Studies in Systems, Decision and Control

Volume 388

Series Editor

Janusz Kacprzyk, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland

The series "Studies in Systems, Decision and Control" (SSDC) covers both new developments and advances, as well as the state of the art, in the various areas of broadly perceived systems, decision making and control–quickly, up to date and with a high quality. The intent is to cover the theory, applications, and perspectives on the state of the art and future developments relevant to systems, decision making, control, complex processes and related areas, as embedded in the fields of engineering, computer science, physics, economics, social and life sciences, as well as the paradigms and methodologies behind them. The series contains monographs, textbooks, lecture notes and edited volumes in systems, decision making and control spanning the areas of Cyber-Physical Systems, Autonomous Systems, Sensor Networks, Control Systems, Energy Systems, Automotive Systems, Biological Systems, Vehicular Networking and Connected Vehicles, Aerospace Systems, Automation, Manufacturing, Smart Grids, Nonlinear Systems, Power Systems, Robotics, Social Systems, Economic Systems and other. Of particular value to both the contributors and the readership are the short publication timeframe and the world-wide distribution and exposure which enable both a wide and rapid dissemination of research output.

Indexed by SCOPUS, DBLP, WTI Frankfurt eG, zbMATH, SCImago.

All books published in the series are submitted for consideration in Web of Science.

More information about this series at http://www.springer.com/series/13304

Olexandr Kyrylenko · Andrii Zharkin ·
Oleksandr Butkevych · Ihor Blinov ·
Ievgen Zaitsev · Artur Zaporozhets
Editors

Power Systems Research and Operation

Selected Problems

Springer

Editors
Olexandr Kyrylenko
Institute of Electrodynamics
National Academy of Sciences of Ukraine
Kyiv, Ukraine

Andrii Zharkin
Institute of Electrodynamics
National Academy of Sciences of Ukraine
Kyiv, Ukraine

Oleksandr Butkevych
Institute of Electrodynamics
National Academy of Sciences of Ukraine
Kyiv, Ukraine

Ihor Blinov
Institute of Electrodynamics
National Academy of Sciences of Ukraine
Kyiv, Ukraine

Ievgen Zaitsev
Institute of Electrodynamics
National Academy of Sciences of Ukraine
Kyiv, Ukraine

Artur Zaporozhets
Institute of Engineering Thermophysics
National Academy of Sciences of Ukraine
Kyiv, Ukraine

ISSN 2198-4182 ISSN 2198-4190 (electronic)
Studies in Systems, Decision and Control
ISBN 978-3-030-82925-4 ISBN 978-3-030-82926-1 (eBook)
https://doi.org/10.1007/978-3-030-82926-1

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Ensuring operational reliability and safety of objects integrated power system of Ukraine's complex task. Solution of which is related to the optimization of operating modes of electric power facilities and their control systems, information and measuring systems and metrological support in the electric power industry, ensuring the functioning of the electric power system in the conditions of a competitive market of the electric power.

Monograph presents the research results aimed at covering solutions to current scientific and practical problems, occuring during the operation of integrated power system of Ukraine in modern market condition in the next areas:

- implementation of new approaches to the calculation of the capacity of intersections between power systems or their parts;
- study of power system stability by frequency with considering account the influence of renewable generation sources and the operation of frequency emergency automation devices of power plants;
- research methods for identification of dominant modes of low-frequency electromechanical oscillations are suitable for use in real time in monitoring systems;
- development of new methods of flow distribution analysis in electric networks of arbitrary structure, which allows to take into account the limitations of power flows when modelling the decentralized combination of electricity markets in the market segment "day ahead";
- studies of short-term forecasting electricity generated by renewable energy sources and development new neural deep learning networks architecture;
- development structural and parametric operating modes optimization methods for main electric networks with considering design features of ultra-high-voltage power transmission lines and coronation effects in their wires;
- development methods and devices for improving metrological and technical characteristics of measuring systems for monitoring and diagnosing generating equipment of power plants.

Develop these areas, the monograph covers new technologies and methods related to the management of large interconnected power systems, solving a stable and reliable problem of electricity generation, ensuring optimal operation of transmission lines taking into account the probabilistic nature of corona losses, sources of electricity from renewable sources and energy sources. Devices with remote control, which is reasonable in the case of cyclical and long-term changes in load, as well as assessing the impact of transmission network constraints on electricity exchange in the context of integration of electricity markets into the European electricity market. So, the monograph can be divided into several main sections.

