

## Research and Design in Unified Coding Architecture for Smart Grids

Gang Han\*, Jianwen Zhang, Xin Chu

School of Information and Electrical Engineering, China University of Mining and Technology  
Xuzhou Jiangsu, China, 221116

\*Corresponding author, e-mail: kdhangang@163.com

### Abstrak

Standarisasi dan platform untuk berbagi informasi adalah dasar dari Smart Grids. Dalam rangka meningkatkan pengiriman pusat integrasi informasi dari jaringan tenaga listrik dan mencapai pertukaran data yang efisien, berbagi dan interoperabilitas, maka didalam artikel ini suatu arsitektur coding terpadu diusulkan. Arsitektur mencakup pengkodean lapisan manajemen, lapisan generasi coding, lapisan model informasi dan lapisan aplikasi sistem. Desain hirarkis membuat keseluruhan arsitektur pengkodean agar dapat beradaptasi dengan lingkungan yang berbeda aplikasi dan antarmuka yang berbeda yang dapat mewujudkan integrasi model fungsi pengelolaan jaringan listrik. Didalam makalah ini, siklus hidup dan metode evaluasi kelangsungan hidup dalam sebuah arsitektur yang terpadu diusulkan. Hal ini dapat menjamin stabilitas dan ketersediaan dari arsitektur pengkodean. Akhirnya, terdapat prospek yang jelas dari arah pengembangan teknologi Smart Grids di masa depan.

**Kata kunci:** smart grid, arsitektur pengkodean terpadu, platform informasi terpadu, model manajemen, evaluasi survivability

### Abstract

Standardized and sharing information platform is the foundation of the Smart Grids. In order to improve the dispatching center information integration of the power grids and achieve efficient data exchange, sharing and interoperability, a unified coding architecture is proposed. The architecture includes coding management layer, coding generation layer, information models layer and application system layer. Hierarchical design makes the whole coding architecture to adapt to different application environments, different interfaces, loosely coupled requirements, which can realize the integration model management function of the power grids. The life cycle and evaluation method of survival of unified coding architecture is proposed. It can ensure the stability and availability of the coding architecture. Finally, the development direction of coding technology of the Smart Grids in future is prospected.

**Keywords:** smart grids, unified coding architecture, integrated information platform, model management, survivability evaluation

### 1. Introduction

Smart Grids can be reliable, flexible, efficient to complete the measurement, control, regulation and protection functions of power system, which is based on the advanced information technology, automation and analysis technology [1-3]. One of the key technologies of supporting Smart Grids is to establish an integrated operation management model of power system, which can improve the integration of information system and ensure data consistency, accuracy and real-time[4-7]. It can achieve efficient data exchange, sharing[8-10]. Unified and standardized information coding can analyse and process massive amounts of data for different power grids interconnection. In order to achieve the calculation and analysis of steady-state, transient and dynamic within the whole power system and promote the development of Power Grids Auxiliary Decision Support System, it can provide standardized interface, which can greatly enhance the efficiency of the power system operation and management[11-13].

CIM (Common Information Model) [14-17] is widely promoted and applied in the Power Dispatch Center System, which is based on IEC61970 [18]. However, different kinds of coding caused a lot of problems. For example, the reusability of application system data of power dispatching system is not high, which is difficult to achieve the integration, sharing and interoperability. Thus, it is very important to set the standard, open, integrated unified coding system. In [19] a CIM based architectural of coding of smart dispatching is presented. It includes

the specification of dispatching coding, CIM/XML, the specification of interchanging and checking, which can offer solution for the implementation and promotion of coding system. In [20], a CIM based adaptive unified coding system is presented, which includes data layer, model-driven layer and coding layer. The purpose of adopting the approach of model-driven is to adapt to the differences among various versions of CIM standard and CIM models belonging to different systems and to implement the unified model.

In this paper, on the basis of the analysis of the main features of Information Standardization coding of Smart Grids, a unified coding architecture is proposed. It includes coding management layer, coding generation layer, information model layer and application system layer. Hierarchical design makes the whole coding system to adapt to different application environments, different interfaces, loosely coupled design requirements and the integration model management function of power grids. A life cycle model and evaluation method of survival of coding system is proposed, which ensure the stability and availability of the coding system and provide solutions of dispatching coding technology for Smart Grids.

