Information Technology Platform for Automation of Decision-Making Processes by the Organizational Management System

Zelim Borukaiev, Konstantin Ostapchenko, Olexandr Chemerys, and Volodymyr Evdokimov

Abstract The chapter examines the development problems of specialized tools for mathematical and computer modeling, information technology support for automation of the preparation and decision-making process by appropriate organizational management systems (OMS) with advanced tools for meaningful data processing and user interface of competitive electricity market participants operating in complex relationships and potential risks. The peculiarities of the electricity market functioning are determined, which require advanced computer simulation tools that provide market participants with the opportunity to formulate and accept strategies for their own behavior in different segments of the competitive market. Existing solutions and research in the field of creating modern software tools for modeling, forecasting and optimizing the functioning of energy markets in the world are analyzed. The development direction of such tools is determined and the structural-functional composition of the information technology platform for OMS is proposed, that is represented by the functional components of the preparation and decision-making process to develop a strategy for market participant's own behavior on its segments. The basics of creating an information technology platform for building decision support systems (DSS) for energy companies as entities/subjects of the electric energy market, a feature of which is a new formalization of the components of the DDM (Data-Dialog-Model) paradigm, are considered. In particular, typical operations of the decision maker interaction in the performance of functional tasks that are interrelated with data processing methods are classified. A unified model of the DSS data structures is proposed, which defines common approaches to representing market entities at all management levels through the selection of their properties and relationships and creation of a unified system of classifiers, reference catalogs that ensure the operation of the entire set of mathematical models of computational and analytical problems that are logically and informationally interconnected between

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itself according to its intended purpose, input and output data parameters of energy companies on the market, optimization and forecasting algorithms.

Keywords Information technology platform · Decision support system · Organizational management system · Electricity market

1 Introduction

Among the main tasks of energy companies at the current stage of the electricity market development are to determine the main directions of strategies formation and conditions for their implementation in different segments of the electricity market, methods and tools for modeling decision-making processes in optimizing the structure of sales/purchases of electricity and ancillary services by the criteria of profitability and opportunities to level the risk of decisions. However, effective work in these market segments requires not only experience but also software tools that will allow market segment participants to perform the necessary modeling and forecasting calculations to identify risks and find effective strategies for their behavior in these segments.

Solving only these problems, necessitates the creation of specialized tools for mathematical and computer modeling, information technology support for the automation of the process of preparation and decision-making by the appropriate OMS of market participants at all stages.

Thus, a problem of improving information technology tools for the development of DSS with advanced tools for meaningful data processing and user interface through the use of modern information technology, developing and formation of the necessary databases that characterize the performance indicators state of the management object and changes in its external environment, including changes in energy markets, continues to be relevant. A separate and very important task is to develop a simulation models database of the functioning of electricity market segments to solve the computational problems of analysis and forecasting of the changes in indicators for the segments functioning and their management.

2 Automation of Decision-Making Processes by the Organizational Management System

2.1 Problem Formulation of Creating the Organizational Management System of the Electricity Market

Complicated organizational-technical systems (COTS), which certainly include the electricity market, usually combine many interdependent human-machine objects—subsystems that interact with each other and with other technical systems in various fields' vital activity of society, and differ in the purpose of production and products. Many of them have common characteristic features of management tools, such as OMS as structural subsystems of COTS. The main of these features are the following [1]:

- hierarchical multilevel nature of organizational, technological and information interaction of subsystems;
- changes in time of own structure and functions;
- incomplete compliance of the structure with the development goals of COTS due to changes in the management and functioning mechanisms over time, etc.

To implement the functions and tasks of interconnected organizational, production, technological and information management in the management structures of the COTS, it is necessary to create computer modeling systems that are designed to solve the problems of decision-making support in their OMS. The application and development of such systems, which actually function as COTS, requires continuous improvement of mathematical and information technology. And this in turn encourages finding solutions related to unification in the processes and technologies of design and improvement of such modeling systems.

Obviously, the main purpose of building modeling systems to solve decision-making support problems is to significantly increase the productivity of organizational management, namely:

1. Efficiency–as a result of reducing the number of service personnel;
2. Operativeness—due to the reduction of processing time of large amounts of information;
3. Validity of the adopted decisions—as a result of carrying out a multivariate analysis of the proposed options for making changes to the OMS functioning mechanisms (rules) to achieve the management goals and assess the consequences of the adopted decisions.

Many experts associate the increase in productivity of organizational management with the development of research on improving the methods and tools of mathematical and computer modeling of decision-making processes and the creation of qualitatively new computer OMS based on them. Computer OMS are usually used to adequately represent the research processes of the OMS functioning mechanisms, monitoring, analysis and forecasting of key informative indicators that reproduce the components of the COTS entities state vector, taking into account the subsystems interaction included in them.

In the OMS theory, the functioning mechanisms are understood as a set of rules and procedures that determine the sequence of actions of elements (subjects included in systems) in decision-making processes for managing organizational, technological and information activities [2]. The decision-making process to improve the OMS functioning mechanisms for a wide range of COTS for industrial and technical purposes, whose products are sold in competitive markets, includes the formulation and comprehensive solution of a large number of interdependent tasks.

It is natural to assume that the construction of a modeling system, which is actually designed to implement interactive, intelligent functions of DSS, is possible only with a computer modeling system, which provides the ability to design and build simulation computer models of OMS functioning processes. Such a system should include:

- tools of formal mathematical description of OMS complex subjects and processes of their organizational interaction between themselves and the external environment;
- a single information space that combines the means of object-oriented conceptual and information modeling of the interaction processes of OMS complex subjects between themselves and the external environment;
- unified system of classifiers and reference catalogs, data storage structure, unified system of protocols and interfaces;
- single tools of programming computer models.