The main part of the monograph is devoted to the management of power systems. Total transmission power is an important indicator of any system interfaces used to maintain system stability in a market environment. Information about the total transmission power for power systems management used. In addition, total transmission power daily or even hourly to estimate the reliability margins for all power transmissions through the interfaces of each network. According to the proposed approach, users spend their time setting up and preparing big data for calculations. This approach significantly reduces the number of errors of operational staff when performing calculations. To optimize the modes of operation of the transmission line, proposed to solve problems of voltage and reactive power optimization. Power lines operating mode monitoring consists of correct choice of the composition of the charging power compensation devices in order to regulate the voltage levels and power coefficients at the bus terminals. By using modern devices for controlled compensation of power line charging, it is possible to achieve deeper regulation of reactive power and voltage, and, accordingly, to minimize the loss of active power. Interconnected mathematical models set to determine the economic effect of optimizing the mode of operation of the electrical network with ultra-high power lines in terms of voltage and reactive power, taking into account the probabilistic nature of corona losses. Methods, algorithms and methods of operative optimization of operating modes of separate power lines taking into account corona losses are developed.

Methods for solving the problem of choosing the optimal places of disconnection in electricity distribution networks and implementing its results are considered. This shown that a universal solution is the use of power electronic devices, which makes it possible to form the so-called “soft points” of the distribution circuits in the active control and reactive power flows to ensure minimum power loss due to rapid response to changes in electrical load and/or modes of production and energy storage in the presence of scattered sources of production means and electricity storage. New technological solutions are proposed that allow to effectively reduce electricity losses in distribution networks with local sources of energy production and storage due to the possibility of dynamic management of the network configuration.

Devoted to the analysis model checking technique applicability in energetics scenarios. Proven and widely adopted TLC (TLA checker) model checker has been considered as an instrument for design solutions verification. To this end, the Temporal Logic of Actions (TLA) and corresponding formalisms—TLA+ and PlusCal—have been applied to formally specify the functional properties provided

as block-diagrams. Power systems management scenarios taking place in electricity markets have been approached as promising problem domain.

Unsatisfactory accuracy of RES electricity generation forecasts leads to additional production and/or consumption disparities and additional costs for settling these imbalances. In such circumstances, it is possible to improve the quality of decision-making when planning regimes, using accurate forecasts for the markets for the day ahead and intraday. For this purpose, a new architecture developed for short-term energy forecasting of aggregate RES production.

The other part of the monograph on the monitoring and control system designed to identify the danger of disruption of the stability of self-energy and its equipment. To assess the condition of generators as mechanical systems, a structural system of systems and a new type of mechanical parameters meter proposed. The use of the system and sensors allows for depth monitoring of the condition of individual generator units in real time, in order to implement the automatic ability to decide on the possibility of operating the generator based on the use of identification systems and artificial intelligence.

In power systems, especially in interconnected ones, Low-Frequency oscillations (LF) periodically occur, leading to accidents with severe consequences. The study of frequency stability in power systems based on the consideration of local frequency control to mitigate the impact of renewable generation on high-load linear flows and the impact of frequency stability considered frequency alarm systems and AGC modelling. The results of researches of various methods of signal analysis for their use in real time for detection of modes of electromechanical oscillations in power systems presented. Using real-time methods under certain conditions, different results of LFO mode identification obtained. This approach allows you to get a more reliable estimate of the parameters of the LFO modes more reliably.

The presented research results in monograph allow increasing the reliability and efficiency of operation of energy facilities and ensuring the stability of power systems, the introduction of effective methods and tools for forecasting electricity supply, optimize power systems, suggest road map to integrate electricity markets taking into account network constraints in modern conditions of electricity markets.

The authors of the monograph are mainly from Institute of Electrodynamics of the National Academy of Sciences of Ukraine.

Kyiv, Ukraine
April 2021

Olexandr Kyrylenko
Andrii Zharkin
Oleksandr Butkevych
Ihor Blinov
Ievgen Zaitsev
Artur Zaporozhets

Contents