## 2. Unified Coding Architecture Features

On the analysis of current Information Standardization coding of Smart Grids, such as *IEC61968 Series of Standard: Application Integration at Electric Utilities-System Interfaces For Distribution Management*. This paper pointed out that the main features of unified coding architecture as Figure 1.

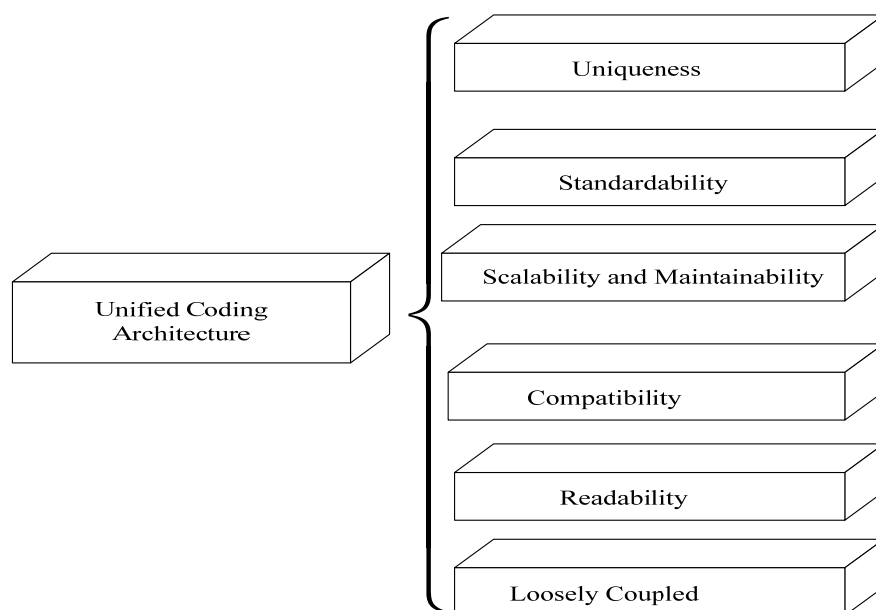


Figure 1. The main features of Unified Coding Architecture

### 2.1. Uniqueness

Power grids have a wide range of equipments, complex network topology structure, a large number of nodes. The same object does not allow different coding style. The coding of boundary objects may appear conflict, especially the management objects of different region, province have part of the cross-cutting, which includes the geographic area, substation, voltage level, transmission line sections. Unified coding architecture standards should uniquely identify every device and node within the whole power system. Thus, the operating status of devices will be monitored.

## 2.2. Standardability

Dispatcher, DAS (Dispatching Automation System) and system developers have inconsistent understanding on the power grid model. This issue led to the barrier on the various systems for synchronization and sharing of information. Unified coding architecture should take into account the tripartite roles to achieve integration between the various systems and reduce the probability of errors.

## 2.3. Scalability and Maintainability

When the topology of power grid changes, such as new transmission lines create or changes, equipments repair or replace, the dispatchers need to modify and maintain the topology of power grid and Energy Management System, which will lead to ranges of workload, error-prone, and low flexibility. Thus, unified coding system should be flexible to maintain, upgrade and expand system.

## 2.4. Compatibility and Readability

Information systems integration is very complex system engineering. Unified coding architecture must not only meet the dispatch coding and equipment coding, but it can integrate with other systems. It should also be easy to transplant and promote the application of emerging technologies and business.

Unified coding architecture not only should meet the function of dispatching automation system coding, but also meet the dispatchers' conventional concept of the power grid. It has a variety of features as follows: semantic representation of power system, readability and processing of coding information. Thus, it can be easy to understand and operate, demonstrate the equipment and running status information of the power grid.

## 2.5. Loosely Coupled

On the process of traditional power grid operation and management, the equipment coding always exists with dispatching coding from the planning, purchase, repair, maintenance and retired of equipment. However, when the equipment was replaced, equipment coding is also failure, and dispatching coding would be failure because of the tight coupled between equipment coding and dispatching coding. This issues lead to a waste of codes resources, and it cannot meet the flexibility requirements of coding architecture. Unified coding architecture has loosely coupled, even if the equipment coding is failure, it will calculate the new equipment coding through its associated coding, and it can ensure that dispatching coding continue to be effective.