This paper proposes an original approach to solving the problem of building DSS with advanced tools for object-oriented modeling (OOM) of the COTS subjects functioning processes to form a single database structure of a unified user modeling environment.

The main purpose of the proposed approach is to create an information technology platform (ITP) for building an integrated adaptive DSS to increase information support of DSS users by reducing the time to automate decision-making processes, accelerate the provision of user interaction interfaces with integrated information DSS resource—data base, model base, knowledge base, and creating a single unified software environment for automation object.

Achieving the stated goal determines the following areas of development work of ITP construction of DSS for electricity market OMS:

- building an organizational model of information technology platform for DSS design;
- conceptual representation formation of the organizational structure for the integrated adaptive subject-independent DSS;
- object modeling of the subject area data for automation object in order to form a single unified database structure for the organizational management entities;
- functional modeling of the data processing and presentation technological processes for the purpose of unification (standardization) of the system software interface by the classification of user interaction operations with objects from subject area in the software system;
- information protocols/interfaces development for data exchange with the different purposes models which are connected to a database of the organizational management subjects.

2.2 Analysis State of the Modern Research on the Creation of Organizational Management Systems for Energy Markets

Among the arising problems of OMS creating are the high cost of implementing a market model, the complex structure of market division into its segments, the inevitable volatility and manipulation of spot prices, manipulation of individual players by market authorities, the difficulty of reducing generation costs, unpredictability of market prices energy resources, unpaid cost of electricity production by part of generating capacity, unequal distribution of revenues from the sale of jointly produced and supplied to consumers [3]. Therefore, in many countries around the world are simulating models of market functioning to conduct research to find the most rational and optimal mechanisms for balanced revenue distribution between market segments and their participants—market subjects/entities.

Paper [4] qualitatively describes the analysis of various methodologies and modeling methods, computer tools and information technologies used to create such simulation models and systems. The methodological basis for the energy markets OMS creation is formed by economic, macroeconomic, simulation, retropolation, multicriteria models. Therefore, the core in the form of a module/subsystem of the problem “solver”, which is presented as a library of mathematical methods, is one of the most widely used OMS in the world. In the simplest OMS in terms of size and amount of data used can be utilizes “solvers” that are publicly available. But in more advanced systems, it is advisable to use libraries of methods which are developed and improved by leading research institutions and specialized commercial companies.

Currently, almost all well-known major global manufacturers of software and hardware platforms, such as SAP, ORACLE, IBM, Siemens and others, provide comprehensive solutions and tools for building computer systems, as well as, the most ready-made systems, including for organizational management of energy markets. But in addition to these platforms, specialized computer systems have been built and are in operation in the world today, which provide modeling of the energy markets functioning. The most famous of them are NEMS, GEMS, GEMINI (USA), PRIMES, PLEXOS, AURORA (EU), NEMSIM (Australia) [5–7].

All these software packages are mostly focused on modeling energy in general and are used by national regulators to analyze strategies for the development of energy complexes. However, the structure analysis of the producers and suppliers of electricity markets shows that energy markets of this scale in the world are formed not only from large players, but also from a large number of participants with small working capital. And such participants do not have economic incentives and opportunities to use complicated software packages as an “assistant” in shaping the strategy of their own behavior in the market. In addition, these packages usually do not provide an opportunity to assess the mutual influence of strategy and tactics of many market participants, which may in the future become objects of “distributed generation” in the energy system and influence pricing processes in the market. This fact adds a significant share of uncertainty in shaping the strategy for the development of the electricity market as a whole.

Therefore, the urgent task is to create a user-friendly information modeling system in the competitive electricity market as part of the OMS energy markets, which aggregates all available information about the processes of their operation and focuses on reproducing stages in the development and decision-making on the formation of the own behavior strategy of market participants in its segments.

2.3 Directions for Improving the Organizational Management Systems of the Electricity Market

At present, in the theory and practice of OMS based on DSS, new trends have emerged both in approaches to the classification of such systems and in determining their place in the organizational management cycle. Thus, the analysis of a wide variety of papers [8–12] on the creation of DSS or systems with elements of automation of decision support processes allowed formulating the following conclusions about the conceptual development of DSS theory and practice for organizational management:

1. Developed only a general concept and general approaches to building information systems, which should be classified as DSS. Each variant of DSS implementation can be considered as a specialized system that solves specific problems and implements calculation methods specific to a given applied subject area of the automation object. That is, in terms of unification in the approach to the DSS construction, they should be attributed to problem-oriented systems with their own approaches;
2. All modern areas of information systems development—OLTP, OLAP, Data Mining, Data Warehouse, Business Intelligence, focused on methods and mechanisms of data collection, processing and presentation and are not related to the mechanisms of development, analysis and decision-making. That is, they are secondary to the subject of research—the process of DSS building.
3. Functionally, DSS should implement the following main stages in working with data—data collection, situation analysis, development (selection) of solutions, solution implementation. Thus by performing these tasks one differs from other classes of automated information systems.

Structures of complex management systems, which should include OMS, are usually built using hierarchical and functional principles of subsystems allocation for situational management—management based on established facts and circumstances, which can be represented as a functioning indicators set of the management object [13]. As a result, the management systems of each level actually become subsystems in the overall management system on the higher level. Thus each level is characterized by the own features of the management purposes and operations which are connected with data processing [14]. It is known that management operations implement the information function of the control object, which is to perform in the automated mode the information collection, processing, interpretation and presentation for production function realization of this object, namely the implementation of management tasks [15].

As a result, several levels of subsystems can be identified in the OMS structure due to different degrees of the information function automation, among which especially should be noted the information-analytical monitoring system (IAMS) and the information-modeling system (IMS) for preparation and analysis of development options based on object management models.

