

## Principles of Smart Grids on the generation electrical and thermal energy and control of heat consumption within the District Heating Networks

Neuman, P., Pokorný, M., Weiglhofer, W.  
NEUREG, Plc., Prague, Czech Republic  
e-mail: neumanp@volny.cz

**Abstract:** One part of the process of development and application of methods and principles of Smart Grids in electricity and heat production is numerical modeling and simulation of Power and Heating Plants, Power Systems, and also District Heating Networks. Due to the venue of the IFAC Congress this paper deals with the comparison between Czech and South Africa. Similarity is given by the fact, that basic fuel is coal. In the Czech Republic, it is produced 64% of its electricity from coal, mostly lignite (brown), in the heat generation the coal has an even larger share of 90%. In South Africa, it is produced 85% of its electricity from coal (heat is insignificant due to climatic conditions). From this perspective, the Czech Republic and South Africa dealt with similar problems, e.g. using of coal mills, combustion chambers and equipment, whole powdered steam boilers and their optimal intelligent Smart Control. The power and heat source is controlled according to the Daily Consumption Diagrams, which are corrected by the current and predicted weather conditions (air temperature, solar irradiation, wind, rain and frost). For predicting consumption are used methods of classical and artificial intelligence control. Control of electricity and heat is carried out using advanced methods of optimal control, including the different configurations of machine room equipments and the Main Heat Exchangers Station - MHS. The developed Information and Control System serves as an on-line support system for the operators and dispatchers and is part of the operating procedures in the implementation of Smart Grid.

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### 1. INTRODUCTION

Almost half of all energy generated in Europe is used for heating and cooling, and the benefits of optimizing these systems are overwhelmingly large. In a district heating system there is no operational information link between the energy company and customers (Balate, et al., 2006). The whole system is purely demand driven in the sense that the production units can only react to the aggregated demand of the customers. However, the control systems in each consumer substation operates solely on very local parameters which typically leads to volatile demand profiles with peak loads during morning and evenings which is not desirable from either a technical, financial or an environmental point of view (Project InCoSysE, 2011).

Smart Heat Grid technology turns all this around by providing a platform for operational interaction between the energy company and their consumers. In a typical district heating system an energy company can only react to the heat demand without doing anything about it. On the other hand, in a Smart Heat Grid the energy company takes control of the heat demand. The reason that Smart Heat Grid technology works from a business perspective is that the energy company is generally interested in optimizing the operational behaviour in relation to the heat load (MW), while the building owners want to save energy (MWh). A Smart Heat Grid combines these two goals into an operational unity, and provils all actors with added benefits in relation to financial and environmental impact (Neuman, 2012b).

Effects designed and verified method of intelligent control in the Smart Grid Heating are following:

a. A combined heat and power (CHP) plant produces electrical power as well as heat for the DHS (Neuman, 2012a). In a CHP plant water is boiler to steam which is in turn overheated to about 500-600 °C. The steam is then used to run a turbine, which in turn is connected to a generator which converts the mechanical energy to electrical energy. When the steam has passed through the turbine its pressure and temperature is decreased in a condenser unit which absorbs the heat from the steam and transfers it to the water medium in the district heating system. The condensed water (previously

steam) is then led back to the original boiler in which the process is repeated. In a normal power plant the heat is normally emitted as waste heat in the turbine/generator process.

b. By instead utilizing this heat a CHP plant is capable of achieving higher levels of energy efficiency in relation to the primary fuel (80-90%) than traditional power plants (30-50%), see (Project InCoSysE, 2011). CHP plants are common in many DHS and when building new production plants CHP is many times the preferred choice of production, since its efficient use of primary energy makes the system financially and environmentally sound.

Firstly, this paper will show a model of the coal mill, which was developed for realization of a simulation model for Operator Training Simulator (Neuman, et. al., 2004). The models of steam boiler and turbine are depicted in (Neuman, et. al., 2009). District heating units connection model was also developed, i.e., steam boiler - steam common pipeline - condensing turbines, turbines with controlled extraction steam pressure, and back pressure turbines, i.e., whole machine room – also see in (Neuman, et. al., 2009). In the case of heat generation it is technology equipment of machine room and the Main Heat Exchangers Station (MHS), related to the heat distribution system - District Heating Networks. Complex system serves as an on-line support system for the operator and (thermal) dispatcher (Neuman, 2011b).

Secondly, this paper will describe in detail the model and simulation experiments with on-line support system for control of central power and heating plant in company United Energy - Komorany for region District Heating Networks MO-CHO-LI (connecting towns: Most - Chomutov - Litvinov) in Northern Bohemia (Project InCoSysE, 2011).

### 2. CONTROL OF DISTRICT HEATING NETWORKS

The object of complex project is Hierarchical Intelligent Control System of Municipal District Heating Networks (Project InCoSysE, 2011). The district heating supply system (DHSS) is mostly very large and complex system and its behavior and characteristic depends on many various and parameters. Many of them are unfortunately very strong stochastic, some are known with little or

bigger uncertainty and all this brings many problems to control for such system. Mostly we should use some non-classic control methods, which can be included in class of intelligent control methods. Their main characteristics are:

- The ability adapt control algorithm to the state of controlled system and its relevant environment
- The ability change control goals depend on conditions for controlled system operation
- The ability use and handle uncertain and/or uncompleted input data
- The ability to predict some important data and parameters (Balate, et. al., 2006).

