AN OBJECT ORIENTED PERSPECTIVE FOR AC/MTDC SYSTEM SIMULATION

M.R.Bhanu Prakash H.S.Chandrasekharaiah

Department of High Voltage Engineering

Indian Institute of Science

Bangalore - 560 012 , INDIA

email: bhanu@hve.iisc.ernet.in

ABSTRACT

Object Oriented Methodology (OOM) has added a new dimension for the representation, modeling and simulation of various day-to-day applications. The basic paradigm of OOM reflects the closeness to which the methodology relates to the real world entities. Over a period of time, the requirement of detailed and exact representation with no approximation of real world objects that reflects its behavioral pattern is on the rise. This has resulted in the terminology of 'Complex Objects' in system simulation. An AC-MTDC system has several interrelated/ interconnected components and pose a complex picture. Objectifying such system will render the system design/ analysis/ identification/ performance evaluation and control, more easy and help in better understanding of the system in its entirety. In this paper, a full representation of the various DC systems sub components are used for developing classes of components. Detailed representation along with the various attributes and methodologies associated with each of these components are represented. The case study undertaken in this paper is a Four Terminal AC/MTDC system with all its terminal components. The paper highlights the various advantages the OOM technique offers for Power System Modeling. This notation is of immense help especially during the system design stage wherein the tuning of various system components can be achieved without undergoing the rigor of the conventional methods.

KEYWORDS :

Object Oriented Methods (OOM), Object Oriented Design (OOD), Object Oriented Analysis (OOA), HVDC Transmission System, System Simulation.

1. INTRODUCTION

The basic building block of an OOM is an Object. An Object represents a set of data and its associated methodology/functionality bundled into a single unit. In the conventional paradigm, the data and the functions associated with them (i.e., with data) are separated and are different entities. An Object is complete by itself and embeds both the data structure and the associated methods. An Object Oriented Approach is characterized by the following important properties

1.1 Class Identity : Classes are collections of objects that has common features viz., the methods and data structures. Objects are instantiation of these classes. Typically, the identification of the classes are based on the real world entities and concepts of the application of domain. The classes/objects communicate with each other by message passing paradigms. By this data duplication is avoided and changes within the objects are not propagated to other objects. The class has the following properties :

- Captures the instance-of relationship between an instance and the class to which it belongs to.
- Aggregates the collection of related objects.

- Enhances the notion of semantic integrity.

- Factors out the specification of attributes and methods from all instances of the class into a single object, which results in saving of spaces.

The attribute of the classes and the classes itself can be classified into three groups depending on the scoping required for the application

- Private Attributes/Classes
- Public Attributes/Classes
- Protected Attributes/Classes

It is these features that enables to define classes of components each with its own specific properties

1.2 Encapsulation : The property of encapsulation and the information hiding allows the data structure and the implementation details of the object to be hidden from other objects/utilities in the system. To capture the current state of the object, message is passed onto the objects whose method on execution retrieves the information. This property of object has made OOM a very attractive proposition for the power system applications wherein the utilities are cross connected.

1.3 Inheritance : Inheritance of classes lets to propagate the features of the classes not only to the objects belonging to same classes but also from other classes. This feature termed as Multiple Inheritance. Also the inherited properties can be overridden, new features can be added, modified or appended, so that new classes can be evolved.

1.4 Polymorphism : Polymorphic property refers to the ability of using the same expression to denote different operations. Polymorphism is generally implemented by what is termed as Dynamic Binding. Basically inheritance is a special kind of polymorphism that characterizes an object oriented system.

2. MERITS OF OOM

The above mentioned properties (1.1-1.4) provide the following advantages over the conventional structured typed notation

- The Object Oriented Architecture's are Decentralized and hence it is possible to support the needs of the applications that create and manage objects with object oriented semantics.
- With the definition of classes and inheritance concepts, it is possible to reuse code, thereby avoiding any replication of code.
- With Classification being part of the system, the class structuring provides two basic relationships : Inheritance Relationship and Client-Server Relationship. These relationships in turn build several semantically rich notions to the philosophy of object building. This being : is-a, behaves-like, implements, combines, uses, needs, has-a, consists-of relationships.
- Appropriate for designing objects whose complexity is high in terms cost of development, maintenance, etc.
- The basic building blocks being Object, the methods and attributes are manipulated from the requirement phase down to implementation stage with no shift in the paradigm i.e., the OBJECT.