## 3. Unified Coding Architecture Design

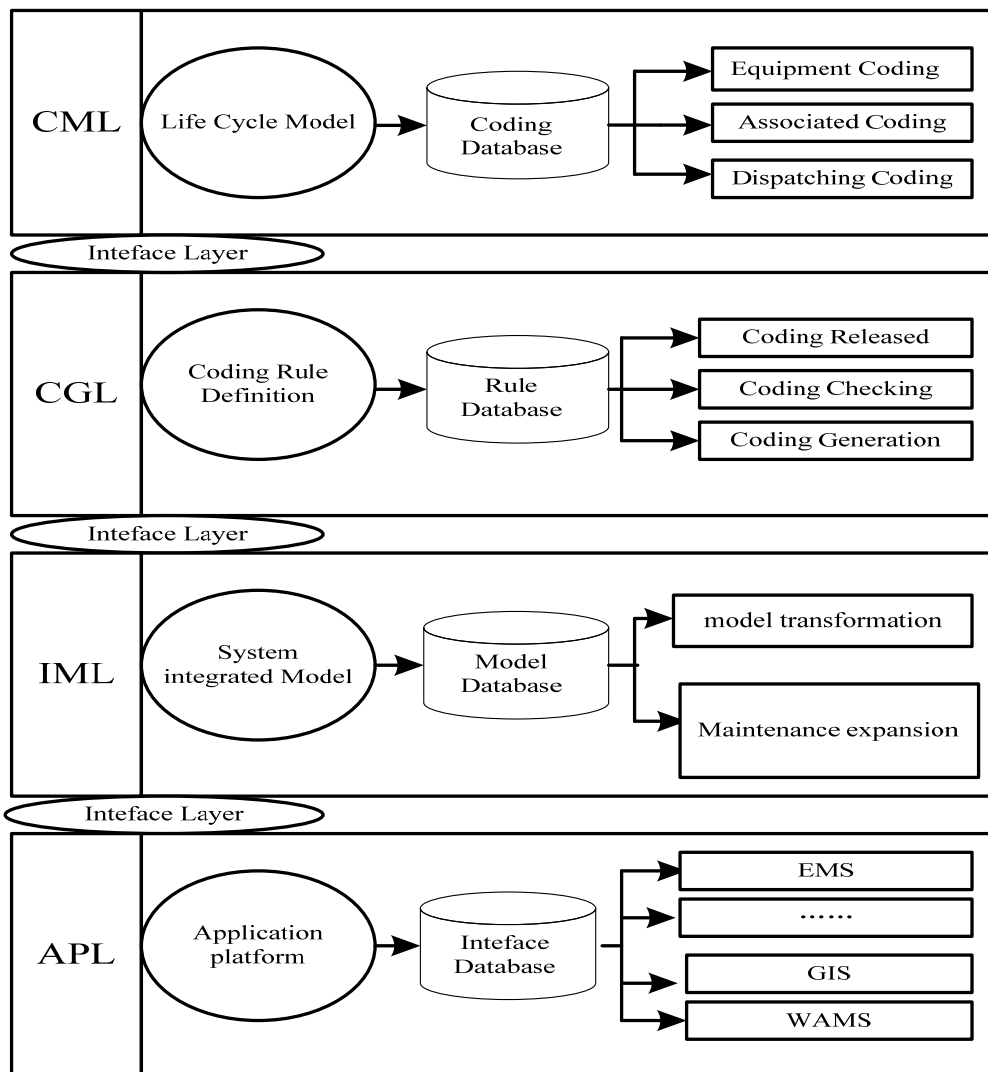
On the basis of the main features of unified coding system, a unified coding architecture is proposed. It includes coding management layer, coding generation layer, information model layer and application system layer, as shown in Figure 2. Hierarchical design makes the whole coding system to adapt to different application environments, different interfaces, loosely coupled design requirements and the integration model management function of power grids. Different layers can connect by adapter interfaces, which ensure a unified application system.

### 3.1. Coding Management Layer

The life cycle of unified coding architecture is coding management layer. It includes the life cycle model of unified coding system and the evaluation of survivability, which is the basis of the equipment cost management. It can ensure the availability, reliability and integrity of unified coding architecture.

