Energy management system (EMS) based on WebGIS

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Abstract

The study on the energy management system (EMS) is not perfect at present research, the energy database, knowledge database; model database has detailed design in this paper. This system (EMS) has several functions include energy consumption analysis, alerts, reports and recommendations. EMS will compatible with existing devices and systems in order to make the system more convenience. The program modules and parameter tables were selected to store energy prediction model, this EMS system can predict the desert evolution through energy early warning system. The results show that, the simulation of the energy distribution can reached 90%. At the same time "Auto Set Energy instrument - Monitoring Platform" can conducted energy data and make an analysis at anytime. In addition, the WEBGIS platform can provides necessary decision support for the local government.

Keywords: Energy management system (EMS), Model library, Knowledge base

1 Introduction

An energy management system (EMS) is a system of computer software used by decision maker of electric utility grids to monitor, control, using the optimize the performance of the generation and transmission system. SCADA is known for the monitor and control functions; the best packages are often referred to as "advanced applications".

According to the computer technology trends, this usually meaning as EMS/SCADA or SCADA/EMS. In these respects, the EMS that excludes the control functions and monitoring, but the further meaning refers to the generation control and scheduling applications and to the collective suite of power network applications. EMS maker also usually supply a corresponding dispatcher training simulator (DTS). This technology usually makes use of many components of EMS and SCADA as a tool for centre control operators. It is also may acquire an independent DTS which from a non-EMS source such as EPRI. Energy management systems usually use individual commercial party to measure, control, and monitor their electrical loads. Energy management systems was also used to control devices centrally like lighting systems across multiple locations and HVAC units, such as restaurant sites, retail and grocery. Energy management systems may provide sub-metering, metering, and monitoring functions that permit building managers and facility to collect data and insight that accept them to make other informed decisions about energy activities across their sites [1]. This paper Computer software technology, GIS technology with communication technology, reliable continuous data for the energy management system research. The energy management system includes three modules: energy monitoring software system and energy data control terminal and energy web publishing platform. These three parts can complete the energy data management, processing and analysis. Ground monitoring major refers to using automatically collecting energy instrument to collect the energy characteristic, which can return data through the communication network. Energy data control terminal provides data sources for the entire system. Energy monitoring center include the energy recycle monitoring and energy database and energy model base and energy knowledgebase, which can provide energy database for system. Energy web publishing is a publishing platform of energy monitoring and warning system, which releases energy monitoring data, etc.

2 The design of Energy monitoring system

2.1 OPERATING SYSTEMS OF ENERGY MANAGEMENT SYSTEM

Up to the early 1990s, it was common to find EMS systems being delivered based on proprietary hardware and operating systems. Back then EMS suppliers such as Harris Controls (now GE), Hitachi, Cebyc, Siemens and Toshiba manufactured their own proprietary hardware. EMS suppliers that did not manufacture their own hardware often relied on products developed by Digital Equipment, Gould Electronics and MODCOMP. The VAX 11/780 from Digital Equipment was a popular choice amongst some EMS suppliers. EMS systems now rely on a model based approach. Traditional planning models and EMS models were always independently maintained and seldom in synchronism with each other.

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Using EMS software allows planners and operators to share a common model reducing the mismatch between the two and cutting model maintenance by half. Having a common user interface also allows for easier transition of information from planning to operations.

As proprietary systems became uneconomical, EMS suppliers began to deliver solutions based on industry standard hardware platforms such as those from Digital Equipment (later Compaq), HP, IBM and Sun. The common operating system then was either DEC OpenVMS or UNIX. By 2004, various EMS suppliers including Alstom, ABB and OSI had begun to offer Windows based solutions. By 2006 customers had a choice of UNIX, Linux or Windows-based systems. Some suppliers including NARI, PSI-CNI and Siemens continue to offer UNIX-based solutions. It is now common for suppliers to integrate UNIX-based solutions on either the Sun Solaris or IBM platform. Newer EMS systems based on blade servers occupy a fraction of the space previously required. For instance, a blade rack of 20 servers occupy much the same space as that previously occupied by a single MicroVAX server.

