Expert Systems With Applications 145 (2020) 113125

Contents lists available at ScienceDirect

Expert Systems With Applications

journal homepage: www.elsevier.com/locate/eswa

# A harmonic estimator design with evolutionary operators equipped grey wolf optimizer

Akash Saxena[a,*], Rajesh Kumar[b], Seyedali Mirjalili[c]

[a] Department of Electrical Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan, Jaipur, India
[b] Department of Electrical Engineering, Malaviya National Institute of Technology, Jaipur, India
[c] Centre for Artificial Intelligence Research and Optimisation; Torrens University Australia, Fortitude Valley, Brisbane, 4006 QLD, Australia

ARTICLE INFO

*Article history:*
Received 28 June 2019
Revised 14 October 2019
Accepted 8 December 2019
Available online 13 December 2019

*Keywords:*
Grey Wolf Optimizer (GWO)
Mutation
Crossover
Harmonics
Power quality
Optimization
Algorithm

ABSTRACT

Harmonic estimation is a challenging design problem in power networks. Accurate estimation of the inter, power and sub harmonics in networks can be a helpful aspect for designing potential solutions for elimination of these harmonics. Harmonic estimation design problem has been considered as an optimization problem with the amalgamation of least square algorithm in past. In this paper, we first propose an Evolutionary Operators Equipped Grey Wolf Optimizer (E-GWO). In this proposal a sinusoidal function enabled bridging is proposed and along with this tournament selection operator and crossover and mutation operation are incorporated at position updation phase. The variant is first benchmarked on latest CEC-2017 functions and then this design problem is addressed. After a meaningful comparison with the previously published approaches, we arrive at the conclusion that proposed modifications have positive implications on the performance of GWO. Proposed harmonic designs are robust when tested with different operating conditions.



## 1. Introduction

Modern power system possesses consumer centric policies, hence comfort of the consumers in terms of reliability and quality of power supply are the utmost priorities of the power producers and distributors. The quality of power can be characterized as the quality of the voltage and current at distribution level rather at end user. Often the use of electronic circuits, nonlinear inductive loads and time varying loads in industry introduce harmonics in the system voltage and current. Harmonics are nothing but unwanted spectral ingredients of the distorted electrical signals. Frequency of the harmonics are the integer multiple of the fundamental frequency. These harmonics can be considered as power line pollutants that contaminate the system's fundamental voltage and current signals (Wiczynski, 2008).

These unwanted signals in the fundamental signals are catastrophic, the adverse effects of these harmonics can be observed in terms of losses in electrical systems, loss in terms of data, reduction in life span of electrical appliances, functioning of the electrical appliances and many more. The most adverse effect of the harmonics can be seen in communication networks. For example in Power Line Carrier Communication Systems (PLCCS), the communication and protection schemes are based on the measurements of receiving end and sending signals. Any harmonic in the electrical signal can affect the working of these communication channels. Regulatory bodies such as Institute of Electrical and Electronics Engineers (IEEE) and other have defined standards and regulations for harmonic levels.

Along with the power harmonics there are several adverse effects of inter harmonics namely thermal effects, telecommunication interference, erroneous firing of the apparatus which are derived from the thyristors, contamination in control signals used for protection and operation of the power devices that can results in a mal-operation of the relays and circuit breakers, frequency overload (high) of passive parallel filters and many more (Lin, 2012).

From this discussion, one can arrive on a strong conclusion that a special care is to be taken while dealing with the harmonics, hence, the studies of harmonics can be done in two directions. The first direction is to conduct analysis for accurate estimation of the harmonic levels in the power networks and second is the elimination of the harmonics by designing filters. Conservatively, discrete Fourier transform method is an efficient one for signal spectrum tracking but it possesses several drawbacks such as effect of spectral leakage and picket fence effect due to improper sampling (Lin, 2012). As it's a known fact that power system frequencies are subjected to change hence, spectral leakage cannot be avoided.

* Corresponding author.
*E-mail addresses:* aakash.saxena@hotmail.com, akash@skit.ac.in (A. Saxena), rkumar.ee@mnit.ac.in (R. Kumar), ali.mirjalili@gmail.com (S. Mirjalili).

https://doi.org/10.1016/j.eswa.2019.113125
0957-4174/