Software and Dataware for Energy Generation and Consumption Analysis System of Gas Processing Enterprises

I V Dolotovskii, N V Dolotovskaya, E A Larin

Gagarin Saratov State Technical University, 77, Polytechnic Street, Saratov, 410054, Russia

E-mail: Dolotovsky@mail.ru

Abstract. The article presents the architecture and content of a specialized analytical system for monitoring operational conditions, planning of consumption and generation of energy resources, long-term planning of production activities and development of a strategy for the development of the energy complex of gas processing enterprises. A compositional model of structured data on the equipment of the main systems of the power complex is proposed. The correctness of the use of software modules and the database of the analytical system is confirmed by comparing the results of measurements on the equipment of the electric power system and simulation at the operating gas processing plant. A high accuracy in the planning of consumption of fuel and energy resources has been achieved (the error does not exceed 1%). Information and program modules of the analytical system allow us to develop a strategy for improving the energy complex in the face of changing technological topology and partial uncertainty of economic factors.

1. Introduction

In order to determine and generalize characteristic features of gas processing enterprises (GPE) that affect their energy generation and consumption, we have performed systemic analysis of design compositions, primary and auxiliary equipment roster, production technologies and economic parameters of several Russian and foreign GPE [1, 2]. The primary features include:

- complex GPE structure with lots of multivariable connections between energy complex (EC) elements, engineering units and external power supply sources;
- variable composition, pressure and volume of raw gas condensate (RGC) taken for processing and preprocessing at various product lines;
- various stages of production cycle for a GPE located at RGC deposit (i.e., construction; multiple years of operation in suboptimal and optimal conditions; modernization and reconstruction in accordance with changing parameters of raw materials and products; decommissioning) with significantly different energy consumption rates and type of energy sources used.

Thus, in order to perform monitoring of operational modes and advance planning of production activities and development strategy (that accounts for various potential factors) as well as predict energy consumption and generation rates for GPE energy complex, such complex requires a specialized analysis system.
2. Structure and composition of dataware and software for GPE energy complex analysis system

Currently there are many successful data analysis systems (DAS) for industrial enterprises that provide logistical support to chemical production facilities maintenance [3], regulate energy conservation systems of engineering companies [4], optimize operation modes for heat and energy co-generating plants that account for variable temperature loads [5, 6] etc. However, existing DAS cannot be used as an integrated system of planning and analysis of GPE energy consumption and generation due to aforementioned technological features of such facilities.

We have developed a specialized DAS [7] for fuel and energy sources (FES) of GPE that is capable of performing the following tasks:

- advance planning (for any period of time) of FES and water consumption and water disposal rates based on RGC composition, operational characteristics of designed equipment and GPE production schedule;
- analysis of actual FES and water consumption and water disposal rates based on GPE performance data for appropriate period of time that allows evaluating efficiency of FES consumption and generation by operating equipment, production units and cycles;
- optimization of FES and water consumption and water disposal rates by normalizing power engineering balance (PEB) based on simulated changes in process system (PS) and GPE energy complex structure or operational parameters of equipment, production units and cycles.

DAS for fuel and energy sources contains the following functional elements connected via inputs and outputs (Figure 1).

The primary dataware element of memory unit 3 is database 4 that allows designing GPE structure and calculating energy balances for various types of FES in addition to total power engineering balance. Database 4 development consisted of three stages – conceptual, logical and actual (physical) design. Conceptual design included the following: studying production activities of several GPE [2]; setting tasks for designed database to solve; analyzing data requirements for functions and processes that will enable the database to perform such tasks. As a result, we have produced a compositional database model that is actually implemented as a series of structured data on equipment of primary systems of GPE energy complex.

We chose the following characteristics of relevant GPE systems as primary classification criteria:

- equipment role (pipe furnaces, flame evaporators for process flows, gas heaters, gas turbine
and combined cycle power plants and gas disposal systems; in addition, each type of equipment and production units also has its own classification) in production cycle for fuel consuming equipment;

- equipment role (power engineering units that produce heat energy as steam and exhaust heat boilers installed after production cycle furnaces) and pressure and temperature of produced steam for heat generating units;

- equipment role (heat exchangers, steam turbine drive, heat tracing equipment of production pipelines, mixing equipment – ejectors, deaerators, mixing tanks, steam smothering equipment; each type of equipment has its own implicative classification) for heat energy consuming equipment;

- equipment role (air / gas blowers; pumps; compressors; air conditioner fans and dry coolers; life support systems (air conditioning and input-exhaust ventilation of industrial premises) and other electric equipment such as stirrer bars, electrical dehydrators, control and automation equipment, alarm system, fire alarm and fire extinguishers) and type for electrically driven production equipment.

In order to develop software for DAS we have designed applied mathematical tools including a series of interrelated thermodynamic, power engineering and mathematical economic models describing FES generation and consumption processes related to primary RGC preprocessing and processing operations.

Software package of DAS for FES is based on modular hierarchical approach [8]. Personal computer consists of several separate software modules interrelated with each other (Figure 2). The modules are discrete components of personal computer; they are capable of completely separate compilation, packing with other elements or loading.

Mathematical tools used to compute heat and chemical engineering process parameters (5 and 6, Figure 2) were developed via standard technique used to create functional models for complex chemical engineering systems [9]. Generalized quantitative assessment of GPE energy complex operations quality is performed by unit 11 via metering hierarchical population of partial parameters and criteria with various levels of significance. We used hierarchical analysis methods [10] and expert solutions for generic GPE [11] to develop mathematical tools for unit 11.
3. Results of dataware and software application

Application of applied mathematical tools for corresponding software modules of DAS for FES installed at several facilities allowed us to evaluate functional quality of energy complex elements and propose and patent several engineering solutions that can improve performance parameters of systems used in aforementioned facilities. Engineering and design solutions developed via software package of DAS for FES utilize principles of maximal circularity of in-process energy supply systems by integrating secondary energy and material sources with production system and using innovative, environmentally safe and reliable equipment for low pressure gases and combustible solid and liquid wastes recycling.

Validity of personal computer operation and resulting database of DAS for FES has been confirmed by comparing calculation results with actual data provided by energy complex power generating equipment and simulation modeling system of Astrakhan gas processing plant. We have used DAS for FES to analyze and standardize FES consumption and generation for aforementioned GPE as well as to determine optimal structure and operation modes for its energy complex by using partial and multicriteria efficiency parameters. The margin of error of planned FES consumption rate calculated via simulation modeling does not exceed 1%; such planning precision helps avoiding additional costs for maintaining power reserve in external energy supply system.

Simulation modeling via DAS for FES software package can be used to calculate specific consumption and generation of FES by GPE with various production process structures that can be further used to develop industrial standards and norms for designing power supply systems of raw hydrocarbon processing and preprocessing facilities. DAS for FES also helps in developing differential methods that account for specific features of each facility, choice of balanced process flow diagrams, optimal operating conditions and equipment roster for GPE energy complex systems with multicriteria assessment of alternative configurations.

4. Conclusion

Developed dataware and software of DAS of FES of gas processing facilities allow performing real-time accounting and advance planning of FES consumption and generation rates for every hierarchic level of the facility as well as performing strategic improvement of energy complex within the framework of variable process structure and partial uncertainty of economic factors or optimizing energy complex structure and parameters by accounting for reliability and dynamics of facility operation modes during various stages of its production cycle.

5. Acknowledgments

The study was funded by the Ministry of Education and Science of Russia (project No. 13.7071.2017 of the basic part of the state task)

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