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A Data Warehouse Architecture supporting Energy Management of Intelligent Electricity System

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Abstract—**Intelligent electricity utilization is a topical and difficult subject in the study of smart grid. Current energy management systems do not have the capabilities of energy specific monitoring and management. Therefore, this paper addresses this deficit by introducing a data warehouse based energy management system with these component: Data Warehouse Model Construction, Extraction, Transformation and Loading (ETL) Process and Information Representation. The purpose of the developed system is to store, integrate, and analyze complex data sets from multiple data and information sources.**

Keywords-Data Warehouse, Intelligent Energy Management, ETL, Graphical User Interfaces, Smart Grid.

I. INTRODUCTION

China is in the process of industrialization, urbanization rapid development, which leads to constantly rising of energy demand, and the annual electricity consumption increased by 25%.As the largest users of primary energy, the power industry has the obligatory responsibility in reducing greenhouse gas emissions and climate impact. Thus, in 2009, the State Grid Corporation proposed the construction of strong smart grid with Chinese characteristics. Smart grid is a complete information architecture and infrastructure system covering the modernization of power generation, transmission, distribution and electricity networks. The intelligent electricity is an important pillar of the strong smart grid building, the basis and physical carrier to achieve various functions of the strong smart grid, the focal point and foothold of the strong smart grid construction. The construction of intelligent electricity has a direct relationship with the grid energy use efficiency, economic operation and orderly power utilization. It will have a profound impact on grid construction, energy conservation, environmental protection and power quality management.

According to Standard System Research and Development planning of Smart Grid Technology, the focus of intelligent electricity is in two-way interactive services, information collection, and intelligent energy consumption services, electric vehicle charging and discharging, intelligent measurement, etc... Through real-time monitoring of energy consumption, intelligent energy consumption services can provide users with optimal resource planning configuration and detailed scientific use plan based on improving end-users' electricity services level, to realize flexible interaction between electrical equipment and power system. Intelligent energy consumption services technology has been researched and applied abroad. In 2008, Colorado Boer becomes the nation's first smart grid city, where per household installed smart meters. Users can intuitively understand the tariff at the time, and thus can arrange some things at low tariff periods. At the same time, the grid can collect electricity consumption per household, and redistribute electricity once there is a problem. Based on traditional electricity business system, China has carried out the orderly power management practice. Through a series of intelligent electricity community construction work, we have made an active explore in the interactive aspects of the smart electricity. However, intelligent electricity consumption services are still in an initial stage. Interactive technology of meeting personal, differential service demands need to be rich. It still cannot meet the needs of flexible interactive intelligent electricity.

In order to address the above issue, in this paper we propose an intelligent electricity management system based on data warehouse (DW) technology. Traditional energy management database systems, with emphasis on electricity data monitoring, lack the ability to create data aggregation and do not support the analysis of electricity data to deliver reports and actionable information. In addition, information requirements become complex, as it is difficult for a DSS to extract information from the data found in energy consumption databases. Therefore, DW technology is introduced to manage and analyze energy consumption data in an integrated way. Research, comparison and analysis the energy-using equipment data, power users' electricity behavior and policy information, then establish the logical and physical models, organize and classify the data into various types through data warehouse technology according to analysis theme. On this basis, establish business demand model, electricity utilization model and electricity utilization forecasting model. Develop electricity users energy manage system, as a part of the intelligent electricity interactive support platform, analyze and evaluate the users' power utilization situation, form an energy decision-making recommendation. Finally, show the analysis result and recommendations to the corporate decision-makers, and distribute to family intelligent interactive system, which can guide the power users scientifically. Eventually establish a flexible and interactive electricity supply mode.

The DW concepts will be introduced in Section 2, and a multi-dimensional DW design for energy consumption data will be developed in Section 3. Section 4 will introduce a graphical user interface providing analysis functions. And finally, we make a conclusion.

II. DW TECHNOLOGY

A data warehouse is a subject oriented, integrated, time varying, non-volatile collection of data that is used primarily in organizational decision making. A DW is designed to support data analysis. It contains historical data derived from transaction data. It separates the analysis workload from transaction workload. This help to maintain historical records and enhance the understanding of the business processes. A DW environment includes an extraction, transformation, and loading component (ETL), an online analytical processing engine (OLAP), and client analysis tools. DW technology has been used in business and marketing to improve various processes. It supports complex queries and more sophisticated features for aggregating, analyzing, and comparing data. It has also been introduced to the construction management domain to improve the management of historical data.

Generally, DW includes 5 main components.

- Data Sources, providing source data for the data warehouse, including OLTP database, data files, and other internal data sources and a variety of external data sources.
- ETL Process, extracting existing data from sources, transforming and loading into the DW.
- Central Repository, storing data model and meta-data.
- Data Mart, storing data processed through verifying, sorting, processing and re-organizing.
- Data Access and Analysis, for business and decision makers to access the target database and used for further in-depth analysis.

