Studies in Computational Intelligence

Volume 822

Series editor

Janusz Kacprzyk, Polish Academy of Sciences, Warsaw, Poland
e-mail: kacprzyk@ibspan.waw.pl

The series "Studies in Computational Intelligence" (SCI) publishes new developments and advances in the various areas of computational intelligence—quickly and with a high quality. The intent is to cover the theory, applications, and design methods of computational intelligence, as embedded in the fields of engineering, computer science, physics and life sciences, as well as the methodologies behind them. The series contains monographs, lecture notes and edited volumes in computational intelligence spanning the areas of neural networks, connectionist systems, genetic algorithms, evolutionary computation, artificial intelligence, cellular automata, self-organizing systems, soft computing, fuzzy systems, and hybrid intelligent systems. Of particular value to both the contributors and the readership are the short publication timeframe and the world-wide distribution, which enable both wide and rapid dissemination of research output.

The books of this series are submitted to indexing to Web of Science, EI-Compendex, DBLP, SCOPUS, Google Scholar and Springerlink.

More information about this series at http://www.springer.com/series/7092

Erik Cuevas · Emilio Barocio Espejo ·
Arturo Conde Enríquez

Metaheuristics Algorithms in Power Systems

Springer

Erik Cuevas
Departamento de Electrónica, CUCEI
Universidad de Guadalajara
Guadalajara, Mexico

Emilio Barocio Espejo
CUCEI
Universidad de Guadalajara
Guadalajara, Mexico

Arturo Conde Enríquez
Universidad Autónoma de Nuevo León
San Nicolás de los Garza, Nuevo León, Mexico

ISSN 1860-949X ISSN 1860-9503 (electronic)
Studies in Computational Intelligence
ISBN 978-3-030-11592-0 ISBN 978-3-030-11593-7 (eBook)
https://doi.org/10.1007/978-3-030-11593-7

Library of Congress Control Number: 2018967415

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

Preface

Power systems represent one of the main technologies in this electricity-driven modern civilization. In this context, there exist a great variety of problems in which power systems can be applied. Such problems are generally nonlinear and complex, demanding other complementary methods to solve them. Recently, power systems have been conceived as a multidisciplinary field regarding the multiple approaches used for their design and analysis. Therefore, each new scheme that is developed by other scientific community is quickly identified, understood, and assimilated in order to be applied to power system problems. This multidisciplinarity covers from signal processing, electronics to computational intelligence including the current trend of using metaheuristic computation.

In the last years, researchers, engineers, and practitioners in power systems have faced problems of increasing complexity. These problems can be stated as optimization formulations. Under these circumstances, an objective function is defined to evaluate the quality of each candidate solution composed of the problem parameters. Then, an optimization method is used to find the best solution that minimizes/maximizes the objective function.

Metaheuristic methods use as inspiration our scientific understanding of biological, natural, or social systems, which at some level of abstraction can be conceived as optimization processes. They are considered as general-purpose easy-to-use optimization techniques capable of reaching globally optimal or at least nearly optimal solutions. In their operation, searcher agents emulate a group of biological or social entities which interact with each other based on specialized operators that model a determined biological or social behavior. These operators are applied to a population of candidate solutions (individuals) that are evaluated with respect to an objective function. Thus, in the optimization process individual positions are successively attracted to the optimal solution of the system to be solved.

The aim of this book is to provide an overview of the different aspects of metaheuristic methods in order to enable the reader in reaching a global understanding of the field and in conducting studies on specific metaheuristic techniques that are related to applications in power systems. Our goal is to bridge the gap between recent metaheuristic optimization techniques and power system applications. To do this, in each chapter we endeavor to explain basic ideas of the proposed applications in ways that can be understood by readers who may not possess the necessary backgrounds on either of the fields. Therefore, power system practitioners who are not metaheuristic computation researchers will appreciate that the techniques discussed are beyond simple theoretical tools since they have been adapted to solve significant problems that commonly arise in such areas. On the other hand, members of the metaheuristic community can learn the way in which power system problems can be translated into optimization tasks.

