Engineering Science and Technology, an International Journal xxx (2017) xxx–xxx

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

Engineering Science and Technology, an International Journal

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

Full Length Article

Hybrid fuzzy charged system search algorithm based state estimation in distribution networks

Sachidananda Prasad *, D.M. Vinod Kumar

Department of Electrical Engineering, National Institute of Technology Warangal, Telangana State, India

ARTICLE INFO

Article history:
Received 25 January 2017
Revised 31 March 2017
Accepted 4 April 2017
Available online xxxx

Keywords:
Distribution system state estimation (DSSE)
Charged system search (CSS) algorithm
Fuzzy adaptive charged system search (FACSS) algorithm

ABSTRACT

This paper proposes a new hybrid charged system search (CSS) algorithm based state estimation in radial distribution networks in fuzzy framework. The objective of the optimization problem is to minimize the weighted square of the difference between the measured and the estimated quantity. The proposed method of state estimation considers bus voltage magnitude and phase angle as state variable along with some equality and inequality constraints for state estimation in distribution networks. A rule based fuzzy inference system has been designed to control the parameters of the CSS algorithm to achieve better balance between the exploration and exploitation capability of the algorithm. The efficiency of the proposed fuzzy adaptive charged system search (FACSS) algorithm has been tested on standard IEEE 33-bus system and Indian 85-bus practical radial distribution system. The obtained results have been compared with the conventional CSS algorithm, weighted least square (WLS) algorithm and particle swarm optimization (PSO) for feasibility of the algorithm.

1. Introduction

The power system state estimation (SE) is a process of determining the reliable state variables such as bus voltage magnitudes and angles from the noisy data received at the control centers so that all other quantity of interest in a system can be found for real time monitoring and control of the system. It is the heart of the energy management system (EMS) to have real-time monitoring and accurate estimation of DGs output, loads and network voltage magnitudes for better management and planning of the power and distribution networks. This is possible only if the state variables are estimated accurately and efficiently. State estimation in distribution network has not been given much attention in early days, but due to the growing demand of controllable devices and renewable sources, it is now necessary to have efficient and accurate state estimator to provide reliable data set to EMS for other control functions in distribution systems. Fundamentally, in a distribution system, the number of real measurements is significantly smaller than the pseudo-measurements [1,2]. Therefore, state estimation (SE) technique is used to obtain the status of the network more accurately from the available measurements. SE is a digital filtering algorithm which can accurately determine the states of the system from the noisy data. However, due to the limited number of real time measurements, accurate SE in distribution systems is more challenging. So, a large number of pseudo-measurements (historical data) retrieved from a priori knowledge are necessary to maintain observability of the network and convergence of the SE algorithm. Additionally, the accuracy of pseudo-measurements is comparatively low.

For the last two decades many researchers have been carried out to alleviate state estimation problems in distribution network using variety of SE algorithms. Baran and Kelly [3], proposed a state estimation algorithm for unbalanced distribution networks using traditional weighted least squares (WLS) approach. Authors have used three phase node voltage formulation and historical customer load data as pseudo measurements in estimation process. In [4], an efficient algorithm for branch current-based distribution system state estimation (BC-DSSE) is developed. In this algorithm a constant gain matrix is developed which is more efficient and reliable than three phase node voltage formulation SE technique. In [5], a BC-DSSE is proposed, where branch current phasors in polar form have been used as state variable. The voltage magnitudes, power flows, real and reactive power injections along with amplitude of branch currents are considered as measurements and the impact of type and location of measurements in a distribution network have been discussed. In [6], a design approach is proposed for meter placement in distribution network to reduce the relative errors in voltage magnitude and angle which improves state

* Corresponding author.
E-mail address: sachidananda_prasad@yahoo.in (S. Prasad).
Peer review under responsibility of Karabuk University.

http://dx.doi.org/10.1016/j.jestch.2017.04.002
2215-0986/

Please cite this article in press as: S. Prasad, D.M. Vinod Kumar, Hybrid fuzzy charged system search algorithm based state estimation in distribution networks, Eng. Sci. Tech., Int. J. (2017), http://dx.doi.org/10.1016/j.jestch.2017.04.002

estimation accuracy. Pau et al. in [7], proposed an efficient BC-DSSE which includes PMUs to improve the accuracy of the estimator. This method has considered both polar and rectangular form of branch currents as well as slack bus voltage as state variables. A hybrid particle swarm optimization for DSSE is proposed in [8]. This algorithm considered the non-linear characteristics of the practical equipment with limited measurements used in the system for state estimation. In [9], a linearized form of DSSE is proposed for unbalanced distribution system. The estimator has employed a complex variable formulation to incorporate phasor measurement units. Recently, in [10] a three-phase state estimation method is proposed for radial distribution network. This method is based on the adjustment of loads on feeders to model the pseudo-measurements of power and also it considered the imbalance of load in distribution feeders. In [11], a hybrid PSO for three phase state estimation in unbalanced distribution network is proposed. It assumes transformer taps along with bus voltage magnitude and angles as state variable.