III. DW MODEL CONSTRUCTION

A. System Framework

The overall framework of intelligent electricity interactive system is shown in Fig. 1. From top to bottom, it is divided into six layers: standard layer, network layer, data layer, data processing layer, and application layer. Standard layer is the foundation of entire system. Network layer is the basis of the operating system, and the top-level application layer is user decision-making layer, which shows the multi-dimensional energy to the power company in report or chart form.

The data layer is the source platform of the intelligent power utilization data warehouse system, including new energy system, electro mobile system, AMI system, wireless sensor network system, and external information system. Data of this layer is not fixed, but update with the source data and access of new data system. Data processing layer is the core of the entire system, which transfers and loads processed data to dynamic systems in scheduled data warehouse model after ETL (Extract, Transfer, and load) process. Then it transfers them into three data marts, that is electrical auxiliary supervision data mart, electricity decision support data mart, and real time electricity query mart. Through tool-set, like analysis tool, reports tool, OLAP tool, data mining tool, query tool, and metadata management tool, power company managers can have an electricity query and analysis, which can assist power company managers make electricity decisions by association rules technology.

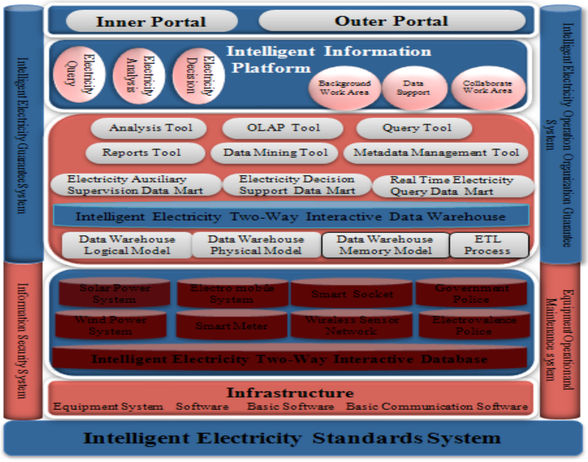

Fig. 1 The overall framework of the system

B. Multi-Dimension Information Analyses

The intelligent electricity system data has following three characteristics:

- Hierarchical nature of the data

Intelligent electricity system data includes device data, user data, district-level data, municipal data, provincial data, and regional data. Each level is relatively independent, but in use, the underlying data fit and support the upper-layer data.

- Diversity of the data.

Intelligent electricity system data include not only the electricity consumption data, also the basic parameters data of each device, and the data reflecting electrical behavior of electricity users, renewable energy power generation data, peak shifting data, as well as some government policy data, such as electricity tariff information.

- Complexity of the data using.

According to the different information to be obtained, the same data record needs to be used in a plurality of calculation simultaneously. For example, the analysis of electricity users' behavior requires the user data, the user data are also used in calculation of different levels of electricity. Data are used differently in different application backgrounds.

In view of above characteristics, the design process of data warehouse logical model is as follows:

- Dimension Design.

Dimension is the attribute of factual information, which generally changes rarely, and the number of whose is relatively small. In our design, follows several dimensions: users dimension, equipment dimension, new energy dimension, external factors dimension and time dimension.

- Granularity Design.

The granularity is the division units of dimension, which can also be referred to conceptual level. User dimension is divided into 4 granularities: street, district, city, and region; equipment dimension is divided into 3 granularities: equipment, equipment type, and equipment level; new energy dimension is divided into 2 granularities: new energy, and new energy type; time dimension 4 granularities: day, month, quarter, and year.

- Metric Design.

The metric is the actual basis of data analysis. Give electricity consumption as metric value.

- Model Design

The data model of data warehouse usually has two kinds of forms: star model and snowflake model. Star model queries fast, and can facilitate various queries. So in this article, we use star model, as shown in Fig. 2. The star model is a relational database model, used to save the metrics and dimensions in data mart, where metrics are stored in the fact table, and dimensions in the dimension table.

- Metadata design.

The metadata design is a relatively important part of the data warehouse design. It can help the data warehouse designers have a clear and comprehensive understanding of the physical layout of the underlying data source, help data warehouse users effectively use the information in the data warehouse, and help database administrators understand what impact will be exerted on the data warehouse when some tables change. Dimensional information and facts table information are stored in the metadata. Checking the metadata, we can know what dimension tables combine into what kind of fact table, and whether the fact table exists. If it does not exist, then the fact table will be dynamically formed. In addition, set time flag in fact table, delete some facts table recently used rarely to save storage space. Set the granularity weights. When dynamically generates facts table, combine the granularity from large.