3. OBJECT ORIENTED ANALYSIS & DESIGN METHODOLOGY

Analysis in general is the process of decomposition of problems into their component parts i.e., a process of specification of user requirement and system structure and function independently of the means of implementation or physical decomposition of modules or components. Analysis focuses on 'WHAT' a system is to do and embodies the rule of traceability, 'WHY', which justifies the existence of given result by tying it back to the stated goals and objectives.

On the other hand, Design in general is an architectural modeling that adds details, precision and implementation dependent features to the analysis model. Designs include both Physical Design i.e., provides rigorous specification of the interface provided by a set of object types and Logical Design that merges with Object Oriented Analysis.

3.1 Object Oriented Analysis (OOA) : Several Object Oriented Analysis techniques Shlaer/Mellor OOSA [1], Coad/Yourdon [2][3], Rumbaugh [4], SOMA[5] and several others are proposed and different terminology are introduced, however the underlying principles of these techniques that constitute a OOA principles can be summarized as follows

- Abstract User Requirement.
- Identify Key Domain Objects.
- Assembly of those objects into structure of a form that will support physical design

In this paper SOMA, a Semantically rich Method for Object Oriented Analysis is adopted for the case under study. The main reason for the choice of this methodology is that it incorporates all features of Coad/Yourdon (its simplicity), confirms with Chen's ER modeling convention and supports all structures i.e., Classification, Composition and Association. In addition, this methodology supports Rules, which enhances the Semantic richness of the analysis model. Also it supports FUZZY OBJECTS and INHERITANCE.

Following are the major steps involved in the analysis methodology,

- Identify Layers
- Identify Objects
- Identify Structures
- Define Data Semantics and Associations
- Add attributes to Objects
- Add Operations to Objects
- Add Declarative Semantics of the Objects

Each of these steps with a typical case study is dealt in detail in the following sections.

3.2 Object Oriented Design (OOD) : Several Object Design techniques are available viz., Booch'86 [6], GOOD [7], HOOD [8], OOSD [9], JSD & OOJSD[10] and Booch'91[11]. The methodology adopted in this paper for the object based design is based on Booch'91 design criteria, which can be classified into following steps

- IDENTIFY CLASSES & INSTANCES - usually done with by either Data Flow Diagrams (DFD)[12] and/or the textual analysis[13] on the specification of the network under study. From the DFD, objects are identified by looking for both concrete objects and abstract objects in the problem space, objects will be found from the bubbles and data stores in the DFD. Methods are obtained from the process bubbles. On the contrary, in textual analysis the objects, its methods and attributes are identified by identifying the grammar of the specification provided. Table 1 identifies parts of speech that is associated with various model components of the object terminology.

Parts of Speech	Model Component
Proper Noun	Instance
Improper Noun	Class
Doing Verb	Operation
Being Verb	Classification
Having Verb	Composition
Static Verb	Invariant condition
Modal Verb	Data Semantics
Adjective	Attribute value
Adjective phrase	Association phrase
Transitive Verb	Operation
Intransitive Verb	Exception/Event

Table 1.0 : Parts of Speech utilised for OOD development

- ESTABLISHMENT OF THE VISIBILITY OF EACH OBJECT IN RELATION TO OTHER OBJECTS : In this step, the definitions of the semantics of the classes are identified and their relationship between them is identified.

- **ESTABLISH THE INTERFACE OF EACH OBJECT AND THE EXCEPTION HANDLING** : Basically this step involves in the establishment of the interface that each class should have with its associated classes. By doing this step, it is possible to have proper security to the various classes. This is done by defining the classes and its attributes in any of the following categories

- PUBLIC
- PRIVATE
- PROTECTED

- **IMPLEMENT AND TEST OBJECTS** : Implement the design as a prototype. Test the system for cohesion and consistency. Redefine the classes, instances(Objects),

Semantics and structures on the basis of what has been learnt.

