The results of individual activity investigations were merged to complete the PIN. This was accomplished by converting activity investigation results into a tabular form and resolving differences between activities in terms of data definitions, interfaces, and levels of detail. The results of merging these activity documentation packages are presented in a series of reports in Appendixes E–H.

The appendixes contain the results of the activity investigations, which are a subset of the total list of plant activities identified. Users of this recommended practice should contact the IEEE with further activity investigation for subsequent incorporation.³ Consistency of activity investigation scope and detail shall be mandatory for inclusion in this recommended practice.

4.2.1.2 Scope and Level of Detail. The PIN includes over 400 activities that occur throughout the life of a generating plant. These activities are key links in the generating-plant life cycle and are common throughout the power generation industry. In this context of the PIN, plant modifications are considered to be reiterations of the original design and construction activities, and as such, are not listed as separate activities. Similarly, plant-life extension tasks are not addressed as separate activities in the plant life cycle.

The activity and data definitions presented in these guidelines are generic to ensure universal applicability for most types of generating plants and organizations using this information. In practice, different tasks within an activity may be performed by the utility, contractors, or both. However, the activity is presented in these guidelines as a continuous process without regard to who performs each task. Therefore, in many cases, the activity boundaries and data definitions will require some expansion and/or customization when developing computer implementations of these concepts. Instructions for customizing this information are given in 4.3.4.

Also, since the purpose of the PIN is to identify the plant data and data usage, the major emphasis in each activity investigation is on activity data contents, relationships between the data, and data interfaces to other activities, rather than on the process of performing the activity tasks. Brief descriptions of the activities are documented only to clarify their scope and boundaries in relation to other activities and to help in defining their data requirements.

4.2.2 Activity List. The activity list is a list of all activities defined by the scope of the PIN. This list is categorized by phase and functional area, and is supplemented by a list of activity short descriptions that help define the scope and boundaries of each activity. The

³Instructions are included in 5.2.

activity list, including the activity short descriptions, is included as Appendix C of EPRI Report NP-5159-Ms [1].

Activities were individually numbered according to the numbering system shown in Fig 4.

Activity Number

2 E 21

where

The first character is the phase (2)

The second character is the functional area (E)

The third and fourth characters are the suffix (21)

Fig 4

Numbering System for the Plant Activities

For example, the activity number for the cable routing activity is 2E21. The first character of the four-character activity number represents the power plant phase in which the plant activity is listed (2 is the design phase). The second character identifies a functional area within the phase (E, in the design phase, represents the electrical functional area). The last two characters are a suffix that uniquely identifies the activity within the functional area.

Fig 5 is a sample page from the activity list (from Appendix C of EPRI Report NP-5159-Ms [1]) that shows activities for several functional areas within the design phase. The asterisk preceding the activity name indicates that the activity was researched and documented as one of the activities selected for detailed investigation. In this sample page, the cable routing activity (2E21) is shown as part of the electrical (2E) functional area within the design phase.

Fig 6 is a sample page from the activity short descriptions (also part of Appendix C). The activity short descriptions list is organized in the same sequence as is the activity list, which is by phase and functional area. This example shows several activity short descriptions from the Civil (2C) functional area within the design phase.

4.2.3 Activity Documentation Package. Each activity investigation is documented in an individual report called an activity documentation package (included in Appendix D of EPRI Report NP-5159-Ms [1]). These packages describe the scope, major tasks, data definitions, data relationships, and data interfaces at a general level. The documentation package contains the data and data relationships for an investigated activity. Those activities documented by an activity documentation package are identified in the activity list by an asterisk beside the activity name.

The activity documentation package for each activity consists of the following five major components:

- (1) Activity description
- (2) Activity process diagram
- (3) Activity data list
- (4) Activity entity-relationship diagram and table
- (5) Activity support modules

4.2.3.1 Activity Description. The activity description gives an overview of the activity, describes the activity and its scope, and delineates the boundaries and the major tasks of the activity. Additional information includes relevant background information, any restrictions or constraints on performing the activity, and the relative position of the activity in the generating-plant life cycle. It is provided to define the activities' relationships to

2. DESIGN

FUNCTIONAL AREA	ACTIVITY
2C CIVIL	01 SITE SEISMOLOGY AND GEOLOGY 02 * GENERAL ARRANGEMENT 03 SEISMIC CRITERIA DEVELOPMENT 04 ENGR/DESIGN CRITERIA DEVELOP 05 * ARCHITECTURAL DESIGN 06 * FLOOR RESPONSE SPECTRA DEVELOP 07 ROADS & RAILROADS DESIGN 08 EARTHWORK & DRAINAGE DESIGN 09 FIRE PROTECTION CRITERIA 10 * FIRE PROTECTION ZONES 11 * STRUCT ANALYS/DESIGN CONCRETE 12 * STRUCT ANALYS/DES STRUCT STEEL 13 STRUCT ANALYS/DES MISC STEEL 14 * TANK DESIGN 15 * EQUIP SEISMIC QUALIF/ANCHORAGE 16 * DAM DESIGN 17 INTAKE/DISCHARGE STRUCTURES 18 CCW PIPE DESIGN 19 BURIED PIPE DESIGN 20 EMBEDDED PIPING DESIGN 21 * PROTECTIVE COATINGS 22 CRANES AND HOISTS DESIGN 23 COAL HANDLING DESIGN 24 COOLING TOWER DESIGN
2D ENVIRONMENTAL	01 METEOROLOGY STUDIES 02 AIR QUALITY STUDIES 03 GROUNDWATER STUDIES 04 SURFACE WATER STUDIES 05 BACKGROUND NOISE STUDIES 06 AQUATIC ECOLOGY STUDIES 07 TERRESTRIAL ECOLOGY STUDIES 08 DEMOGRAPHY STUDIES 09 AERIAL PHOTOGRAPHY
2E ELECTRICAL	01 * AUX POWER SYS CONFIG & LAYOUT 02 ENGR/DESIGN CRITERIA DEVELOP 03 * SWITCHING STATION LAYOUT 04 * CONTROL ROOM LAYOUT 05 * ELECTRICAL EQUIPMENT LAYOUT 06 * CABLE TRAY LAYOUT 07 * CABLE TRAY HANGER DESIGN 08 * I&C CONCEPTS/ENGINEERING 09 I&C LOAD ASSIGNMENTS 10 OPERATOR-AID-COMPUTER CONCEPTS 11 * OPERATOR-AID-COMPUTER DESIGN 12 * POWER LOAD ASSIGNMENT 13 * PROTECTIVE RELAYING & METERING 14 * EMERG POWER LOAD SEQUENCING 15 * DETAILED POWER SYSTEM DESIGN 16 * DETAILED CONTROL SYSTEM DESIGN 17 * PANEL/CABINET DESIGN 18 * POWER EQUIPMENT SIZING 19 * EQUIPMENT ENGINEERING 20 * CABLE SYSTEM DESIGN 21 * CABLE ROUTING 22 * FIRE DETECTION SYSTEM DESIGN 23 SECURITY SYSTEM DESIGN 24 TRACE HEATING DESIGN 25 LIGHTING DESIGN 26 ELECTRICAL GROUNDING DESIGN 27 CATHODIC PROTECTION DESIGN 28 LIGHTNING PROTECTION DESIGN 29 COMMUNICATION SYSTEMS DESIGN

Fig 5
Sample Page From the Activity List