2.2 SYSTEM SOFTWARE ARCHITECTURE

The energy system is architecture of B / S and C / S combined which divided into four layers: application, middle, data layer and infrastructure layer. Application layer can uses for energy visual display and view data with user, the decision maker take actions through the energy monitoring center client and using browser sending a package to the network server. The middle layer is used for response and processing user requests to making energy data analysis, which achieve by the ARC engine and IIS. Data layer is the important part and was responsible for manage energy data and accept the request of which server operates on the database. This system architecture was adds the energy data acquisition subsystem, which sends energy data to the monitoring center and received.

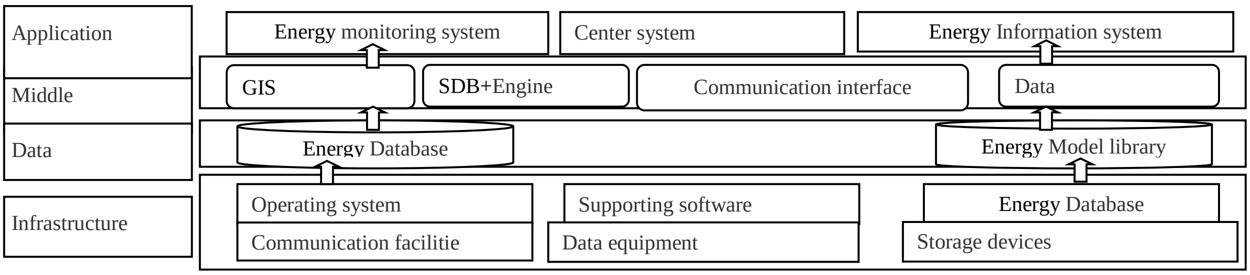

FIGURE 1 The structure of software system

2.3 THE DESIGN OF OVERALL ENERGY SYSTEM FEATURES MODULAR

The system using energy monitoring equipment and base on computer hardware and software, we also establishes a energy monitor center based on C / S and receiving and managing the energy monitoring data, energy database, energy data processing and analysis, energy model management, computer applications of model. It also setup an energy publishing platform based on B / S structure, provides decision maker with features including energy monitoring data, energy mapping analysis through background management system.

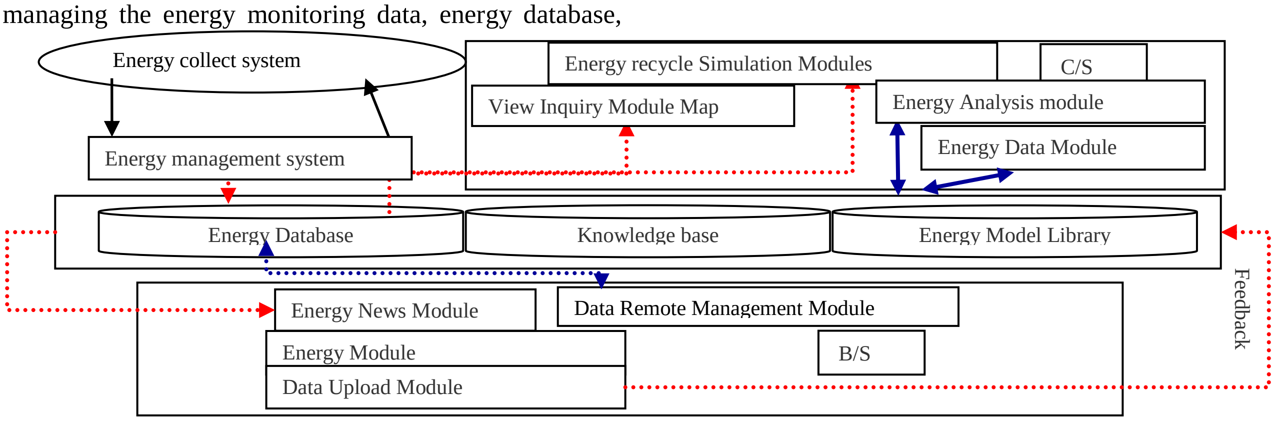

FIGURE 2 The design of Overall system's functions

1) Energy Data Monitoring System

Energy Data Monitoring System receives data and stores data in Energy Database and service energy control, energy system parameter setting, energy web registration and energy data analysis.