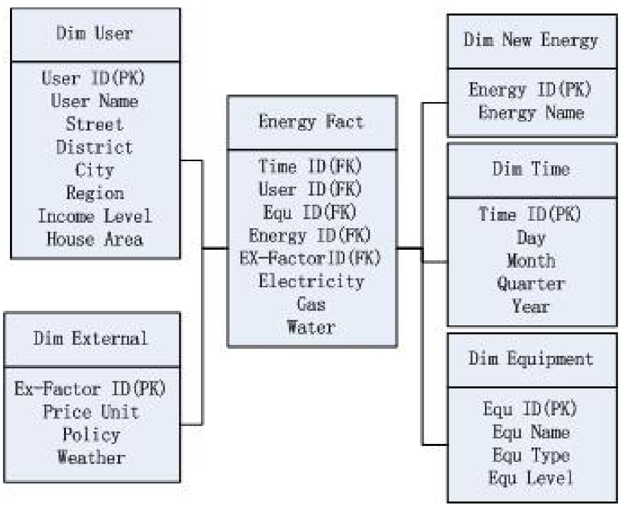

Fig. 2 The data ware house logical model

C. ETL Process

We need to load and update dimension tables and fact tables after modeling the data warehouse, namely the ETL process, as shown in Fig. 3. For frequently changing dimension-time dimension, this paper applies regular updating method; for rarely changing ones, including equipment dimension, user dimension, new energy dimension, external factor dimension, this paper updates through connecting the server and triggers approach. The key of multidimensional data warehouse design is the Cube design, including Conventional cube, Virtual cube, Link cubes and Local cube. We use the Conventional cube in this paper. Then, optimize the storage mode of OLAP in cube editor, where we store OLAP as MOLAP model. MOLAP cube is stored in a multi-dimensional database, where its pretreatment aggregate value is also stored. As a result, the entire data request return from a multidimensional database, which makes a fast response. So far, power company can analyze electricity consumption from different dimensions of power, also drill, cut, and slice from multiple angles, which make them in-depth understanding the information contained in the data, then assist them make electricity decisions.

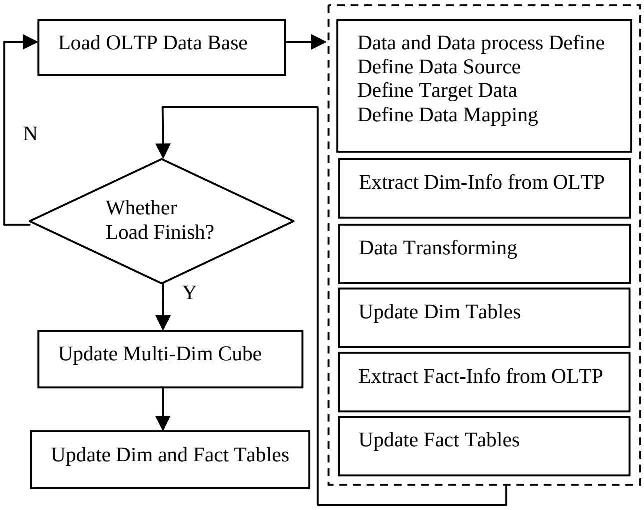

Fig. 3 ETL and update process of data ware house model

D. Information Presentation

The availability of aggregated data is a very important pre-requisite for optimized energy management to oversee energy consumption, control operation and maintenance costs to provide a steady high level of intelligent electricity services with minimal energy consumption. This requires tailored graphical user interfaces (GUI). The common goal of GUI is to represent the energy consumption information to the end users with regards to their roles and functions. In the proposed system's information representation section, a Java based interface is developed which enables end users easy querying without dealing with complex SQL statements.

Fig. 4 depicts a GUI developed for the relevant energy company. This is designed to track electricity, gas and water consumption of specific equipment within a specific zone with regards to selected time intervals. The proposed GUI also provides consumption cost and material unit prices. At the data warehouse level, system queries meter readings for the specific zone selected by the end user. Simultaneously, the system queries spot unit prices which are updated in a regular interval. The GUI represents the data in graphical format and/or in tabular format with regards to end user preferences.

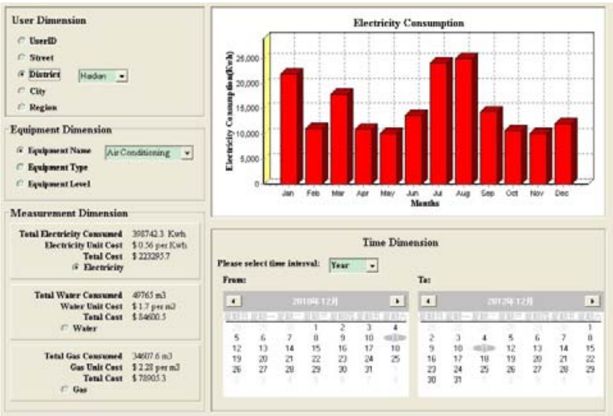

Fig. 4 Graphical user interfaces for energy consumption

IV. CONCLUSIONS

The intelligent electricity management system describe in this paper provides necessary tools for efficient energy management and monitoring. It allows combining data from different sources. Implementing multi-dimensional modeling using DW techniques facilitates the aggregation of information at all desired levels concerning energy consumption. The introduced web-applet GUI represents aggregated data in desired granularity in order to meet different user requirements.

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