*mathematics*

*Editorial*

# Preface to "Model Predictive Control and Optimization for Cyber-Physical Systems"

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The concept of cyber-physical systems (CPSs) in electrical, civil and mechanical engineering is closely related to Smart Grids and Smart Cities, based on advanced computing technologies used for monitoring, control and communication. They help to ensure a reliable and safe power supply, as well as the high efficiency of generators and distribution networks in order to provide a flexible choice for consumers. An overview and the prospects for the use of cyber-physical systems in electrical engineering are presented in [1] (see also the review provided in [2]).

Recent widespread power outages around the world have motivated the research community to develop and improve the sustainable multi-energy CPS and increase fault tolerance. In the event of a large-scale outage that could occur due to various extreme events, sustainability studies ensure that electricity, heat and gas are available to consumers. Since energy is critical for the national security and the life cycle of the national economy, the above developments highlight the need and urgency for building a robust self-healing Smart Grid. Governments, large companies and research scientists have also proposed the building of highly resilient energy systems [3,4]. In order to slow down the rise in temperature and reduce carbon emissions, China put forward the "double carbon" objectives in September 2020.

Such a policy implies the eventual replacement of traditional energy systems to achieve carbon neutrality by 2060. The "double carbon" policy will further promote the energy internet, energy-to-gas conversion, hydrogen production, combined cooling, electric vehicles, heating and power generation, etc. A number of scientists [4,5] also note the close connection of the concept of "digital energy" with other concepts and approaches, such as the Internet of energy, transactive energy, energy cloud, etc. Some scientists argue that it is extremely necessary to adopt state programs on the digitalization of the domestic fuel and energy complex [6]. And such a program should accompany the already adopted Program "Digital Economy of the Russian Federation" and the Decree "On the national goals and strategic objectives of the Federation for the period up to 2024". Since 2016, the Russian government has been implementing the EnergyNET National Technology Initiative in order to develop smart energy services. The main idea of EnergyNET is to create a new image of the Grid and the Energy Market that meets current and future challenges [6]. Russia aims to reach net zero emissions by 2060. The U.S. Energy Department also runs several programs and support projects to increase the Smart Grids' efficiency and to remove carbon dioxide from the air with the goal to achieve net zero emission by the middle of the 21st century. India also committed to establishing a non-fossil fuel electricity generation capacity of 500 GW to achieve zero-net emissions by 2070.

Complex nonlinear dynamical systems such as multi energy microgrids or shipboard systems require effective coordination of the functioning of a whole set of independent spatially distributed devices and digital twins in conditions of limited access to the data about the current state of physical systems under control.

Model predictive control (MPC) has been widely employed in chemical engineering since 1980s. Nowadays, MPC (also called receding horizon control) is widely used in various electrical engineering projects, microgrids stabilization, power system balancing models and other dynamical system control projects. The Volterra-model-based nonlinear predictive controller design is a conventional nonlinear problem related to the identification and control of nonlinear dynamical systems [7].

Future energy and telecom systems will become even more complex to effectively integrate various distributed renewable energy sources. Progress in advanced cyberphysical systems and computational intelligence requires a rethinking of the conventional methods of dynamical system modeling and control.

For this purpose, we collected nine papers covering different problems including power quality in transmission and distribution systems, aircraft flight control, control methods for EV charging stations and speed tracking problems for EVs, synchronous generator control, optimal integration of distributed generators in the DC networks, adaptive fault estimation and control methods for a reverse osmosis dynamical system.

The voltage sag exact location detection approach is proposed in [8] by Yu. Yalman, T. Uyanık et al using real voltage and current data provided by the power quality monitoring system in the distribution company, Enerji Yönetim Sistemi | Inavitas, in Turkey. Four fault types, such as a single-phase ground fault, two-phase ground fault, three-phase ground fault, and two-phase fault were successfully classified.

P. Ilyushin, A. Kulikov, K. Suslov and S. Filippov [9] also focused on the fault location. The problem of double-ended power transmission line fault location was considered. Various distorting factors were analysed. The influence of interharmonics and noise errors in the double-ended transmission line fault location procedure was analysed. The authors concluded that the error in the calculations of the power line fault location does not exceed 0.2% of the length of the power transmission line.

An MPC controller for a longitudinal motion of aircraft flight system is proposed by M. El-S. M. Essa, M. Elsisi et al. [10]. Direct application of MPC requires locating the optimal values of the parameters. A heuristic approach using the bat-inspired algorithm is proposed in this article to attack this issue. The efficiency of the proposed MPC control methodology is validated and compared with the state of the art methods. It was concluded that method guarantees the stability of the aircraft system under system perturbation.

M. Sadiq, Carlos A. Aragon, and Y. Terriche et al. [11] developed a continuous-control-set MPC-based control strategy of a half-bridge balancing DC-DC converter for a bipolar EV charging station. Experiments with such an improved topological DC bus system in the MATLAB/Simulink environment demonstrated the efficiency of the proposed MPC-based control strategy.

Yu. Bulatov, A. Kryukov, A. Batuhtin et al. [12] proposed a new approach for building a digital twin of the distributed generation plant using hierarchical fuzzy inference systems. In order to optimize the fuzzy model membership functions, the authors employed subtractive data clustering and neural networks to generate fuzzy rules as well as a genetic algorithm.

L. F. Grisales-Noreña, and O. D. Montoya et al. [13] proposed a principal/agent strategy between the population-based incremental learning optimisation method (to minimise the power losses associated with energy transmission) and the vortex search algorithm for the optimal integration of distributed generations into DC networks. Overall, 21 and 69 bus test systems were employed to test the proposed approach.

Y. Yuan, X. Xu and S. Dubljevic [14] proposed an efficient scheme for the state and multiplicative fault estimation of a linear hyperbolic PDE system with unknown disturbances based on the plant observer canonical form. It is demonstrated that in sense of Lyapunov stability, fault parameter estimation converges exponentially. In fact, the proposed scheme ensures the existence of arbitrarily small errors in fault parameter estimation, despite the presence of unknown external disturbances.

F. Liu, H. Li, and L. Liu et al. [15] focus on control issues for Electric Vehicles (EVs). Namely, the authors considered the interior permanent magnet synchronous motor speed tracking problem. The cascade speed controller and a current controller are proposed. Accordingly, the active disturbance rejection control technique and finite control set model predictive control strategy were employed. Simulations based on parameters from Toyota Prius Hybrid vehicles demonstrated the efficiency of the proposed controllers.

Finally, S. Noeiaghdam, D. Sidorov, and A. Zamyshlyaeva et al. [16] employed stochastic arithmetic for dynamical control of the numerical method for the reverse osmosis system (pre-treatment of the feed-water for combined heat-and-power plants) described by an advection–diffusion equation. Numerical examples are included to illustrate the efficiency of proposed approach.

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