2) Energy Monitoring Center system is the central of the energy monitoring system, the decision maker may

manage on background data and energy data analysis by using energy monitoring center system.

3) Energy management module:

including management the energy database, energy knowledge base and energy model base.

4) Map Browse and Inquiry Module: This model can displays energy images through the map window and combines energy graphic data and energy attribute data in order to enable decision to conduct energy data inquiry and energy data analysis.

5) Energy forecast and Analysis module: This predicts the trend of Energy of the study area based on prediction model.

6) Energy recycle simulation modules: This model can using Energy data simulate terrain and provide a variety of energy recycle analysis functions.

7) Energy information Distribution System: We using this system to publish with energy-related news, the results of energy warning and energy monitoring data and provide energy data query including monitoring data and basic energy data meanwhile allow the system administrators to manage the database remotely.

2.4 THE ENVIRONMENT OF ENERGY MANAGEMENT SYSTEM DEVELOPMENT

C / S part of the system uses ArcEngine as development framework, The B / S framework by using Microsoft Visual Studio2008 as development environment, with. NET Framework 4.0, using Visual C # as programming language, IIS as an internet server, ArcEngine as development platform for development. The whole system uses SQL Server2005 Database and spatial data.

2.5 CONSTRUCTING A EARLY-WARNING DATABASE

The energy database includes energy spatial distribute data and energy monitoring data, statistical data. The database can be divided into three: Energy meta-base, Energy spatial Database and Energy attribute Database.

1) Energy meta-base: there are several data types in energy Database, system establishing Metadata table of Spatial data and Metadata table of Attribute data to Presentation contents of data, quality, data formats, data owners.

2) Energy spatial Database: stores the vector, raster, digital elevation with Energy-related and image data scanned maps. Spatial database is also the basis of decision support systems [2].

3) Energy attribute Database: The energy database usually stores energy monitoring data and stores multiple energy database tables. Energy attribute data mentioned in this study is relative to the energy spatial data, basic property data and energy monitoring data. Energy spatial data and the basis of attribute data can be associated through keywords, such as the NAME, Entity ID. Energy spatial data and Energy monitoring data, system through the unambiguous ID code of spatial objects (Such as the site ID) association with energy attribute data fields in the table. There is a certain relationship between the energy monitoring data table and energy spatial data table and energy monitoring data table.

