Energy Management System for CHP Plants

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Abstract: This paper presents an energy management system for combined heat and power (CHP) plants. The system consists of an energy production plan optimization and energy management controls relying on advanced process control (APC) solution coordinating process control. The energy production plan optimization has an objective of minimizing energy costs in real-time in terms of optimizing purchased and generated energy, fuel consumption and steam generation for steam consumers. The energy management controls is supervised and commanded in real time by the energy production plan optimization system and it executes the commands in order to accomplish the set targets.

Keywords: Energy management, efficiency, advanced process control, combined heat and power

1. INTRODUCTION

Energy management and energy efficiency has gained a lot of world-wide attention in recent years. Not only in political debates but also in every day talks among power generating companies and research institutes has it been an interesting topic for many kind of discussions, studies, surveys and practical actions. A need for improving energy efficiency in terms of improved energy management has been clearly accelerated by observed changes in global climate and, thereby, also in political climate.

It has been estimated by the International Energy Agency (IEA) that the energy consumption is to be increased by 50% before the year 2030 (Fig. 1.) for all the currently used fuel sources such as coal, oil, gas, biomass and waste. At the same time, there is an urge to improve energy efficiency by making more out of available fuels. Energy efficiency has nothing but to win: when improved, it results in savings in fuel consumption, power generation and in pollutant emissions (Leppäkoski, 2009).

For combined heat and power plants, it is of great significance to balance between different energy forms in real time (Airikka, 2009, Jalkanen & Farrand, 2007, Leppäkoski, 2008). A CHP plant generates electricity with district heat and/or process steam and it should be able to satisfy all the energy consumers at all times. There are many ways to lose energy in terms of reduced energy efficiency due to lacking energy management system that could control and supervise a coordinated and optimal process controls system, most of those ways are illustrated below (Fig. 2.).

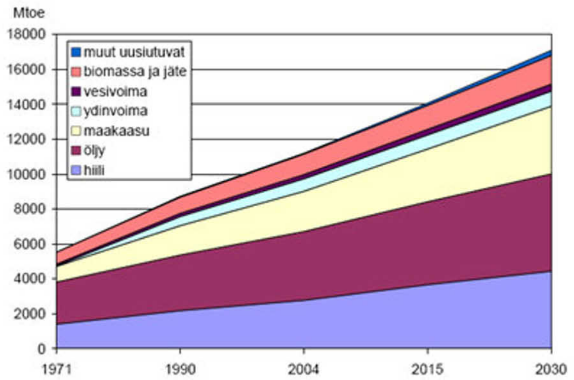

Fig. 1. Measured (1971-2008) and estimated energy consumption (2009-2030) for different fuels (From down to top: coal, oil, natural gas, nuclear power, hydropower, biomass and waste, other renewables).

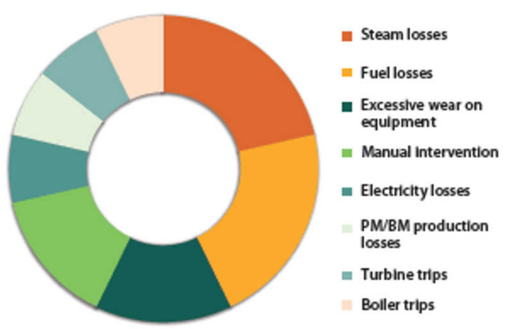

Fig. 2. Energy efficiency issues in the mill' steam network (PM = Paper machine, BM = Board machine).

The CHP plant should be able to balance between consumption demands coming from different energy consumers for given boundaries in energy purchasing and fuel costs. For accomplish this, one solution is presented in this paper with the following outline (Airikka, 2009, Jalkanen, 2007). Chapter 2 introduces the energy management system and focuses on the upper part of it. Chapter 3 gives insight how the targets coming from the energy management system can be put in practise in terms of advanced process control. Chapter 4 introduces some implemented practical cases with results. Chapter 5 finally summarizes the paper.