4. AN OBJECT BASED AC-MTDC SYSTEM

The prototype system under study is a Four Terminal DC System with representation of terminal components. Fig.1.0 represents the system under study. In this paper, a Novel Modular Converter Modeling Approach [14] is used for representing the thyristor and its triggering scheme. The network is further analyzed in [15] by using digital simulation techniques. The algorithm used for solving the system equations is Modified Euler's method and Fourth Order Runge Kutta procedure. The same analysis and design methodology are used for developing the object notation for the system. A step-by-step procedure involved in the development is shown. This application can be extended to any kind of electrical network.

Fig. 1.0 : A typical MTDC system

4.1 OBJECT ORIENTED ANALYSIS (OOA)

4.1.1 Layer Identification : Is a methodology by which a given problem domain is decomposed. This is evolutionary step wherein changes can be made as the analysis step is performed. The Layers exist at the top of composition structures and are genuine objects themselves in their own way. The Layers have methods implemented by methods of embedded objects that form a Layer, by what are termed as IMPLEMENTED-BY links. Layers in general receive and send messages and on the receipt delegate responsibilities to objects that they encapsulate. Also Layers resolves the polymorphic conflicts that might exist in the embedded objects.

For the current application, Two Layers are identified, one each representing an AC system and a DC system. The AC system Layer or the AC system Wrapper Object (can be treated as AC Bus) embeds the following objects

- Object SOURCE
- Object FILTER
- Object SHUNT COMPENSATION
- Object LOAD

The DC system Layer (can be treated as DC Bus) on the other hand embeds

- Object CONVERTER TRANSFORMERS
- Object CONVERTER
- Object DC LINE

Fig. 2.0 represents the Layers identified along with the embedded objects and IMPLEMENTED-BY links. Here the term Class & Object is used interchangeably, however the classical definition of an Object being an instantiation of the Class is maintained in its implementation and otherwise.

Fig. 2.0 : LAYERS identified for MTDC System

4.1.2 Structure Identification : Structure Identification can be classified as

- Usage Structure
- Classification Structure
- Composition Structure
- Association Structure

4.1.2.1 Usage Structure : This structure records the message passing topology of the system. By building the usage structure, it is possible to reduce the complexity of the structure. The Behavioral model of the objects and their interaction will be the outcome of building a Usage structure.

Fig.3.0 reflects the usage structure or the interlinks of various objects of the system under consideration. The Fig.3.0 shown is for a typical single AC and DC system interface. The same principle is extended for the MTDC system.

Fig. 3.0 : USAGE STRUCTURE of the MTDC System Components

4.1.2.2 Classification Structure : The classification structure records the several underlying semantics of the typical class hierarchies that are logical outcome of the instantiation of the classes. The attributes of classification structure must contain the special attributes : A Kind Of (AKO) : attribute and MEMBER:attribute. Multiple Inheritance and Disjunctive Inheritance can be reflected in the classification structure. Other relations that can be reflected are

- E/O or Exclusive Optional : indicate that each subclass's intersection with the other subclass is empty.
- I/O or Inclusive Optional : indicate the subclass may overlap.
- Optional : indicate that list is not exclusive, there may be more as yet identified subclasses.

All AKO relationships are Many-to-One association. Fig. 4.0 represents the classification structure of the typical Filter Class along with its associations.

Fig.4.0 : CLASSIFICATION STRUCTURE of the Class Filler

4.1.2.3 Composition Structure : must contain A Part Of (APO):attribute and Parts: attribute. These attributes are used as the navigational tools. The composition links can be interpreted at both Class and Object level. Like classification structure, relations E/O, I/O, O and M can be used but parts do not overlap.

Fig. 5.0 represents the composition structure for the Class Filter. Likewise all the composition structure for all the other classes were developed

Fig.5.0 : Composition Structure of Class Filter

4.1.2.4 Association Structure : is structural relationship other than Usage, Classification and Composition. OMT is used for identified composition structure and association structures.

4.1.3 Object Identification : Several methodologies viz., Coad/Yourdon, Shleier/Meller, Objectory Case Use [5], State Transition Models (STD) are used for the object identification. Fig. 6.0 shows Data Flow Diagram (DFD) from which objects are inferred from the bubbles and data stores.