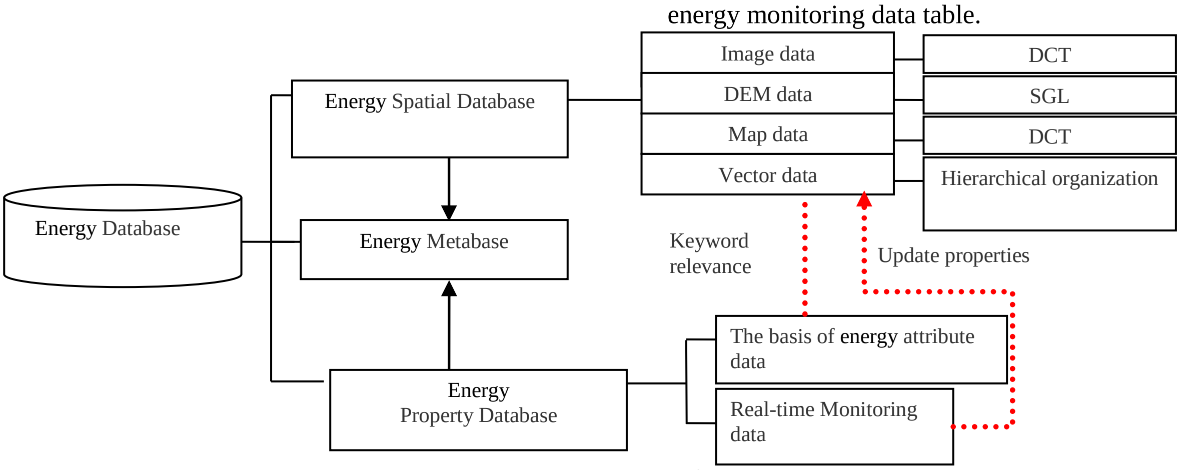

FIGURE 3 The constitution of Energy Database

2.6 THE CONSTRUCTION OF EARLY WAMING MODELS OF ENERGY AND MODEL LIBRARIES

The energy model library is a important part in this system, It's used to drive decision support system for energy decision-making. The energy model library refers to a collection of stored in the computer according to a certain structure [3].

The models of energy can be split in to three parts: variables, parameters and relationship, where variables are input interface of model, different regions may correspond to different models, the same area in different years corresponds to a different parameter sets. Parameter is used to adjust the every variable indicator (Relational database has been conducted data storage), In order to adapt to different situations. Relationship is the relationship between the expressions.

In this study, when the energy parameter sets, energy relations and energy model storing are stored separately. Energy parameter sets are adopted parameter list and stored in relational databases which achieve an integrated storage between spatial Graphic data and attribute data. Relationship of models is stored in the program module.

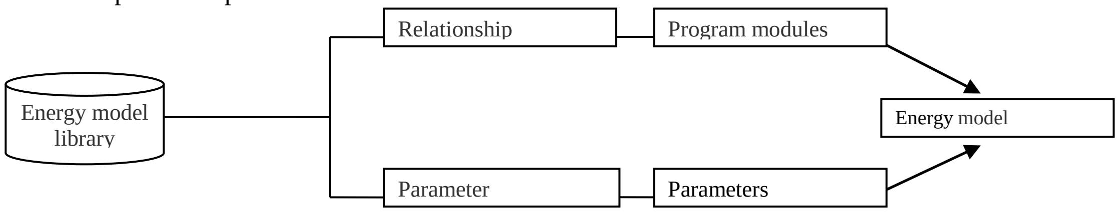

FIGURE 4 Energy Model Library method

2.6.1 Relational storage of energy models

In order to facilitate expression of energy models, parameters and variables are used in the form. The Energy model shows a relational storage of models program modules. The energy variable is obtained from the selection of list box, so for the energy list box control using array control forms and parameters can be read from the energy model library.

2.6.2 The storage of model parameter

The parameter sets energy model are classified by year, since index factors on the impact of energy will gradually change, each year is a corresponding parameter sets. Although shortly amount of relationship between the energy models，each relation corresponds to a very large set of energy parameters. Therefore, the organization and management of parameter sets are the key to early warning model library of Energy. The structure of energy parameter table of models library shows in Table 1.

TABLE 1 Structure of parameter table

Field	Type	Illustrate	Index	Nu-ll
energy _ID	Integer	ID	√	
energy _year	Char(20)	Years		
energy_ name	Nvarchar(30)	Model Name		
energy _Attribute	Nvarchar(MAX)	Characteristic parameters		
energy _CreateDate	Datetime	Creation date		
energy _EditDate	Datetime	Modified date		√
energy _Modified	Nchar(20)	Modified By		√
energy_description	**Nvarchar(30)**	**Description**		√

2.7 THE CONSTRUCTION OF KNOWLEDGE REPOSITORY EARLY WARNING OF ENERGY

Repository is knowledge base of energy system，providing knowledge, experience and decision support for energy monitoring and recycle simulation. The repository use three types to store: energy meta-knowledge table, energy knowledge of examples and rule knowledge table. For instance, indicators of energy and the summary of energy, energy management methods and policies is established. The structure of rule knowledge table shows in Table 2.

