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Heat production optimization using bio-inspired algorithms

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ABSTRACT

Energy efficiency of industrial systems is one of key features for optimal use of resources and the lowest costs of energy for users. In the recent time optimization of heating plants and heat distribution systems becomes an important venue for novel methods and innovative constructions. Various proposals can be seen for more efficient performance of heating systems in changing weather conditions.

In this article results of using bio-inspired methods for intensification of the district heating plant to work with maximum efficiency at the lowest costs are presented. The research is focused on developing bio-inspired approaches for a mathematical model of a district heating plant in various weather conditions. The research model represents a sample district heating plant, in which circulation of hot water is performed in two heat exchangers supplied by controlled pumps. The system was calibrated with the use of proposed Polar Bear Optimization and the results were compared to one of best known heuristics, Particle Swarm Optimization. An objective function describing the operation of the plant was developed and found applicable for proposed bio-inspired approach. The research results have shown that proposed methodology is efficient for all simulated weather conditions and various boundary conditions. Comparison the obtained results with non-optimal parameters confirms huge profits from applying right settings of the system.

1. Introduction

Heating plants and their efficiency in different conditions are influenced by many factors. Various analyses are provided to show which aspects of the weather and which technical elements in heating plants influence the overall evaluation. Effectiveness of a power plant can be maximized by means of modifications in structure, application of more efficient subsystems and thoroughly controlled operating parameters. The research reports many advances in these aspects, both by using new technologies for improvements in construction and by application of intelligent algorithms in search of the best available parameters adjustment.

The analysis is done in various countries, and therefore it is possible to compare the results to draw conclusion on the influence of weather conditions. Bauer et al. (2010) discussed aspects of heating plant adjusted for seasonal changes in weather in Germany. Palander (2011) presented an analysis of power generation from natural fuels on the example of one of the Finnish heating plants. In Turanjanin et al. (2009) was discussed possibility to replace traditional fuels by the solar energy used in Belgrade heating plant, and Zago et al. (2011) presented an analysis of the heating plant efficiency in northern Italy. These articles have shown how the weather conditions can influence on the use of heating systems. Since each of these plants was located in other place, various climate features can be noticed. However, the environmental aspects of thermal technology are similarly important. Proposals of technological developments to heating plants give ideas which elements can take changes for higher conversion rates. Construction characteristics for a district heating plant which can be changed for reduced ash production and more efficient chemical conversion were proposed in Dahl et al. (2009) and Pöykiö et al. (2009). In Çomaklıet al. (2004) was discussed the influence of the distribution network on losses in the energy balance.

Beside to technological development it is essential for any thermal plant to operate with highest possible efficiency and lowest costs, regardless of fluctuating heat demand. The statistical study of various aspects that define control conditions of heating systems was presented in Kuosa et al. (2013). The authors concluded some interesting ideas for possible improvements of operation. In Aringhieri and Malucelli (2003) optimal settings for a district heating plant were discussed. Each of heating plants needs a control strategy, which is not only to be adjusted to weather conditions, but also to the technical conditions of components and current demand from users. All these may

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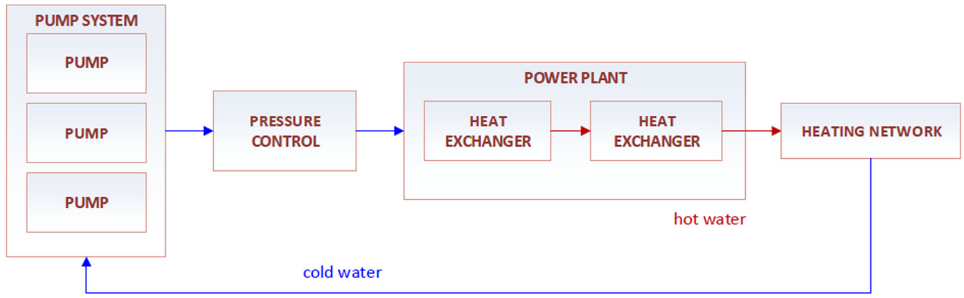

Fig. 1. Block flow diagram of the analyzed district heating plant system, in which three controlled pressure pumps supply the returned cold water from the district network to two heat exchangers which warm the water up in two different pressure conditions and forward it back to the network to condition connected buildings.