### 3.2. Coding Generation Layer

Coding generation layer includes coding generation, coding checking and coding released. Coding generation contains equipment coding, dispatching coding and associated coding. Associated coding is calculated by equipment coding, dispatching coding. This style avoids the failure of dispatching coding that was caused by the failure of equipment coding.



Legends:  
 CML: Coding Management Layer  
 CGL: Coding Generation Layer  
 IML :Information Model Layer  
 APL: Application System Layer

Figure 2. Unified Coding Architecture

### 3.3. Information Model Layer

Information model layer is based on IEC61970 protocol group and IEC61968 protocol group [18]. IEC61970 protocol group mainly oriented EMS (Energy Management System), and IEC61968 protocol group mainly oriented DMS (Distribution Management System). Two protocols group used Common Information Model. CIM used object-oriented to describe the model of power grid model and its information. UML diagrams can describe the inheritance, connection and resource properties of relationship belonging to the components of power system. As for data sharing and interoperability. CIM defines CIM / XML files and ensure that CIM can transfer data through XML files. Thus, it can communicate with different application systems. In order to ensure non-destructive expression of the converted information, and mutual reading, processing, unified encoding system used RDF (Resource Description Framework) to check and set each other. It is effective to solve the interconnection of different model. Figure 3 shows the two model transformation.

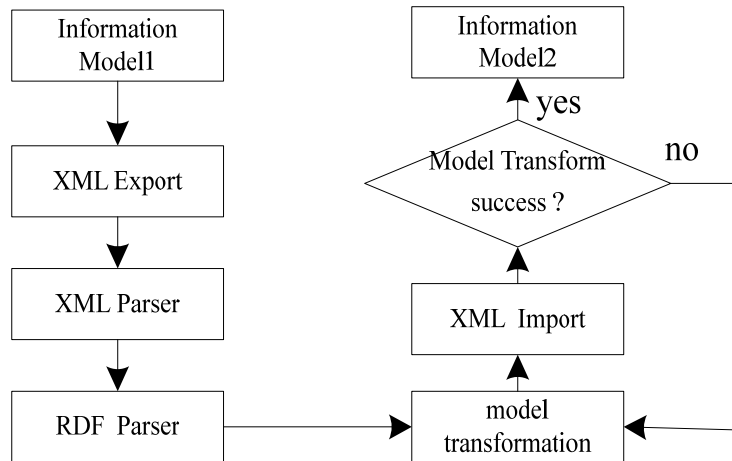
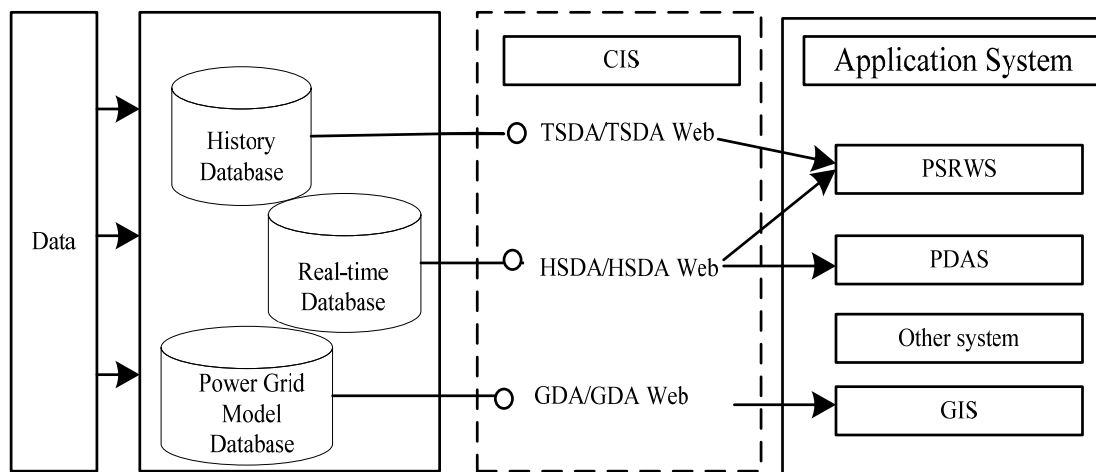


Figure 3. The two model transformation

**3.4. Application System Layer**

IEC61970 series of standards define CIS (component interface specification), It can effectively realize the integrated application system to meet the demands for the business and application, data sharing and interoperability. Tightly coupled interfaces include GDA (generic data access), HSDA high-speed data access (high speed data access), GES (generic event and subscription), TSDA (time series data access) etc. Tightly coupled middleware system uses CORBA (Common Object Request Broker Architecture). Loosely coupled interfaces use CIM/XML, data markup language for electric power system (E Language Specification) file format, as well as to meet the service-oriented architecture (SOA), which defined Web service interface associated with CIS, as shown in Figure 4.