Main idea is prepare model of whole district heating supply system (all its parts) as a simulation model. With use this simulation model is then possible simulate different control strategies used in given and predicated state of controlled system. The simulation and its analysis it is possible to make continual and faster as are the control interventions – it is with today computers (they have enough performance) and in process of heat transfer (it is mostly not so fast – there is a big “inertia” against changes) realistic. From the analysis results is possible derive corresponded control operations (or, at least, recommend they to the control personal).

The control strategy is based on prediction of the outside temperature and consumer‘ heat energy (Balate, et. al., 2009).

As consumers‘ demands are predicted, the open loop control could be directly applied to the district heating network. The difficulty is enhanced by the fact that time delays can‘t be neglected in the distribution network. In this paper a model of district heating network is defined for optimization and control purposes. This model is versatile and could be used to model many kinds of heating network. The new control strategy could be applied to various kinds of district heating network (multi supply points, cogeneration or heat-only networks, multi logoped network). This is a general idea of “Smart Grids application to Municipal District Heating Networks”.

### 3. SMART GRID OF COMPLEX DISTRICT HEATING SUPPLY SYSTEM

In the beginning it is necessary to explain the process of project implementation Heat Smart Grid that this post was not entirely clear and debatably. The goal of project was the development intelligent control of district heating systems (DH).

A common District Heating System can be divided into several blocks (Vasek, et. al, 2014):

- a. Production
- b. The primary circuit (Transmission),
- c. The secondary circuit (Distribution)

The basic elements of the district heating is production block, i.e. central cogeneration heat and electricity. This is a classic supply-burning brown coal, including coal bunkers, **coal mills**, combustion chamber, heat exchangers flue gas / steam, steam common bus, condensing steam turbines - condensing steam turbines with controlled extraction steam - a back-pressure turbines - see diagram in Figures 10 and 11.

Other parts of “Production block” are gradually machine room with regeneration, the main heat exchange station (MHS) containing basic heaters (ZO) and top heaters (SO). Next blocks of District Heating System is „Transmission part“ (the primary circuit) and “Distributin part” (the secondary circuit), which is connected with a heat consumption part (individual consumers, houses, industry) via heat exchange stations (HS).

Every part has own basic control system, which perform basic functions of appropriate part of whole system. Over these is proposed Smart Grid, which co-ordinate control of whole system

and try find the optimal control with use of information about state of controlled system and its relevant environment. The configuration of our Intelligent / Smart Grid Control of DHSS is in Fig.1. (Neuman, et. al., 2012b).

Intelligent control of district heating system works based on the prediction of heat consumption, which depends on the behavior of individual consumers (called agents), the weather conditions (outdoor air temperature, sunshine, wind). The requirement for heat production consistent with the prediction heat consumption is sent to a central support system of thermal dispatcher, which on the base of variants simulations "advise" to the dispatcher what configuration of the steam turbines and heat exchangers will be requested amount of heat in the required time available for consumption (Vasek, et. al., 2014).

### 4. ENGINEERING SIMULATOR CONFIGURATION

Intelligent control of district heating system was developed using existing elements, such as a realistic model of the central energy source (coal steam boiler, machine room), which was developed previously for Operator Training Simulator.

Engineering Simulator is created from modules of own NEUREG library called “EnergySIM”. This library could be used for modelling of all types of power plants (Conventional Power Plants, Combined Cycle Power Plants, etc.) based on following modules: Drum Boilers, Steam Turbines, Superheaters, Reheaters, Once-Through Boilers, Fluidized Bed Boilers, Gas Turbines. The “distributed control system” is also emulated in MATLAB-SIMULINK (Neuman et al 2002). The layout of it is in Fig.2.

### 5. MODELING OF SUBSYSTEMS

The base information for creating structure of an Engineering Simulator represents by Process Instrumentation Diagram (P&ID). It is demonstrated on an example of a Coal Feeders & Mills subsystem (Neuman, et. al., 2011a). This subsystem is depicted in Fig.6. Other subsystems modelled by the same way are following: Feeding Water, Air Supply Loop, Flue Gas Loop, Super Heaters, Common Steam Collector, Steam Turbines & Generators.

In the P&ID are depicted all the objects which are either manipulated by control or were some measurement is performed. This specific requirement invokes a need to have technology object-oriented models of all such elements, which are depicted in the P&ID (Neuman, et al., 2003).

#### 5.1 Coal Feeders & Mills subsystem

In the coal mills and feeders technological scheme, which is depicted in Fig.5, such process elements are mentioned in the following description of its function.

- V1 Total air control valve
- V2 Primary air control valve
- V3 Secondary air control valve
- V4 Core air control valve
- V5 Cold air control valve
- PA Primary air
- SA Secondary air
- CA Core air

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