TABLE 2 Rule knowledge table

Rule Name	Type and length	Illustrate	Index	Nu-ll
energy _rank	Integer	Energy grade	√	
energy _evaluation	Char(20)	energy assessment		
energy _index	Float	Index on the world		
energy _index	Float	Index on the world		
energy evaluation=””	Nvarchar	energy evaluation		
Recommendablemethod=””	Nvarchar	Control methods recommended		√
Policy	**Nvarchar**	**Policies, laws and regulations**		√

2.8 WARNING MODEL AND METHODS

2.8.1 Climate quality index in desertification area

The Aeidity Index (AI) was selected to analysis the Climate quality which was developed by Applied meteorological Foundation (FMA) with formula as follows:

$$AI = \frac{P}{PET}, \quad (1)$$

Where P is the Annually mean precipitation, AI is the Aridity index, PET is Annually mean potential evapotranspiration.

2.8.2 Soil quality index (SQI)

The soil quality index was developed by Sahel observatory and Sahara and the index is based on four parameters, include soil depth, texture, parental material and slope. The calculation of SQI is given as follows:

$$SQI = (PM \cdot D_{soil} \cdot T_{tex} \cdot S_{lp})^{\frac{1}{4}}, \quad (2)$$

where SQI is the Soil quality index, PM is the Parental material of Soil, Dsoil is the Soil depth, Stex is the Soil texture, Slp is the Land slope. Parental material can be classed in three classes (Table 3).

TABLE 3 Parental material classes

Parental material	Score
Clay, sandy formation, colluviums and alluvium	2
Maron-limestone, friable sand stone	1.5
Limestone, non friable sandstone	1

2.8.3 Sensitivity desertification index

The sensitivity desertification index (SDI) is calculated as follows:

$$SDI = (AI \cdot SQI)^{\frac{1}{3}} \quad (3)$$

The SDI is classed according as follow (Table 4):

TABLE 4 Classes of the sensitivity desertification index

Classes	Sensitivity desertification index	Description
1	SDI>1.6	Very sensitive areas to desertification
2	1.4≤SDI<1.5	Sensitive areas to desertification
3	1.3≤SDI<1.4	Medium sensitive areas to desertification
4	1.2≤SDI<1.3	Low sensitive areas to desertification
5	SDI<1.2	Non affected areas

3 The implementation of prediction and early warning systems of Energy and key technologies

3.1 DATA MONITORING SUBSYSTEM

Data monitoring subsystem is a field monitoring data and set associated with communication parameter, control energy data acquisition instrument remotely. Energy data transmission components of field data collection instrument use DTU Products of Shenzhen-Hong Dian Company. Development kits of the DSC matched to DTU are the basis for system development. Functions Include communications parameter settings (service control, system settings, DTU management, etc). In addition, a number of functions are added with the actual needs of the project .

3.2 THE DESIGN AND IMPLEMENTATION OF FORECAST AND RESULTS ANALYSIS MODULE OF ENERGY

The functions include: Energy forecast, results analysis and Energy early warning function.

Energy prediction and results analysis: forecast of Energy is the basis for early warning and implemented through prediction model of Energy. Determine the status of data variables, select determined model parameters, Energy model computing settings: open the raster image, select the appropriate variables of operator for predict Energy, and set prediction data names and storage location.