PSRWS: Power Security Pre-warning System  
 PDAS: Power Dispatching Automation System  
 GIS: Geographic Information System

Figure 4. Component interface specification of application system

**4. Unified coding architecture rules design**

Unified coding rule is the key to achieve smart grid information platform for data standardization, sharing and interoperability. It is the basis for establishing the power grid integration management model. On the basis of unified coding architecture design, IEC61970-

301 standard specification, a dual coding system is proposed, which is based on equipment coding and dispatching coding. The associated coding-based as the core can effectively solve the issue that failure of dispatching coding that was caused by the failure of equipment coding.

#### 4.1. Coding Object Classification

In order to the uniqueness and stability of unified coding system, coding object must be classified because of huge large types of equipments and flexible dispatching information in power grid operation and management. Resources in the electric power system contain equipment resources and dispatching resources. It have a huge number of equipment resources, such as transformers, circuit breakers, isolation switch, bus line, the voltage level, AC transmission line and DC transmission lines, etc.. Dispatching resources include regional dispatching, provincial dispatching and the huge number of substations. Figure 5 shows the encoding object classification of power grid.

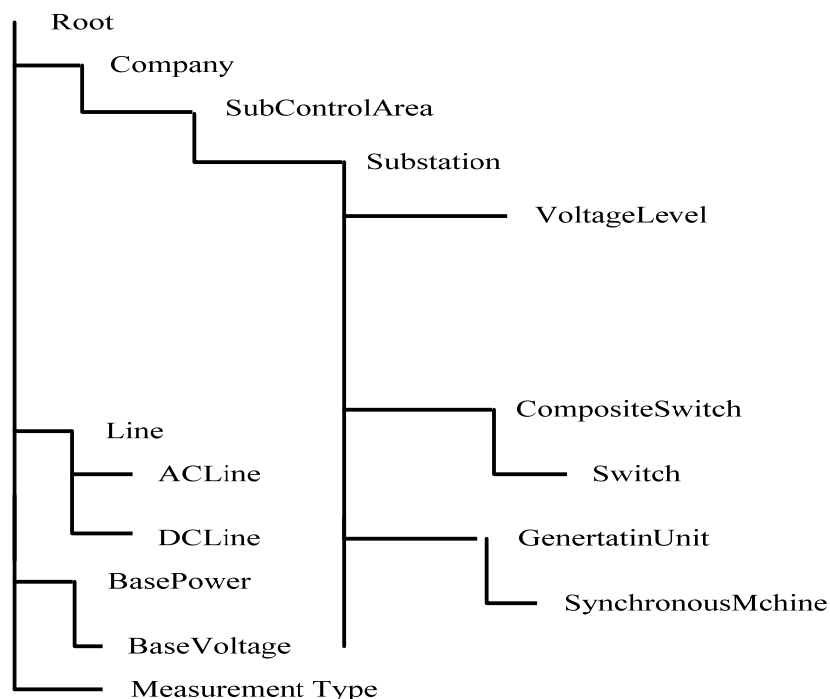


Figure 5. Relational hierarchy of the power system resource

#### 4.2. Equipment Coding

Equipment coding adopts the object-oriented approach. Every equipment coding is uniquely determined by the properties of coding objects, which contains all or part information of the object. The attribute information of the coding objects can achieve mutual check, which can ensure the accuracy of the coding. For example, equipment coding of a transformer is NR/BYQ/20/220-110/200512/135, NR identifies the manufacturers, BYQ identifies the type of device, 20 represents the rated capacity, 220-110 represents the ratio, 200512 identifies the date of manufacture, 135 identifies the flow code numbers. The specific formulation of equipment coding can refer to *the State Grid Corporation Production Management System Code (Trial) and the equipment classification method of IEC 61968*. The result would be put into the equipment coding library.