The main directions of works on the development of a unified approach to the DSS construction for a OMS wide class with advanced tools of semantic data processing and user interface, computer models construction and computational algorithms development for analysis and synthesis of OMS functioning mechanisms, forecasting the consequences of decision-making on the implementation of new functioning mechanisms at all levels of organizational management was formulated in [16].

In order to OMS develop and improve, it is proposed to expand its functionality as a DSS not only through IAMS [17], but also through IMS, which will act as a tools implementing the problem analysis functions and be represented by such unified data processing methods:

- calculation-modeling, which according to the known functional dependence to form the calculation result and are presented in the form of a formula and are used to calculate the state of market indicators;
- calculation-search, which according to the cyclically repeated procedure to form the calculation result and are presented in the form of a procedure consisting of a list of formulas and are used for simulation of changes in market indicators;
- calculation-optimization, which by organizing the option search (selection and comparison) to form the calculation result and are presented in the form of a set consisting algorithm and criterion for evaluating options and are used to optimize market indicators;
- calculation-forecasting, which by purposeful option synthesis and solution analysis of their calculation to form a calculation result and are presented in the form of a predictive procedure and are used to forecast market indicators.

In general, the basic set of object-oriented integrated adaptive DSS can be built on the decomposition principles and structured with subsystems (modules) that implement tasks that reflect the stages of preparation and decision-making process for organizational market management.

3 Conceptual Representation of the Information Technology Platform for Automation of Decision-Making Processes by the Organizational Management System

3.1 Organizational Schema of Information Technology Platform for Decision-Making Process Automation

The basis of the adaptive organizational scheme of ITP for the construction of object-oriented integrated DSS should be based on typical features that can be used to distinguish one data object from another. The expediency of such analysis and allocation of subject area object classes in the development of models for external (reflecting the system software application interface) and conceptual (reflecting the data representation of functional tasks in the system software application) levels in the ITP organizational schema is due to the fact that for different functional tasks of the software application often uses the same visualization and transformation operations over information data sets. In addition, the functions and processes of data processing in the phased implementation of subsystems in the integrated hierarchical system are rapidly modified, reproducing the variable user requirements to the subject area.

All this requires such an organization of the system structure through which objects in the subject area and the relationships between them would be defined regardless of the implementation of specific functional tasks for data processing in software procedures and interfaces and represented a single structure. As a result, the object of design and description in the organizational schema of the system should be not only data structures in the subject area but also the procedures for implementing functional tasks [18]. The introduction of an additional intermediate logical sublevel for representation of procedural and interface parts of the ITP software environment between the conceptual and external levels in the organizational schema for subject area will provide the necessary independence and DSS adaptability to possible changes and extensions in the models and data structures (Fig. 1).

As a result, the visualization logic of functional tasks in the subject area also becomes data presented in the form of its own interface model, which is included to the conceptual model. The ITP technological part becomes as instrumental software package of adaptive information system, whose function is the interpretation and reproduction by the subsystems tasks the interdependent data from the models of the functional tasks interfaces and data structures in the conceptual level of the subject area.

However, the simple availability of separate functional subsystems in DSS does not provide a solution to the whole set of tasks related to reliable and efficient operation during the longest possible life cycle, which will occur both at the stage of practical software development and operation. Therefore, the required functionalities of modern DSS should be the system property as open structure, the availability of a flexible interface (mechanism) for the inclusion of new objects and algorithms to

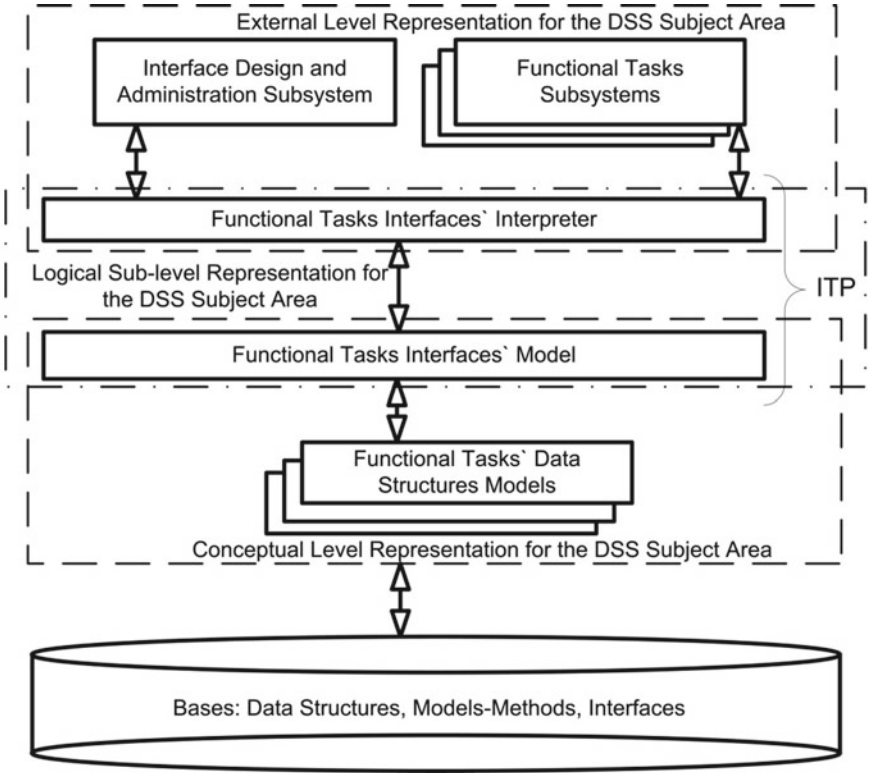

Fig. 1 The ITP organizational schema for DSS construction of organizational management

solve applied tasks and the ability to adapt around changes in both objects structure and parameters values in subject area.

