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Energy information integration based on EMS in paper mill

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A B S T R A C T

The systematic, transparent and accurate on-line energy information of the production process is quite the basis of mill energy management and conservation. An Energy Management System (EMS) was built according to the characteristics of the energy usage in a typical newsprint paper mill. The EMS first realized the process data acquisition and integration, second fulfilled the on-line energy information calculation from the integrated data. A water and steam properties query component based on IAPWS-IF97 was developed and plugged into the EMS to facilitate the energy calculation of water and steam.

The practical performance in the paper mill showed that the integrated energy information of the whole mill was gained and the on-line energy supervisory was achieved. In the end a systematic, transparent and accurate energy usage profile is obtained and it would provide the valuable fundamental energy data for the further energy analysis and optimization in the EMS.

1. Introduction

As global environment deteriorates and global resources become short, the proportion of energy cost in the total production costs soars seriously, and manufactures face significant challenges out of controlling energy cost since industry mills consume so much heat and power, especially in developing countries [1]. No matter what energy-saving approaches are adopted, manufactures must systematically manage energy use and handle as much energy information as possible to get a deep and quantitative knowledge of the process energy consumption [2]. So the systematic, transparent and accurate on-line energy information of the production process becomes the fundamental condition of energy management and conservation.

Many Information Technology (IT) solutions have been used to profile and monitor the sources of energy costs by identifying patterns of energy usage, and then provide further analyzing, optimizing, scheduling etc. [3–6]. However as mills' requirements for information systems are diverse and IT develops rapidly, the information systems in industry field becomes more complicated which indeed sets barriers in getting comprehensive energy information. In fact, present production information systems are multi-vendor based and heterogeneous, such as process control, automatic metering, supervisory control and production management [7,8]. The independence, distribution and heterogeneity of these systems result in the "information island", and this makes it difficult to get the accurate and transparent energy information in a global perspective.

In addition, integrated system only eliminates the isolation among the data sources and provides a systematic view of the material flow, but after the energy sources or utilities are consumed, where the energy flows and how it is utilized in the production process are still in the veil of the complicated production process and the diverse production materials. So the calculation and extraction of the energy information from the material flow become a significant need for energy management and conservation. However because the energy sources and the production materials have the different formulas that calculating their energy and the measurements of some process variables are sometimes missing, these calculation and extraction works are usually done off-line in an inefficient and high-cost way, thus lack much real-time ability.

To manage energy efficiently and promote energy efficiency continuously, a high diversity of energy information systems have been proposed by a number of studies. MSE 2000 [8], an energy management standard developed by the Georgia Institute of Technology and accredited by ANSI, specifies a management infrastructure for increasing energy efficiency and reducing costs, it calls out the need for an information system in several areas to set goals, track performance, and communicate results. Other energy agencies and commercial companies, for example the US Department of Energy [9] and Natural Resources Canada [10], provide a range of energy software systems, including: (i) energy and simulation software, (ii) energy efficiency software for specific technologies that utilize energy modeling and best-practice methods to assess potential energy projects and help improve energy efficiency.

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However these energy information systems are more like assistant tools to support strategic energy management which consisting of modeling and forecasting, benchmarking, energy use and cost analysis, and measurement and verification. An energy information system in Microsoft Office environment was developed by Swords et al. [11] and it realized the major strategic energy management functions such as energy monitoring and targeting, energy measurement and verification. What's more, this system integrates with business enterprise databases and works as an independent system, and it occupies the primary role in the energy management. But the performance of this system is limited because Microsoft Office is intended to business application instead of industrial application and it cannot realize the real-time monitoring for its isolation from the production process. Chen et al. [5] developed a monitoring system of building energy consumption. The network layer adopts the RS485 protocol however the RS485 has too many limitations to be adopted in the multiple information or process control systems.