#### 4.3. Dispatching Coding

Dispatching coding can reflect the dispatching grade of coding objects in DS (Distribution System) through the identification and classification of different coding object.

Therefore, dispatching coding should contain the topological characteristics of the objects. Dispatching coding features is based on CIM grade of Distribution System Topology. For example, the 4567 switcher of the region A, No. 123 10 kV line corresponds to dispatching coding is A/123/10/4567.

#### 4.4. Associated coding

Associated coding can solve the issue that failure of dispatching coding caused by the failure of equipment (equipment was scrapped or withdraw). A mapping function relationship can map equipment coding and dispatching coding. The function output is associated coding. The result put into an associated coding set.

(Definition 1)  $\forall e_i \in E, d_i \in D$ , in the mapping function  $f$ , the result is  $f(e_i, d_i) = ID_i$ ,  $i=1,2,3...n$ . Where  $e_i$  represents one element of equipment coding set,  $E$  represents equipment coding Set,  $d_i$  represents one element of dispatching coding Set and  $D$  represents dispatching coding Set.

As Definition 1,  $f$  function can calculate the associated coding set by equipment coding and dispatching coding. Associated coding can be flexible to ensure mutual index and operation between equipment coding Set and dispatching coding Set, which achieve standardized management model of unified coding system. When the equipment coding was scrapped or withdraw, a new equipment coding would be calculated by dispatching coding,  $f$  mapping function and associated coding, which saved the coding resources and ensure the stability and continuity of unified coding system.

#### 4.5. Coding Generation, Checking and Released

Coding generation, checking and released is based on Coding object topology and the coding rule. Coding object topology can accurately reflect the hierarchical relationships of the various objects in the power grid model. Coding rule-based provides the constraint attribute of coding object.

1. Coding generation. Coding generation is based on Coding object topology. It gets the constraint attribute of coding object from the rule database to generate corresponding code.
2. Coding checking. Coding checking includes the uniqueness checking, normative checking and self-checking. Figure 6 shows the flow chart of code checking. Uniqueness checking has the function of unique identification. Normative checking can ensure generated code with CIM / XML standard. Self-checking can verify the specification of generated code. Coding checking is based on the order of coding generation.
3. Coding released. Coding released included the visual coding display and the CIM / XML standard document.

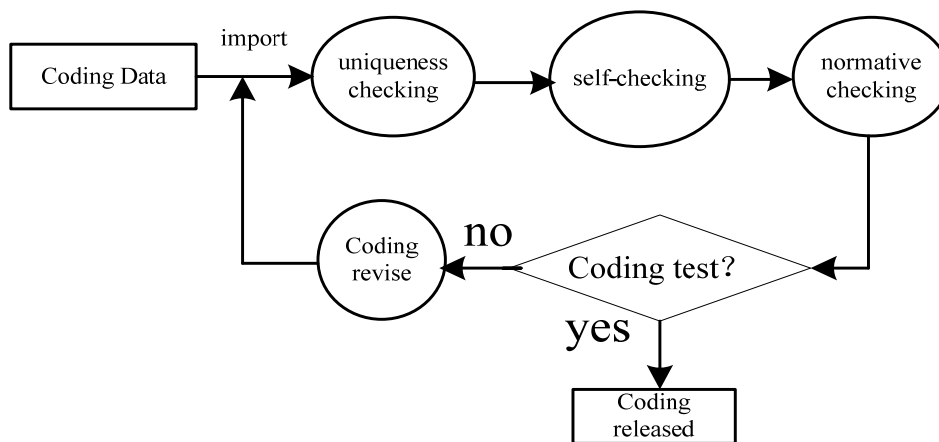


Figure 6. Flow chart of code checking

## 5. Life Cycle and Evaluation Model of Unified Coding Architecture

### 5.1. Life Cycle of Unified Coding Architecture

The life cycle of unified coding architecture is basis of the cost of equipment management [21-23]. The availability, reliability, integrity and robustness are the parameters of evaluating unified coding architecture. From the planning, design, purchase to operation, maintenance and withdraw, equipment coding is not only ensure uniqueness, but also maintain stability throughout the whole process as shown in Figure 7. The life cycle of unified coding architecture can reflect the cost of equipment management.