Thus, the information part as the database and the technological part as the ITP software will consist of functional and information components. Functional will reflect the features and processes, and information will reflect the unified ways of interacting with objects from the subject area.

A distinctive feature of the proposed conceptual approach to creating an information technology platform for building and implementing DSS functions is to formalize the components of DDM-paradigm (Data-Dialog-Model) as problem-independent components in the DSS conceptual model for OMS [19, 20]:

1. The component Data is a block of object-oriented modeling of the subjects participating in structure-forming communications in the organizational management defining rules of the energy market functioning and indicators (parameters) of its functioning.
2. The component Dialog is an adaptive model of interaction (interface) and data presentation to the user, which implements a dynamic binding method organized

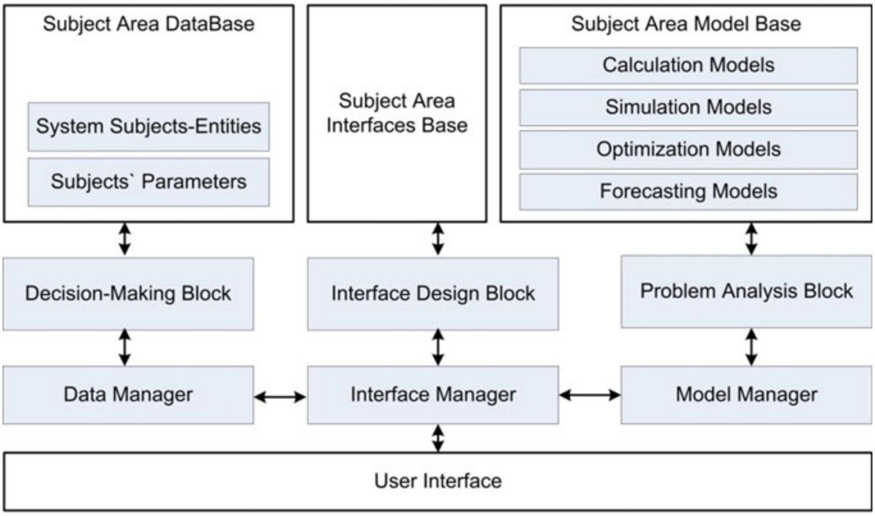

Fig. 2 The ITP conceptual model for DSS construction of organizational management

by the creating a mappings dictionary the data structures and attributes of the energy market functional tasks with the data visualization operations.

3. The component Model is a ITP tools for generating models that provide the problem analysis function, which are presented as unified methods—modeling algorithms to define the rules for formation and change the values of energy market functioning indicators when implementing the data management main stages in DSS.

In papers [16, 18, 21] the DDM-paradigm improvement is offered and the following problem-independent components of representation are substantiated to include in DSS structure for automated management of COTS subjects (Fig. 2):

- models of entities/subjects involved in the structure-forming relations of organizational management to determine the rules of COTS functioning;
- models of indicators/parameters for state definition of COTS functioning;
- modeling algorithms/models with various calculation purposes, which determine the rules for formation and change of indicators values of COTS functioning;
- interfaces model for interaction definition and data presentation to the COTS user;
- managers of data, interfaces, models for the organization of COTS functioning.

An important component of the ITP conceptual model for the DSS construction is the data manager, which provides a user interface to the data structures of the OMS subject area with the ability to further monitor and evaluate the COTS functioning indicators. Therefore, when using the object-oriented approach to the adaptive DSS creation, it is necessary to provide for the object analysis stage of the applied subject area (ASA) and then based on it the implementation next stage of the object-oriented ASA modeling for this management object.

3.2 Analysis of the Functioning Processes Representation for the Organizational Management System

One of the main conditions for creating adaptive information systems is the data unification. The development of a single unification system is a complex and time-consuming task, to solve which it is advisable to use international experience and standards [22, 23]. The basis for building a single classification system and a single data space should be a generalized information model, which in the same way according to IEC standards describes the whole set of typical physical OMS subjects based on the principles of object-oriented modeling (OOM) [24–26]. Adhering to the OOM principles, such a generalized information model supports the description of OMS physical subjects at all levels of COTS, which allows to simultaneously representing in the information system their properties, relationships and behavior, creating the opportunity to apply a single system of classifiers, reference catalogs and unify data access system.

Object-oriented approach to the adaptive DSS creation involves primarily the stage of ASA object analysis. But the essence of this analysis is to identify the entities—OMS ASA subjects and processes in the form of a set of information objects that interact with each other based on the OOM principles and develop on their basis a single representation specification for the subject area of OMS functioning.

It is known that the basic concepts of OOM are objects, classes, properties, events, methods, and the principles are encapsulation, inheritance and polymorphism. Object model describes the structure of objects that make up the formal system $Object = (Attribute, Condition, Behavior)$, which consists of the object attributes *Attributes*, the current functioning state *Condition*, the methods of behavioral operations *Behavior*. Therefore, in such an object model should be reflected those concepts and objects of the already real environment of the COTS ASA, which are important for the OMS being developed. And the created classes of ASA objects must be organized into a hierarchical structure built on the subordination relations, which are based on the principles of encapsulation, inheritance and polymorphism.

The physical OMS subjects and their functioning processes serve as objects of the COTS ASA, which are provided by the OOM means with all its principles. The subjects include organizational structures that carry out activities within the framework of ASA. In the general case, the OMS subject, depending on the management functions may be represented by a hierarchical structure in the composition of other subjects of activity. Therefore, any subject should be characterized by individuality, condition state, structure and certain behavior.