In addition the aforementioned energy information systems mainly focus on the energy sources and utilities, and monitor the energy by calculating in a certain period after the energy has been consumed, thus they lack much real-time ability. Li et al. [12] proposed a dynamic material flow model for a petrochemical MES (Manufacturing Executive System) to realize the management and control of material flow. Though the energy flow is ignored herein many methods can still be referred to. Lampret et al. [13] implemented an energy information center with on-line measured data and the energy flow, exergy flow and cost flow diagrams were presented herein. The system is developed in Visual Basic 6.0 with reference to steam tables and several simplification rules of thermodynamic calculations etc., and it exchanges data with PLC (Programmable logical controller) via serial communication. Possible interface paradigms in EMS and feasible ways of realizing such interfaces were presented in [14] by Liao. These interfaces include the interactions with external systems and data sources as well as the interactions within the EMS. And these interfaces are divided into three categories, they are: (i) through a common data store, (ii) through APIs using socket, RPC (Remote Procedure Call)/RMI (Remote Method Invocation), COM/DCOM/CORBA, (iii) through web services, MOM (Message Oriented Middleware).

Since paper industry is so energy intensive, especially in china, the intention of this work is to establish an EMS according to the characteristics of the energy usage in a typical newsprint paper mill. And the EMS fulfills two integrations to gain the systematic, transparent and accurate energy information. First the process data integration is accomplished to provide the global data view, second based on the data integration the energy information integration is realized by the on-line energy information calculation and extraction from the process data. Then the extracted energy information provides the fundamental information for the advanced energy analysis and optimization in the EMS.

2. Methods

Information integration comes in a wide variety of forms. Aiming at getting a global view of the energy information in the scope of whole mill, the isolation among the distributed data sources should be eliminated first, so data integration is utilized to get the transparent and integrated process data. The basic data integration methods can be divided into two categories: data materialization and data federation [15].

The advantages of data materialization are the high efficiency, and the capability of extracting deeper information for decision making, and the advantages of data federation are the high adaptability to frequent changes of data sources, and the supports of large amounts of data sources and data sources with highly heterogeneity [15–17]. In general, data federation is a read-only method and weak in information extraction and decision support, however data materialization supports data read and write, and strong in information extraction and decision support. So to extract energy information and implement process control the data materialization is adopted.

Moreover because the EMS interacts directly with the process control systems, the primary issue during the data integration is the stability and security of the production process, and besides the operation system environments of the EMS are Microsoft OS, so a combination of common database and DCOM interface approaches are adopted to interact with external systems [14]. DCOM with advantages in high performance is used for exchanging process real-time data and common database with advantages in ease, flexibility and mass-data processing is used for historical data.

And after the realization of the data integration, the extraction of energy information is carried out. The extraction process can be described as follows:

$$E = F(M, S) \tag{1}$$

where M is the material flow, S is its status, mainly temperature and pressure, E is the energy it contained. And F represents the relationship between the energy flow and the material flow of specific states, and it is determined by the thermodynamic nature of the material.

To implement this energy calculation on-line, necessary process data such as flow rates, temperatures and pressure are necessary. However some of these variables, such as the coal flow rates and the air flow rates, are not metered in the production process and therefore the soft sensor technique is used to estimate the very variables from other on-line measured data. And in addition to the thermodynamic properties of water and steam, their relationship with temperature and pressure is complicated, so a query component in DLL (Dynamic Link Library) form is developed to facilitate the on-line calculation of water and steam thermodynamic properties.

3. Paper mill description

In China a typical newsprint paper mill mainly consists of a Combined Heat and Power (CHP) facility, deinking lines, papermaking lines, a waste water treatment plant and some other auxiliary facilities such as dock, warehouse, water station and compressed air station. The common configuration is shown in Fig. 1.

In the CHP facility, the primary energy, mainly coal in China, is converted to steam and electricity, and because steam has the primary impact on the deinking and papermaking process, the steam is first regulated to the desired states and utilized to satisfy the deinking and papermaking processes and then generating electricity by the steam is considered. And in the production process the secondary energy, steam and electricity, are used to drive the deinking and papermaking process and make the material into the product. Meanwhile, the energy recovery takes place in the deinking and papermaking process and water treatment station, which includes the recovery of waste heat from papermachine hoods to heat fresh air, the recovery of condensate water from papermachine to boilers and the recovery of sludge to boilers as energy sources. And from the configuration, the energy system of the paper mill can be divided into three links, energy Conversion Link (C-Link), energy Utilization Link (U-Link) and energy Recovery Link (R-Link), which is known as "Three-Links" system [18]. And the three links interact closely and restrict to each other.

Guangzhou Paper Mill is the biggest newsprint mill in south China, and it produces 800,000 ton papers per year with 6