Unified coding architecture is a full life-cycle coding structure. When the equipment coding is failure, a new equipment coding can be calculated by dispatching coding, associated coding and  $f$  mapping function. It can also ensure the sustainability of the dispatching coding and the uniformity and standardization of applications system layer data, and make for the integration of the various subsystems.

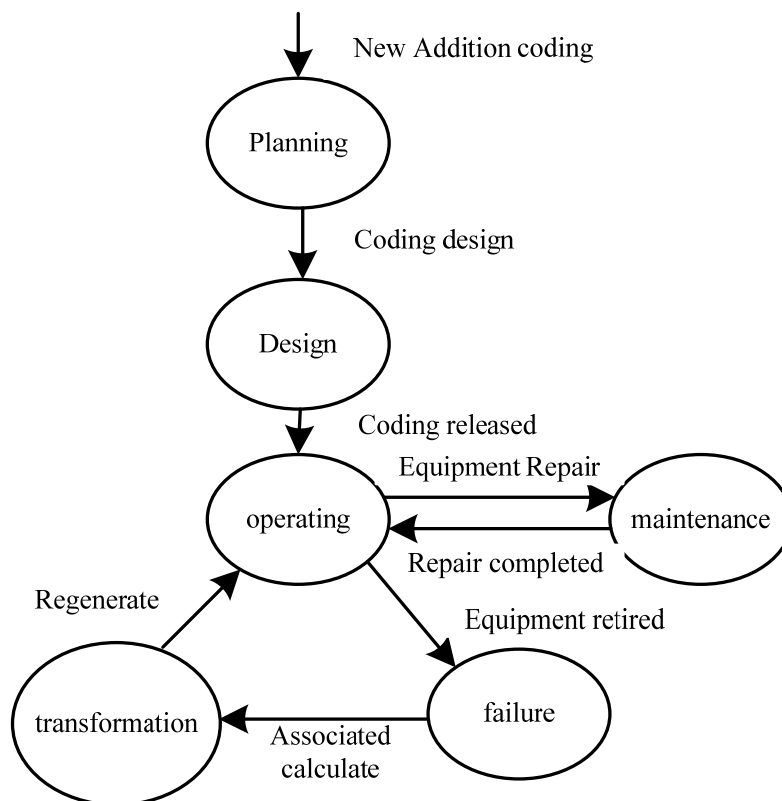


Figure 7. Life cycle of unified coding architecture

### 5.2. Survivability Evaluation of Unified Coding Architecture

The survivability of unified coding architecture can evaluate that whether it can provide services for application system when some disruption events of power grids (such as equipment maintenance and replacement, etc.). Unified coding architecture is a full life-cycle coding structure. When the equipment coding is failure, a new equipment coding can be calculated by dispatching coding, associated coding and  $f$  mapping function. Thus, it is necessary and meaningful to evaluate the survivability of unified coding architecture.

A model of survivability behavior and service status is proposed, which is based on the reliability, availability and maintainability of unified coding architecture. The survivability function of evaluation as Equation 1.



$$Surv(a) = \prod_{i=1}^n (f_i(a))^{\mu_i} \quad (1)$$

$f_i(a)$  represents the attributes of survivability belonging to coding system, such as reliability, availability, maintainability, etc.  $\mu_i$  represents the values of different attributes,  $\mu_i \in [0,1]$ , and  $\sum_{i=1}^n \mu_i = 1$ . It means the degree of different attributes in the calculation of survivability. According to the need, it can set the value of  $\mu_i$ , and it has perfect scalability.

## 6. Conclusion

Unified coding architecture can improve the information integration of dispatching center belonging to power grids and ensure that data is consistency, accuracy and real-time, which can efficiently achieve data exchange, sharing and interoperability. As one of the key technologies to support Smart Grid, it is the basis for the establishment of the integration of the power system operation and management model.

This paper summarizes the main features of unified coding architecture, and a unified coding architecture is proposed. It includes coding management layer, coding generation layer, information models layer and application system layer. Hierarchical design makes the whole encoding system to adapt to different application environments, different interfaces, loosely coupled requirements and the integration model management function of the power grids. The life cycle and survivability evaluation of unified coding architecture is proposed, which can ensure the stability and availability of the coding architecture. This paper provides the solution for dispatching coding technology of Smart Grids.