The individuality of OMS subjects is described by a set of qualitative and quantitative characteristics such as attributes that distinguish each subject from another and characterize changes in its state as a result of interaction with other subjects. As a rule, the subject individuality is represented by constant (technical) characteristics namely functioning properties of the subject and dynamic characteristics namely functioning parameters. The functional state of each subject is determined by a list of parameters and their values, which reproduce the various quantitative indicators of its activities over a time period.

The activity (behavior) of the subject is regulated by the calculation-technological processes that are carried out on the states of all ASA subjects in the OMS. These processes are identified by regulatory documents and implemented using modeling algorithms/scenarios for the formation of parameters values—indicators of the management state for subjects. After completion of all regulated procedures and relevant calculation-technological processes in the ASA, will be obtained data on changes in the COTS functioning state as a whole.

Thus, the composition of the basic elements-ASA entities, which become the objects of the information model are include subjects, subject types, property types of subjects, subordination/relationship types of subjects, parameters, parameter types, types of functional interlink between parameters and subjects. And the mechanisms of change in the functioning states of the subjects are presented by the established schemes of algorithms/scenarios for modeling, forecasting and other calculations, the results of which are reflected in the quantitative values of the calculated indicators.

Therefore, in general the information model of the OMS functioning processes should use the principle of presenting ASA information objects by the metadata as a reproducing means for OOM concepts.

3.3 Information Model for Subject Area of the Organizational Management System

The selection of a set of information objects with these characteristics and the relationship between them, makes it possible to build an object information model of a particular ASA and on this basis to further develop a unified system of classifiers, reference catalogs, storage structure and single system of protocols, interfaces, tools for programming computer models of technological processes in the COTS also [27].

Therefore, the ASA specification of adaptive DSS can be presented in the form of a semantic net of classes in the information model (Fig. 3), which consists of declarative and procedural parts:

$$SP = \left(E, SN, f^{SN}\right),$$

where $E = E^{DECL} \cup E^{PROC} = \{e_i | e_i \in SA\}$, $E^{DECL} \cap E^{PROC} = \emptyset$ is a set of entities in subject area SA, which is determined by the aggregate of its information classes e_i; $f^{SN} : E \times E \to SN$ is a semantic net of classes in the ASA specification, which is defined by a set of semantics (assignments) SN.

Semantics‘ set *SN* establish the information objects‘ typical relationships—“classification”, “belonging”, “composition”, “characterization”, which are associated

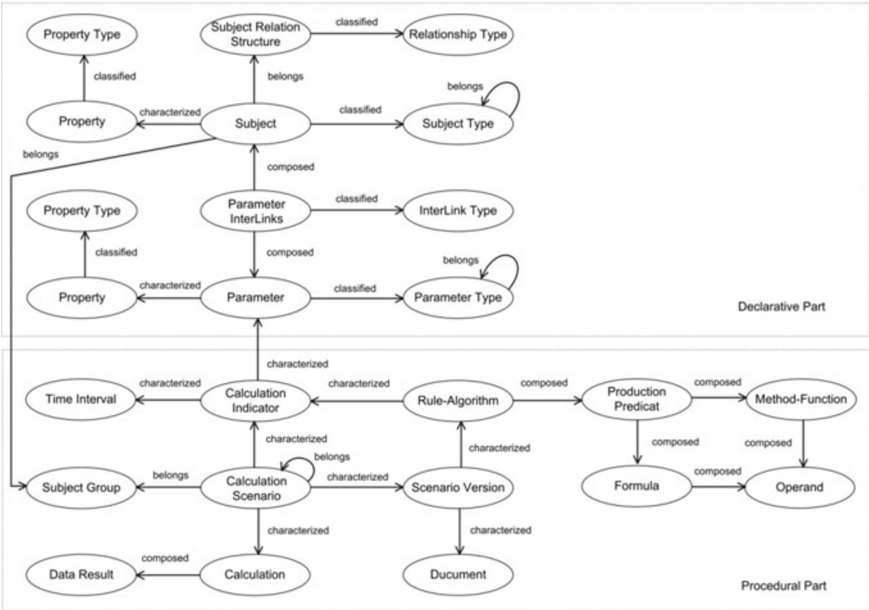

Fig. 3 Semantic net of classes for ASA specification

with the corresponding ways of reproducing information in data structures (relationships between elements, sets and parts of OOM objects [25])—association "IS-A", generalization "PART-OF", aggregation "HAS-PART", dependencies "IN-OTHER".

Object analysis of ASA for the organizational management leads to the following construction of the components in ASA dictionary:

$$SA = \left(S, C, P, ST, PT, f^S, SC\right),$$

where $S \subseteq ST \times C$ is a ASA subject; C is a static property that identifies the subject in its class (subject type) $ST; P \subseteq PT \times S$ is a dynamic parameter that belongs to one of the established classes (parameter types) PT and characterizes the component of the current state vector of the subject $S = (C, P)$; $f^S : S \times S \to LT$ is a ASA subject structure, which is determined by the set of relationship classes (relationship types) LT that are established between subjects within ASA; $SC = \left(O, f^O, V, M, f^V\right)$ are functioning scenarios of subjects in the ASA; O are the calculation-technological operations (operation groups); $f^O : O \times O \to \{0, 1\}$ is a scheme of operations calculation scenario; $V \subseteq P \times D$ are the calculation indicators for subjects parameters in a certain estimated time interval D; $M = \left(R_i | i = \overline{1, n}\right)$ are the rules (algorithms, procedures) for the implementation of calculation-technological operations, built on the basis of product rules predicate R_i; $f^V : O \to V \times M$ is a result of the calculation-technological operation.