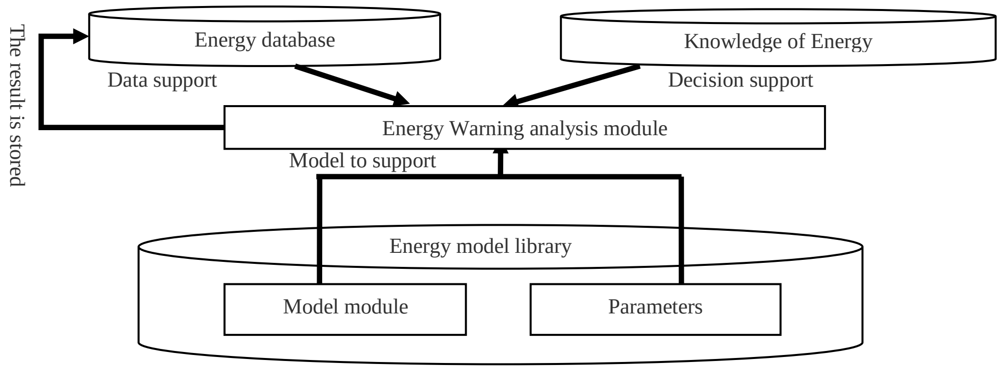

FIGURE 5 Early warning analysis module of desertification

3.3 ENERGY WARNING

Energy Early warning extract the area after a comparative analysis between Energy predicted and Energy status data. There are three types of output for the user to choose. System extracts the area of Energy early warning based on user inputted the critical value. This Energy warning model may apply in other field such as the blowing gas refining technique, directional solidification technique, and vacuum induction refining technique [4-14].

3.4 WEB PUBLISHING SUBSYSTEM

Energy publishing subsystem is B / S framework, The ArcGIS was server as GIS development platform and development environment in Visual Studio2008. The sub-system has user registration, message boards, vector map browse. Decision maker may query the associated vector map, image data, early warning map and related attribute data.

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References

[1] Ma L B, Zhang X C 2010 *Principles and Methods of WebGIS* Science Press: Beijing *(in Chinese)*
[2] Qi P, Liu W P 2009 Research and Realization of WebGIS-SpatialData *Science&Technology* **13** 446-7 *(in Chinese)*
[3] Chen D Y 2005 *The Study on Model Library in Decision Support System* Harbin Engineering University: Harbin *(in Chinese)*
[4] Wei K X, Ma W H, Yang B 2011 Study on volatilization rate of silicon in multicrystalline silicon preparation from metallurgical grade silicon *Vacuum* **85** 749-54
[5] Ji X, Chen G Q 2006 Exergy analysis of energy utilization in the transportation sector in China *Energy Policy* **34** 1709-19
[6] Regulagadda P, Dincer I, Naterer G F 2010 Exergy analysis of a thermal power plant with measured boiler and turbine losses *Applied thermal Engineering* **30** 970-6
[7] Alijundi I H 2009 Energy and exergy analysis of a steam plant in Jordan Applied thermal Engineering **29** 324-8
[8] Kyrke Gaudreau, Roydon A 2012 Fraser and Stephen Murphy. The characteristics of the exergy reference environment and its implications for sustainability-based decision-making *Energies* **5** 2197-213
[9] Min Y, Jiang M F. 2010. Exergy analysis and optimization of ladle furnace refining process *International Journal of Iron and Steel Research* **17**(11) 24-8
[10] Oleg Ostrovski, Zhang G Q. 2005. Energy and exergy analyses of direct ironsmelting processes *Energy* **30** 2772–83
[11] Ünal Çamdali, Murat Tunç. 2003. Exergy analysis and efficiency in an industrial AC electric ARC furnace *Applied Thermal Engineering* **23** 2255– 67
[12] Takla M, Kamfjord N E, Halvard Tveit, Kjelstrup S. 2013. Energy and exergy analysis of the silicon production process *Energy* **58** 138–46
[13] Zhu M S 1988 *Exergy analysis of energy system* Tsinghua Univ. Press: Beijing *(in Chinese)*
[14] Fu Z B 2008 *Induction heating and energy saving-the design and application of the induction heater* China Machine Press: Beijing *(in Chinese)*

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