Metaheuristic algorithms are vast and have many variants. There exist a rich amount of literature on the subject, including textbooks, tutorials, and journal papers that cover in detail practically every aspect of the field. The great amount of information available makes it difficult for no specialist to explore the literature and to find the right optimization technique for a specific power system application. Therefore, any attempt to present the whole area of metaheuristic computation in detail would be a daunting task, probably doomed to failure. This task would be even more difficult if the goal is to understand the applications of metaheuristic methods in the context of power systems. For this reason, the best practice is to consider only a representative set of metaheuristic approaches, just as it has been done in this book.

This book has been structured so that each chapter can be read independently from the others. Chapter 1 describes the main concepts of metaheuristic computation. This chapter concentrates on elementary concepts of metaheuristics. Readers that are familiar with these concepts may wish to skip this chapter.

In Chap. 2, an algorithm for the optimal parameter identification of induction motors is presented. To determine the parameters, the presented method uses a recent evolutionary method called the gravitational search algorithm (GSA). Different to the most of existent evolutionary algorithms, GSA presents a better performance in multi-modal problems, avoiding critical flaws such as the premature convergence to sub-optimal solutions. Numerical simulations have been conducted on several models to show the effectiveness of the presented scheme.

Chapter 3 considers the problem of overcurrent relay coordination under an optimization perspective. Protective relaying comprehends several procedures and techniques focused on maintaining the power system working safely. Overcurrent relay is one of the oldest protective relays, and its operation principle is straightforward: When the measured current is greater than a specified magnitude, the protection trips. However, its main disadvantages consist in increased tripping times and difficulties in finding faults (since faults could be located far from the relay location). In order to solve this problem, a scheme of coordination among relays is proposed. In the approach, the invasive weed optimization (IWO) algorithm is applied for getting the best configuration.

In Chap. 4, the problem of the coordination in overcurrent relays is analyzed. In the approach, both sensitivity and security requirements of relay operation are considered. The scheme has as a basis a metaheuristic algorithm. In order to compare the results, several metaheuristic methods have been employed such as the ant colony optimizer (ACO), the differential evolution (DE) algorithm, and the gray wolf optimization (GWO).

In Chap. 5, a method to solve an optimal power flow problem with one single function and with multiple and competing objective functions is presented. As a first approach, the modified flower pollination algorithm (MFPA) is employed to show its potential application to solve the OPF problem. Then, the normal boundary intersection (NBI) method is considered as a complementary technique to determine the Pareto front solution of the multi-objective OPF problem. To help in the decision-making process, several strategies are compared to select the best compromise solution from the Pareto frontier. To demonstrate the capabilities of the proposed method, different objective functions are combined to calculate the Pareto front solution on the IEEE 30 bus test system. Finally, a visual tool is developed to display the OPF solution. This tool would help the user to intuitively visualize potential damage on the power system.

In Chap. 6, an improved version of the crow search algorithm (CSA) is presented to solve complex optimization problems typical in power systems. In the new algorithm, two features of the original CSA are modified: (I) the awareness probability (AP) and (II) the random perturbation. With such adaptations, the new approach preserves solution diversity and improves the convergence to difficult high multi-modal optima. In order to evaluate its performance, the proposed algorithm has been tested in a set of four optimization problems which involve induction motors and distribution networks. The results demonstrate the high performance of the proposed method when it is compared with other popular approaches.

Chapter 7 presents a method for obtaining the optimal configuration of a set of fault current limiters on a distribution network. The approach considers several popular metaheuristic methods as search strategies to find the best architecture of limiters considering different objective functions. The algorithms involve genetics algorithm (GA), particle swarm optimization (PSO), and differential evolution (DE).

Finally, Chap. 8 presents a method that combines dimensionality reduction (DR) technique with particle swarm optimization (PSO) algorithm for clustering load profile electricity data. The DR techniques allow to obtain a low-dimensional data model that can be used to project representative electricity load (REL) data onto an easily interpretable 3D space. On the other hand, the PSO algorithm and a validation index algorithm are also applied to obtain an optimal number of clusters.

Guadalajara, Mexico — Erik Cuevas
Guadalajara, Mexico — Emilio Barocio Espejo
San Nicolás de los Garza, Mexico — Arturo Conde Enríquez
2015

Contents