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Abstract of a PhD dissertation: Techno-economic evaluation of Combined Cycle Gas Turbine (CCGT) and Adiabatic Compressed Air Energy Storage (CAES) integration concept

In this thesis the effects of expanding a currently operating Combined Cycle Gas Turbine (CCGT) power plant with a Compressed Air Energy Storage (CAES) system thermal integration are examined. The aim of the thesis to build a model of the integrated plant, evaluate its technical and economic feasibility and give a valid prediction on the value that the integration could generate. The key thesis of the study is that the extra investment in the extension of CCGT with a CAES system will pay back, as it will provide the benefit of high flexibility premia on the market and of lower cycling costs. It is expected that the latter will result from less frequent plant shutdowns and a higher FLEOH (Full Load Equivalent Operating Hours) after integration.

In order to achieve the objectives, two models of a realistic study case of a thermally integrated CCGT-CAES plant were built: a thermodynamic model and an economic model. The former provides input values for the latter. Both models were developed in the Python computer programming language without the use of flowsheeting software or purpose-built industry specific tool. The CCGT plant was modelled on PGE Gorzów old block. The main feature of the CCGT-CAES integration concept is using the CCGT installation as a heat recipient and provider for the CAES, so that the latter functions as an adiabatic system without the need for thermal energy storage facility. On the other hand, flexibility of the CCGT part is enhanced, as the heat of compressing the air for the CAES system can be used to keep the HRSG warm. This way a cool down cycle of the steam part can be avoided in times of low electricity prices.

The overall structure of the thesis takes the form of six chapters. Chapter 1 contains an introduction to the issue under consideration and presents the motivations, scope and hypothesis of the work. The presents the current situation on the energy market in Poland, in particular the problem of acute and increasing capacity shortage and the requirement of more flexible operation of the conventional power plants due to the developemnet of variable renewable energy sources (RES). Approaches to to enhancing the flexibility of thermal power plants are presented next, one of them being to integrate the power plant with energy storage. Motivation for using the optimal generation scheduling for the proper investment evaluation in electricity generation complete the chapter.

In Chapter 2 an overview of the economic framework conditions for Polish power market, in particular the structure of power generation, is provided. Additionally, some theory of

economics of electricity is presented. This background information should allow for a better understanding of the results presented in Chapter 5.

In Chapter 3 a thermodynamic model of a plant, consisting of a CAES system and a CCGT power plant, is derived and presented. The input data of the analysis and the assumptions are provided. The integration concept is presented. Energy balances and governing equation for the plant components are described. Results of the thermodynamic model are presented at the end of the chapter.

Chapter 4 presents the developed model for optimizing operating schedule of a power plant participating in the spot market. First an insight in the economic valuation of generating assets is given. Next, the constrained nonlinear optimization problem of the CCGT-CAES integrated is formulated: the objective function and the constraints. At the end the economic assumptions are given.

Chapter 5 presents the computational simulations for three cases: 1) the CCGT plant is operated independently, 2) the CCGT plant and the CAES system are thermally integrated, 3) the second case is recalculated with the assumption that the energy storage system has a round-trip efficiency of 81% (comparable to PHS). Next, operation profiles for the three cases are summarized and compared. The extra revenues gained from CEAS integration are calculated as an estimate of its economic influence and compared against the estimated extra capital costs.

Finally, Chapter 6 summarizes the key contributions of this research and presents recommendations for future work.