Fig.5.0 : DFD of the MTDC network with BYD for the Converter

4.1.4 Addition of Attribute to Objects : From the various structures identified, AKO:attribute and Part:attribute (List-Attributes) form the attribute of the object under consideration. Also APO:attribute and Member:attribute also form the attributes of the object. Attributes in general are

- Pure Attributes - Defined (ADTs) or Primitive Ones.
- Association Attribute

Typical attribute list along with the simulation parameters associated with the converter is shown in Fig. 7.0, these attributes are identified from both structures and DFDs.

4.1.5 Addition of Methods : The Methods/Operations govern the behavior of the object and its interaction (Message Passing) with other objects. The Methods are identified by STDs and DFDs of the system. From the DFDs, the process bubbles correspond to the methods of the objects. Some of the typical methods associated with the Class Converter if shown in Fig. 7.0.

[illegible]

Fig.7.0 : Lists the Class Base Converter with attributes & methods

4.1.6 Addition of Data Semantics to the Objects : Data Semantics to the Objects is reflected by incorporating RULES to the objects. A Rule Window interface provided with each of the objects enables to incorporate the associated rules to the object. Rules aid in disambiguating the Multiple Inheritance Conflicts and also define the priority for the objects. Like attributes and methods, rules may be inherited and overridden, with local variation possible. Decision Tree is used to describe a complex set of rules. In the present study, simple assertions are added to the Class PI Controller. The Class Converter in turn inherits these rules from the Class PI Controller.

4.2 OBJECT ORIENTED DESIGN (OOD)

4.2.1 Identification of Classes and Instances : This step in design overlaps with the analysis methods, it is this advantage that makes the OOD methods attractive for varied applications. This step acts as a measure for devolving the classification of the problem domain further. The DFDs developed are used for object identification. For the current application, following classes are developed.

Fig.8.0 reflects the class hierarchy developed for the current study. Class Converter inherits its properties from the Class Base Converter, Class Conventional Controller and from the Class Intelligent Controller. The implementation is done such that one of the controller is instantiated for a given converter.

Fig.8.D : Class Hierarchy for Converter with Controllers

4.2.2 Establishment of the visibility of the Objects : All the classes developed for the current application was declared global, however certain attributes of classes were declared as private members. Some attributes were declared as protected members in order access the values down the class hierarchy. This step offers security for object management and is useful for interlinked utilities.

4.2.3 Establishment of the interface for each of the Object & Exception Handling : A simple file based interface for handling both dynamic and constant

parameters of the network was provided. The Overloaded constructor methods provided for each of the classes further enhanced the interface part for each of the classes. Exception Handling included in the current implementation is provided by standard C++ features viz., throw, catch and try.

4.2.4 Test and Implement Objects : The program implementation is done using C++. Several case studies were conducted and each of these results was checked with standard bench mark models. Fig.9.0 lists the various class hierarchies developed for the four terminal systems.

Taking the particular class hierarchies into consideration the steady state characteristics at terminals of the MTDC system is determined and is as shown in Fig.10.0 -16.0 . Similar characteristics can also be determined at the other terminals very easily because of the object methodology.

5.0 CONCLUSIONS

An Object notation is developed in this paper for the simulation of Four Terminal MTDC system along with the terminal components. An Object notation offers a mechanism that brings the model closer to its real world entity. The data hiding and data abstraction that forms the heart of object notation, offers a secure environment especially for cross-linked utilities. Also the network connectivity could be inferred by navigating the class hierarchies and class links. This notation further aids the data handling mechanism in real time that is currently under investigation.

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Fig.9.0 Steady State DC Current

Fig.10.0 Steady State DC Voltage

Fig.11.0 Steady State AC Bus Voltage

Fig.12.0 Steady State Source Currents

Fig.13.0 Steady State 7th Harmonic Currents

Fig.14.0 Steady State 11th Harmonic Currents

Fig.15.0 Steady State 13th Harmonic Currents

Fig.16.0 Steady State 17th Harmonic Currents

Note : System Characteristics at a terminal generated with the Object Oriented Methodology based on a particular class hierarchies developed.