The model classes of the declarative part E^{DECL} allow describing the composition, connections and properties of the ASA subjects, but the classes of the procedural (technological) part E^{PROC} allow describing the structure and relationships for technological processes of subject functioning in the ASA.

Based on the given specification the subjects in the semantic net includes objects of organizational management, structures in their technological equipment, legal entities and other organizational structures, the state vector of which changes due to calculation-technological operations of optimization, forecasting and other purposes. Each subject in the description has its own type, a list of its own properties and a list of subjects with whom the relations is established. The functional state of the subject is determined by a list of parameters—components of the state vector, which reproduce various indicators of its activities. Each parameter in the description has its own type, a list of its own properties and a list of subjects to which it relates.

Modeling algorithms of the calculation-technological operations are used to establish relationships between the parameters of different subjects. Algorithms are implemented using scenarios of calculation schemes based on the production rules of their representation, calculation indicators of parameter‘s values, calculation methods-functions, production predicates, formulas and their operands.

Therefore, the information model, which is formalized in the form of an ASA specification of DSS, will be presented as a whole as a set of the following components:

- models of organizational management objects that participate in the structure-forming relations of the ASA subjects;
- models of parameters that determine the functioning state of the ASA subjects;
- modeling algorithms (algorithms for implementing methods) that determine the rules to formation and change the values of the subjects functioning parameters;
- results‘ arrays of optimization, forecasting calculations, which determine the prospects of the ASA subjects.

Thus, the application of OOM to the design of the adaptive DSS specification will provide a number of advantages:

- the system description in the form of information objects corresponds to the semantics (content) of the ASA subjects;
- the behavior of the ASA subjects is presented by the objects of certain classes, which contributes to the easy change of their behavior;
- combining information objects into a net with the certain semantic relations allows to unify the structure of data storage and interfaces of their relationship;
- ensuring the possibility of parallel calculations of the subjects‘ states, each of which has its own properties and behavior.

The use of OOM as the basis for constructing an information model of OMS functioning processes made it possible to present the information space in the form of a unified data system. The developed specification of the OMS subject area for building computer models of organizational management provides adaptation to changes in existing or the emergence of new mechanisms for the COTS functioning and its effective support at different stages of the OMS life cycle when building an integrated adaptive DSS.

3.4 Functional Model of Information Technology Platform for Decision-Making Processes Automation

Functional organization is a structured representation of the OMS functions, data flows and entities of the information model, which link these functions into a single whole. It is built by the decomposition method from complex functions to simpler ones. Elements of each decomposition level are actions on transformation of information flows with use of certain OMS functioning processes under their management. Thus, the functional organization is formed by subsystems that are characterized by input and output data flows, as well as data management mechanisms and implemented functions of their processing.

Consider the functional organization of ITP for the construction of object-oriented integrated adaptive DSS (Fig. 4). The DSS structure for the management of market participants includes the following structural-functional elements for certain components of the ITP conceptual representation.

1. The component Data are:
   - the base of subjects involved in the structure-forming relations of organizational management in the market;
   - the base of parameters—indicators of subjects functioning in the market;
   - the data warehouse on the state of functioning indicators for market subjects.
2. The component Model are:
   - the modeling algorithms—models of calculation, simulation, optimization, forecasting on the basis of unified data processing methods, which determine the rules of formation and change of indicators values about functioning of market subjects.
3. The component Dialog are:
   - the model of interfaces about data interaction and presentation to the user;
   - the managers for data, models and interfaces;
   - the functional subsystems—modules of stages in the preparation and decision-making process on the organizational management of market functioning (tuning, preparation, modeling-calculation, analysis-estimation, reporting, monitoring).

The component Data form the IASM information model and the component Model form the IMS functional model in the DSS for organizational management of market functioning.

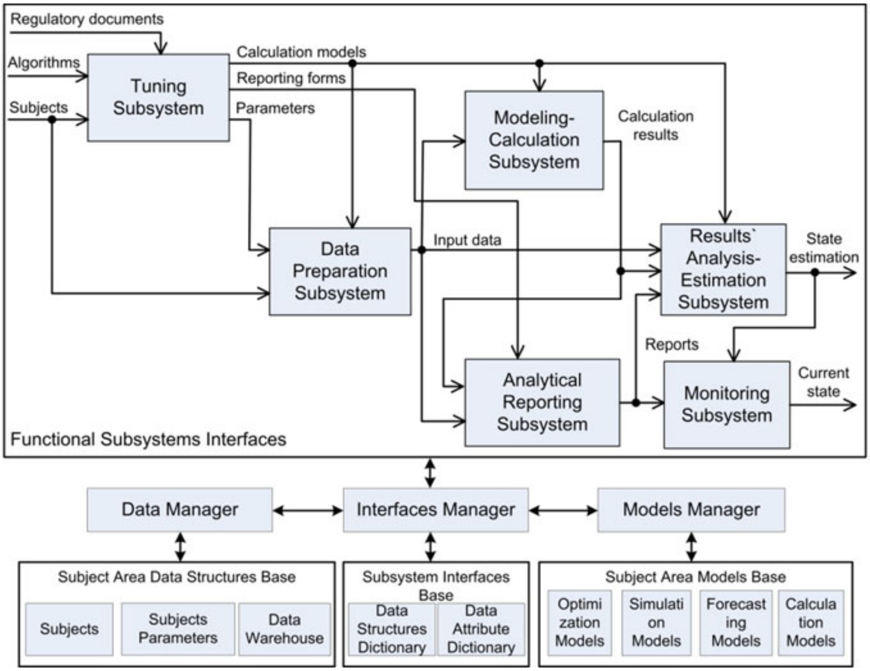

Fig. 4 The ITP functional model for DSS construction of organizational management

The manager of data in the ITP functional model provides manipulation of the state in the information model for the market subject area through the organization of input and output data flows in DSS. As a result, all input and output data in the information model are presented in the form of information blocks of data about the subjects, the parameters of the subjects, calculation algorithms, calculation results, the formation of reporting documents and more.