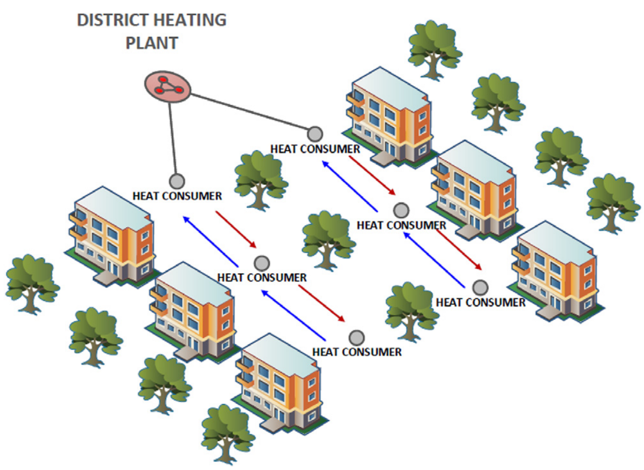

Fig. 2. A schematic organization of a sample district heating system with installed heating plant and connection network.

change and therefore a control strategy must be flexible as proposed in Gustafsson et al. (2010). There are many possible ways to optimize the plant. Recently Computational Intelligence (CI) is reported to succeed in complex optimization problems. Wu et al. (2017) presented risk analysis for complex engineering problems, where CI methods were used to predict features of potential errors and malfunctions. Cheng et al. (2017) described a method based on evolution. The results have shown advantages of nature-inspired algorithms in complex engineering problems. In Hong and Ryu (2017) a simulation method for warship decoy system with the use of a genetic algorithm was described. Dynamic characteristics of electric vehicle in motion were found with the use of heuristic methodology in Woźniak and Połap (2017). In Sangdani et al. (2018) a torque control system for a tracker robot was simulated by a genetic algorithm. Comparative studies on selected heuristics in engineering problems can be also found. In Yıldız and Yıldız (2018) was presented a use of this methods for optimization of vehicle engine connection rod, while in Pholdee et al. (2017) for automotive floor-frame forming. Heuristic algorithms are also very efficient in manufacturing optimization as presented in Yıldız and Yıldız (2017) and miling operations (Yildiz, 2013). Biswas et al. (2018) presented how to use evolutionary algorithm for power flow optimization, and in Tao et al. (2018) similar power optimization problems were solved by using a genetic algorithm. Bio-inspired approaches are also applied for multi-objective optimization in power systems, where optimization is not only constrained due to system composition but vary with the changing demands. In Nguyen and Vo (2017) a hydro-thermal efficiency for lower operation costs of the station was examined by using a cuckoo algorithm to find a balance between operating constraints and lowest emission. While Dubey et al. (2018) presented a comparative overview of recent advances in using bio-inspired methods for managing wind power dispatch. Evolutionary computing is also reported to be efficient

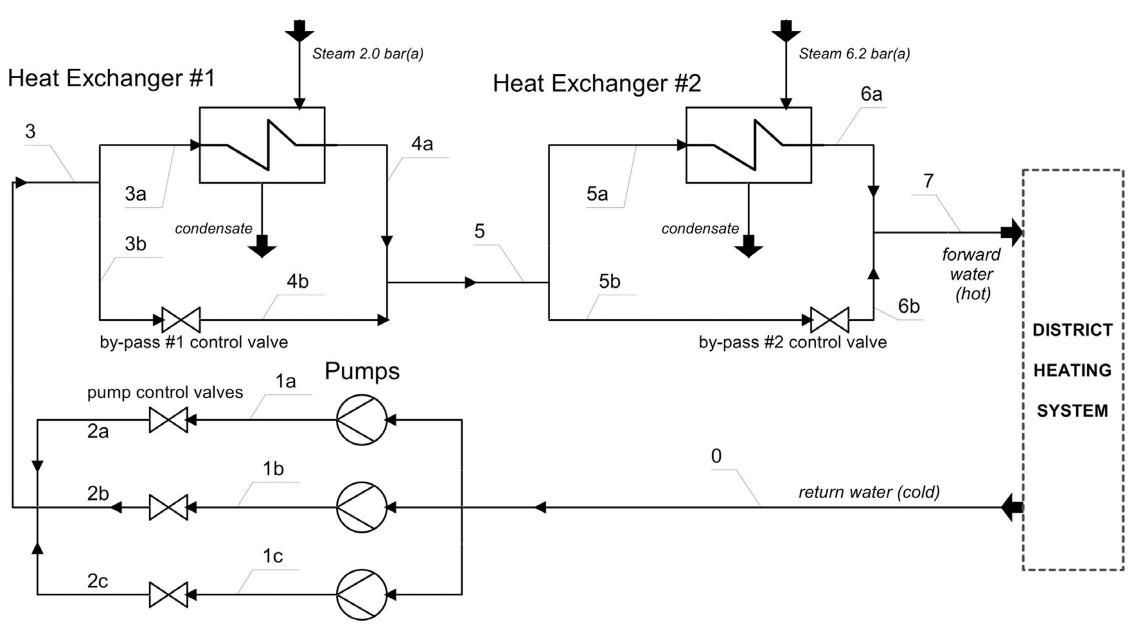

Fig. 3. Process flow diagram of analyzed heating plant system. Cold water from distribution network is compressed by three pumps, which supply it to heat exchangers working at 2.0 bars and 6.2 bars respectively. Hot water is returned from the plant to the distribution network and forwarded to users.