ŁÓDŹ UNIVERSITY OF TECHNOLOGY

FACULTY OF ELECTRICAL, ELECTRONIC, COMPUTER AND CONTROL ENGINEERING

INSTITUTE OF ELECTRICAL POWER ENGINEERING

DOCTORAL DISSERTATION

Long-term, dynamic modelling of the power system development

Długoterminowe, dynamiczne modelowanie rozwoju systemu elektroenergetycznego (PL)

mgr inż. Izabela Filipiak

SUPERVISOR: prof. dr hab. inż. Władysław Mielczarski

ŁÓDŹ, POLAND

NOVEMBER 2018

SUMMARY IN ENGLISH

Simulating power system operation and development is an inherent part of energy policies in every country. There are multiple modeling methods, but their use is limited when it comes to dynamic and complex systems such as the power system. In this project a novel method for the power sector simulation was developed that takes into account:

- difficulties in the prediction of power sector operation conditions in the long-term,
- dynamic reactions of investors in power energy to the constantly changing conditions,
- delays in the investment processes resulting from the feasibility studies, obtaining permissions processes and financing and construction time of the modern power units,
- the influence of the climate and energy policies.

In the method developed, the generation expansion results from the decentralized decisions taken by individual investors that rely on available information, which adequately reflects the generation expansion process.

The proposed method is based on System Dynamics which is a suitable technique for modelling the dynamic behavior of systems. The novelty proposed in this research is the inclusion of an automatic controller that can be seen as the representation of a regulatory body, which is present in every modern power system and creates appropriate investment incentives to prompt new units construction. The automatic controller maintains an adequate level of power reserves in the power system by adjusting a security mechanism and therefore it maintains a long-term energy security. The proposed security mechanism remunerates available capacity (the solution is based on a capacity payment implemented in Spain) with a financial subsidy for each MW of power available, but different solutions can be tested with the method proposed.

To verify the thesis, a model was developed that was based on the Polish power system. The case study was also tested with Polish case study. The choice of the

case study is grounded in its particular characteristics: an urgent need for new power generating assets. Two versions of the model were simulated for four market scenarios. In the first version, the power sector development is regulated by the market signals, while in the second version, the regulating system is implementing incentives to maintain energy security.

The simulations performed proved that the SD method enhanced with the automatic controller (that monitors energy security and based on this signal implements investment incentives) can be used to model the development of the power generating assets in the long-term.

The largest achievement of this research is the introduction of dynamics to long-term modeling of power system development in order to ensure the adequate level of power supply security. It is a step ahead in power system modelling as the commonly used Energy Mix method performs static optimization operation on the “frozen” power system model. The System Dynamics combined with a PID controller is a compromise between the static optimization and more sophisticated state-variable-based, optimal controllers that require precise modelling of the controlled objects with accurate mathematical description. The process of proposed modeling method is presented in the figure below.

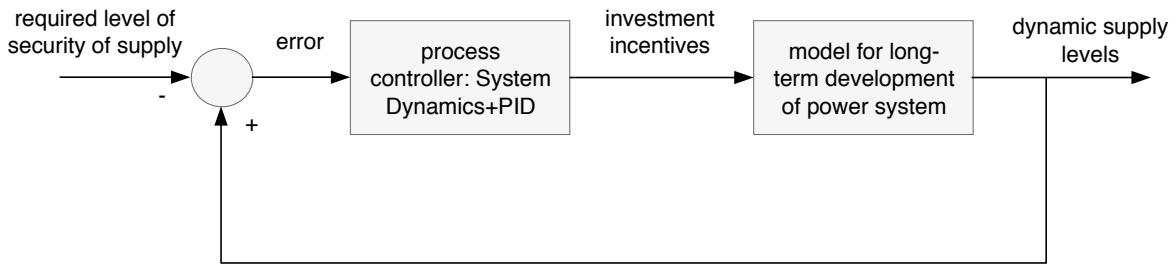

Fig. 1 The block diagram of the system development modelling and its control (own development)