The manager of models in the ITP functional model acts as a means of generating models in DSS, which implement the functions of problem analysis and are presented as unified data processing methods, which include such as formula (used to calculate the state of indicators), procedure (used to simulate changes in indicators), search for alternatives (used to optimize indicators), predictions (used to forecast indicators).

The manager of interface in the ITP functional model acts as a link between data and model managers, which implements the function of presenting and interpreting information generated from data and models.

As a result, managers of data, models and interfaces form the technological part, and databases—the information part of the ITP construction and implementation of functional subsystems in the DSS for market organizational management. In general, the basic software package of object-oriented integrated adaptive DSS built on the principles of decomposition and structured with subsystems, implements tasks that reflect the stages of preparation, analysis and decision-making in the functioning process of the information model for the subject area of market organizational management [17].

4 Organization of the User Interface in the Information Technology Platform for Decision Support System Construction

4.1 Classification of User Interaction Operations with Subject Area Objects of the Organizational Management System

In the organizational structure, the software of object-oriented integrated adaptive DSS consists of functional subsystems and software interpreter of functional tasks interfaces. And its information support is presented in the form of subject area objects conceptual representation and metadata of the user interaction interfaces with DSS functional tasks.

The organization of the DSS functioning technological process provides the functions of preparation, implementation and data processing of calculation results and consists of sequential tasks implementation by the functional subsystems which purposes are corresponds to basic typical interaction operations for end user with DSS.

The manager of interfaces, as a link between data and model managers in the DSS conceptual model, acts as a tool of presenting and interpreting information generated from data and models. As a result, the DSS software built on the basis of object-oriented adaptive ITP should consist of subsystems focused on solving functional tasks in providing user information needs from the OMS subject area.

The adaptive object-oriented organizational model of the interfaces manager should be based on standard features that allow classifying and reflecting the differences between the ASA objects from each other. The expediency of such analysis and selection of object classes in the information models development is due to the fact that for different functional tasks often use the same operations of visualization and transformation over information data flows. In addition, the functions and processes of data processing during the phased DSS implementation are rapidly modified, reflecting the changing user requirements to the subject area. All this requires such an organization of the ITP structure, in which the subject area objects and the relationship between them would be defined in the software procedures and interfaces, regardless of the implementation of specific functional tasks for data processing and represent a single structure. Such a mechanism is a dynamic binding method, which is implemented in the form of its own model by creating a mappings dictionary of functional tasks data structures on visualization operations [18].

Thus, the following conceptual scheme of ITP construction in the form of a three-level organizational structure is proposed, namely this “functional environment of the subject area—functional task—instrumental (operation) processing function". As a result, the software (technological) part of the system will be structured with subsystems, which are distinguished not by problem-oriented features, but only functional (object) ones. Because are focused on typical interaction operations with objects in the subject environment when interpreting and presenting data to the DSS user.

4.2 Information Model for Representing User Interfaces of the Decision Support System

Consider the mechanism of data representation in object-oriented integrated adaptive DSS, built using metadata technology.

The effectiveness of complicated information systems largely depends on the ways of semantic matching of the software application interface with the data of its business logic, which are processed at the conceptual and physical representation levels [18, 28]. It is very important in what way provides a degree of data independence (consistency) from the programs logic. There are several ways of semantic matching through the binding mechanism of data structures with the program application, which can be carried out both at the stages of program compilation (design) and execution (translation).

Embedding data structures in programs and binding them to the business logic, which is carried out before the program start, namely at the design stage, provides static semantic matching. In the case of the conceptual data model modification to successfully perform the functional task of the software application with this binding option, it is necessary to recompile and build a new program image, suitable for use with modified data structures.

Implementation of the binding mechanism for data structures at the stage of program execution, by simultaneous sampling of application data and interface from the database, allows ensuring dynamic data independence from possible changes in their conceptual representation. This mechanism provides maximum flexibility in the software application implementation.

Such dynamic binding is realized by creating a mappings dictionary of data structures for functional tasks in the subject area conceptual level to the software application interfaces and is presented in the form of own model of interfaces for functional tasks. In this case, the conceptual data model modification does not destroy the initial state of the software application, because changes in it will be reproduced by modifying the data in its own representation model, but the structure of which remains unchanged.

Thus, the main structures of one's own model of dynamic binding are models of relations and attributes. The principle of mapping information objects in the subject area to the elements of the ITP interface model is shown in Fig. 5.

Each relationship model record contains general information about the data structure of a particular DSS functional task, the primary key of which is the relationship

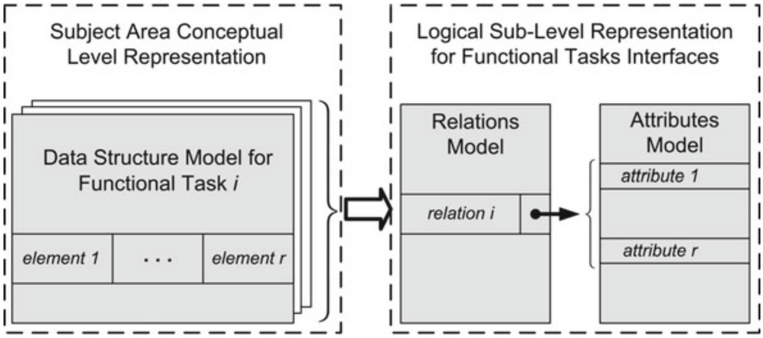

Fig. 5 The principle of mapping the information objects in the subject area

identifier. This identifier uniquely determines the mapping of the data structure from the subject area conceptual level to the functional task interface.