## References

- [1] Chen Shuyong, Song Shufang, Li Lanxin. Survey on smart grid technology. *Power System Technology*. 2009; 33(8): 1-7.
- [2] Falahati Bamdad, Fu Yong, Wu Lei. Reliability assessment of smart grid considering direct cyber-power interdependencies. *IEEE Transactions on Smart Grid*. 2012; 3(3):1515-1524.
- [3] Han Feng, Yin Ming, Li Jun. Discussion on related issues of smart grid development in China. *Power System Technology*. 2009; 33(15): 47-53.
- [4] Petirrin JO, Shaaban M. Overcoming challenges of renewable energy on Future Smart Grid. *Telkonnika*. 2012; 10(2): 229-234.
- [5] Umesh Singh. Standards based intelligent approach for smart grid integration. *Power System Technology*. 2009; 33(15): 30-36.
- [6] Feng Yongqing, Xia Xiang, Zhou Xianfu. On development of Hangzhou power network information integration. *Power System Technology*. 2004; 28(19): 51-54.
- [7] Li Xin, Zang Chuanzhi, Liu Wenwei. Metropolis criterion based fuzzy Q-learning energy management for smart grids. *Telkonnika*. 2012; 10(8):1956-1962.
- [8] Pan Yi, Zhou Jingyang, Wu Xingping. Interoperability test based on common information model. *Power System Technology*. 2003; 27(10): 25-28.
- [9] Liu Chongru, Sun Hongbin, Zhang Boming. An investigation on a common information model for energy management system. *Automation of Electric Power Systems*. 2003; 27(14): 45-48.
- [10] Qian Feng, Tang Guoqing, Gu Quan. Analysis on integration of multilevel power network model based on CIM. *Power System Technology*. 2007; 31(12): 69-73.
- [11] Qian Feng, Tang Guoqing, Gu Quan. Composition of decentralized graphics and model based on CIM and SVG. *Automation of Electric Power Systems*. 2007; 31(5): 84-89.
- [12] Pan Yi, Zhou Jingyang, Li Qiang. The separation and combination of power system model based on CIM. *Automation of Electric Power Systems*. 2003; 27(15): 45-48.
- [13] Liu Chongru, Sun Hongbin, Zhang Boming. Investigation on incremental and partial model transfers based CIM. *Automation of Electric Power Systems*. 2004; 28(12): 51-55.
- [14] IEC 61970 Energy management system application program interface (EMS-API). 2003.
- [15] Yang Lingming, Li Jiajia, Wang Yong. A uniform description scheme of power group asset based on KKS. *Computer Engineering & Science*. 2008; 30(7): 148-154.
- [16] Cao Jinzhang, Zhu Chuanbai, Liu Bo. Research and implementation of the intelligent dispatch encoding system for power grid based on CIM. *Automation of Electric Power Systems*. 2011; 35(2): 43-46.

- 
- [17] Qu Chaoyang, Shen Jing, Liu Jia. Design of model of asset management system possessing service-oriented architecture for power enterprises. *Power System Technology*. 2007; 31(11): 69-73.
- [18] Cao Jingzhang, Zhu Chuanbo, Liu Bo. Architectural research and design of an intelligent dispatching coding based on CIM. *Automation of Electric Power Systems*. 2011; 35 (2):43-47.
- [19] Chen Ji, Guo Chuangxin, Liu Bo. Architectural design of an adaptive unified coding system based on CIM. *Power System Technology*. 2010; 34(2): 52-55.
- [20] Yuan Peng, Gu Jianwei, Guo Chuangxin. Design of Dual-Encoding System for Distribution Network Based on Service Oriented Architecture. *Power System Technology*. 2012; 36(1):271-276.
- [21] Yao Jianguo, Yang Shengchun, Gao Zonghe. Development trend prospects of power automation systems. *Automation of Electric Power Systems*. 2007; 31(13): 7-10.
- [22] Xin Yaozhong. Development of trend of power system dispatching automation technique in 21st century. *Power System Technology*. 2001; 25(12): 1-10.
- [23] Luo Xiaochu, Li Le, Wei Zhilian. Applications of life cycle cost theory in decision-making of investment for distribution transformers renovation. *Power System Technology*. 2011; 35(2): 207-211.