2. ENERGY MANAGEMENT SYSTEM

The Energy Management System (EMS) primarily contains two hierarchical levels that are strongly interconnected: energy production plan optimization and energy management controls (Fig. 3). The EMS is an entity of both financial and energy-balancing decision-making providing both long- and short-term optimization for minimizing energy production costs.

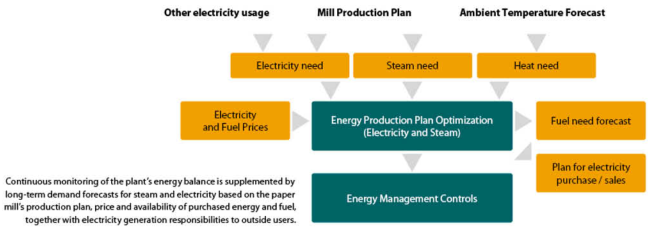

Fig. 3. Energy Management System with its links to energy consumers (electricity, steam heat), production plan and prices.

The EMS has following inputs: mill's production plan, external electricity consumption demand, temperature forecast (for district heating CHP plants), availability and pricing of electricity and fuels. As outputs, the EMS has targets for energy management controls, fuel demand forecast and an updated purchasing plan for electricity.

2.1 Energy production plan optimization

The energy production plan optimization serves as a master and it is responsible of financial decision-making aiming to minimize energy production costs and to stabilize energy balance between supply and demand. It provides a long-term predictive optimization for planning electricity and steam generation. Being initiated by needs of electricity, steam and disctrict heat, it calculates the optimal targets for energy production and passes them to energy management level. Typically, the demand for electricity and steam comes from a mill's own production plan but, for electricity, there may be also external consumption demands. For CHP plants providing district heat, the temperature forecast has a clear impact on calculated heat demand.

For optimizing energy production, availability and prices of fuel and electricity are essential variables to be known. Also, the energy production plan optimization benefits also in terms of providing a forecast for fuel demand and a plan for purchasing electricity in a cost-effective manner.

2.2 Energy management controls

The calculated optimized targets for energy production are given as set-points for energy management controls. Energy management controls is the upper level of process controls (Fig. 4.) and serve as a coordinative level for main process controls.

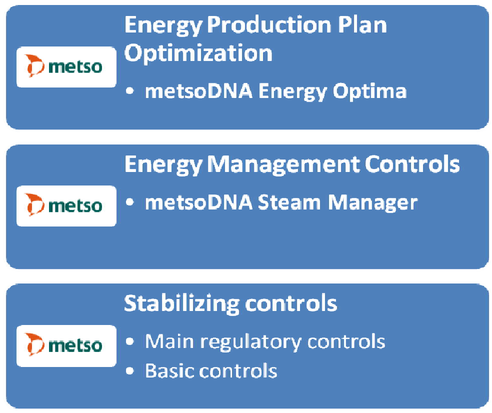

Fig 4. Hierachy of Energy Management System. Upper: Energy production plan optimization. Middle: Energy management controls. Lower: Stabilizing process controls.

The energy management controls must be supervisory, multivariable and optimal by their nature in order to satisfy their complex and diverse task. In recent years, in several projects, it has clearly been observed that a remarkably beneficial way to implement energy management controls is to introduce an APC method for stabilizing and optimizing a mill's steam network. In the next section, the solution entitled as Steam Manager is introduced in more details with an introduction to a steam network.

3. STEAM NETWORK OPTIMIZATION

The steam network of a mill consists of steam suppliers, consumers, and the equipment in between (Fig. 5.). Typically, the steam suppliers are power and recovery boilers that generate the high-pressure steam for the network. The steam consumers, such as paper, board, drying machines and, in some cases, district heating circuits require steam at a certain pre-set pressure level but with varying loads. The varying demands for process steam may disrupt the steam network. When disrupted, pressures and flow rates of the steam network are disturbed and these disturbances propagate through the steam network, causing problems with both steam quality and availability. Consequently, the steam network problems decrease the energy efficiency of the plant, resulting in economic losses and ecological impacts.

3.1 Steam Manager

Steam Manager is an Advanced Process Control solution for stabilizing and optimizing a steam network. Steam Manager supervises and regulates the steam network automatically, to