The attributes model determines the characteristics (properties) of the data structure elements of the functional task, the affiliation of which is determined by the identifiers of the relationship and attribute. Implementation of new data structures to the subject area is carried out by adding new records to the relationship model and the formation of new data about the attributes of this relationship. The operations of the ITP software application is automatically modified depending on the data entered into its own interface model.

Thus, the adaptive ITP software environment will be declared as a set of the following:

$$P = (T, U, G, f_G, f_T),$$

where $T = \{t_i | i \in I\}$ is a set of the functional tasks for software application, $U = \{u_j | j \in J\}$ is a set of the software application users, $G = \{g_k | k \in K\}$ is a set of the user groups, $f_G : U \times G \to \{0, 1\}$ is a user affiliation function by the group, $f_T : (U \cup G) \times T \to \{0, 1\}$ is a access function by the functional tasks.

Software application functional tasks are defined by the following sets:

$$t_i = \left(R, A, f_R^T, f_A^T, D, f_D, M, f_M\right),$$

where $R = \{r_i | i \in I\}$ is a set of the data structures for functional tasks, represented in the relationship model $f_R^T : T \to R$, $A = \{a_y | y \in Y\}$ is a set of the data structure elements for functional tasks, represented in the attribute model $f_A^T : A \times T \to R$, $D = \{d_h | h \in H\}$ is a set of the methods that processing elements of data structures for functional tasks in the form $f_D : D \to T$, $M = \{m_l | l \in L\}$ is a set of the binding types for data structures that define the interface model for functional task in the forn $f_M : T \to M = \{\text{Table,Tree,Card,Report}\}$.

Methods that processing elements of data structures are defined as sets:

$$d_h = \left(S, f_S, f_R^D, f_A^D\right),$$

where $S = \{s_v | v \in V\}$ is a set of the data processing ways in the form—view, edit, create, delete, search (filter), generate aggregated data, call the related data structure, $f_S : D \to S$ is a affiliation function of the data processing ways, $f_R^D : D \to R$ is affiliation function for the related data structures to the data processing ways, $f_A^D : A \times D \to R$ is affiliation function for the related data structure elements to the data processing ways.

4.3 Functional Modules of the Decision Support System User Interfaces

The application of the vertical and horizontal decomposition principles allows distinguishing three interaction levels of the interfaces to the data for DSS functional tasks in the organizational structure of the ITP software package:

- the level of problem-oriented user environment of the OMS subject area;
- the level of tools for solving the functional task selected by the user;
- the level of implementation of the data processing tool for the functional task.

The first level organizes the user's work in solving the applied problem for the OMS subject area and reproduces a set of functional tasks due to the external level of OMS representation. This level is represented by the module "Interface Manager", which reproduces the available set and sequence of tasks in the form of a hierarchical menu or a tree of subsystems.

The second level reproduces the realization procedure of the functional task defined at the first level, the type of which is established depending on the information binding of data structure elements with interfaces of the functional task presented at the OMS subject area conceptual level. Each functional task can use the following types of information links between elements of data structures:

- simple relations of the list type "to each other";
- structured relations of hierarchical type "one to many";
- functional relations of join for several data structures with formation of new data elements by means of aggregative functions also.

Depending on the relations type between the data structures elements that form a functional task in the ITP software package, the following modules are used: module "Table" for simple relations, module "Tree" for structured relations, modules "Report", "Card" for functional relations.

In addition to the above modules, to ensure the proper functioning of the information system, the second level also includes the following service module "Registration", which identifies users and determines their access rights to functional tasks and functions.

The third level provides the typical functions implementation of the processing procedures for data structures of the functional task, such as view, edit, create, delete, search (filter), generate aggregated data and call the related data structure.

As a result, the system basis for formation of the uniform information and software environment for DSS construction is created on the basis of the presented specification of the ITP software package that include:

- a single system of classifiers and catalogues;
- a single system of protocols and interfaces for user interaction;
- unified data storage structure;
- unified system of real-time data collection and commercial accounting of functioning indicators for the market subjects.

Therefore, the development and application of such a software environment on the proposed ITP will provide a single software product for the deployment and DSS maintenance, which will reduce the risk, complexity and costs in the transition to new organizational management tasks for market participants.

5 Conclusions

Based on the analysis of the mechanisms peculiarities of the organizational management in the energy market, it can be concluded that DSS should be considered as an object-oriented integrated adaptive system to automate the organizational management processes in the electricity market. As a result, the functional modeling of technological processes, both in data processing and in the formation of a model for solving applied control problem, plays a significant role in solving the object modeling problem of the organizational management subject area in the electricity market. The functional modeling purpose is the unification of the software interface for a single integrated system through the classification for user interaction operations with the data structures of the OMS subject area.

A distinctive feature of the developed ITP for the DSS construction which implements the organizational management of energy companies in the electricity market is a new formalization of the DDM-paradigm components, namely:

- the conceptual bases for construction of the DSS organizational model are defined, which include bases of data structures, bases of models, bases of user interaction interfaces, and carry it to a information system class of operative short-term decision-making on management;
- the unified model of DSS data structure is defined, which forms unified approaches to the market participants representation at all management levels based on determining their properties and relationships by creating a single system of classifiers, reference books to use in models of parameter calculations, algorithms of parameter optimization and their forecasting;

- the organizational model of ITP as an environment of interaction and data presentation to the OMS user is offered, that provides improvement the technological processes of OMS subjects information interaction in the electricity market due to the flexible mechanism of creation and use the mathematical models for various calculation-analytical tasks, interconnected by purpose, input and output data.

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