The state estimation using traditional approaches in distribution network have been used by several authors. But it has been seen that traditional methods such as Newton or Gradiant methods suffer a lot of difficulties in handling inequalities constraints. All these methods are fully dependent on the initialization of the state variables [12]. If the initial values of the variables are not selected properly then it suffers from the convergence problem. So the solutions obtained from these algorithms are mostly local optimal solution which makes a huge error between actual value and the estimated value of a quantity. Moreover, some of the restrictions like the objective function should be differentiable and continuous are usually imposed on the traditional algorithms. These restrictions can be well handle by artificial intelligence (AI) techniques for distribution state estimation.

However, the search space of traditional optimization algorithm will increase with increase in size of the system. Furthermore, with the existence of non-linear devices such as var-compensator, distributed generators and transformer with on-load tap changer, the objective function becomes non-linear, discontinuous and non-differentiable. Moreover, the conventional WLS algorithm may not converge if the objective functions are highly non-linear as well as the initial guess are far away from the optimal solution. Therefore, the use of meta-heuristic technique is evident to obtain accurate state estimation solution. The synthesis of the solutions provided in the literature is shown in Table 1.

In this paper artificial intelligence (AI) technique is employed for non-linear optimization problem with complex search space. For the optimization problem a new hybridized meta-heuristic, charged system search (CSS) algorithm is proposed in fuzzy environment to estimate the state variable such as bus voltage magnitudes and angles for wide monitoring and control of the radial distribution system. The conventional CSS algorithm is hybridized with fuzzy logic to best handle the exploitation ability of the CSS algorithm. The advantage of this hybridization is that, it takes less computational time as well as producing highly accurate solutions as compared to conventional CSS and PSO [18]. The main contribution of this paper includes, hybridization of the conventional CSS algorithm in fuzzy environment to best estimate the system states for wide monitoring and control of the distribution networks.

This paper is organized as follows. Following the introduction, an overview of distribution system state estimation is presented in section 2. The conventional CSS and the proposed (FACSS) algorithm are discussed in section 3. The implementation of the proposed FACSS in DSSE problem is presented in section 4. Section 5 discusses the simulation results to show the superiority and effectiveness of the proposed algorithm. The conclusion part is discussed in section 5.

2. Distribution system state estimation (DSSE)

The objective of the DSSE problem is formulated as a conventional state estimation problem i.e. minimization of the weighted square of the difference between the measured quantities and the estimated quantities [12]. The aim is to estimate the voltage magnitude and angle of all the buses in a distribution system that minimizes the above objective function. Hence, the objective of the optimization problem can be stated as follows:

$$\text{Min } J(x) = \sum_{i=1}^{m} w_{ii}(z_i - h_i(x))^2 \tag{1}$$

$$\text{Subject to} : z_i = h_i(x) + r_i \tag{2}$$

$$c(x) = 0 \tag{3}$$

$$g_{\min} \leqslant g(x) \leqslant g_{\max} \tag{4}$$

where

x system state variable (bus voltage magnitude and phase angle);
h_i *ith* non-linear measurement function;
r_i i^{th} measurement error;
z_i measured value of the *ith* measurement;
$w_{ii} = \frac{1}{\sigma_i^2}$ weight associated with the *ith* measurement;
σ_i standard deviation of *ith* measurement;
m total number of measurements.

In this paper, balanced distribution network is considered to examine the efficiency of the proposed method of state estimation. In a distribution network the power injected at *ith* bus can be expressed as [7]:

Table 1
Synthesis of the solutions provided in the literature survey.

Authors	Synthesis of the solutions proposed in literature	Algorithm
Baran and Kelly [3]	The state estimation using traditional methods such as Newton or Gradiant methods suffer a lot of difficulties in handling inequalities constraints. All these methods are fully dependent on the initialization of the state variables. If the initial values of the variables are not selected properly then it suffers from the convergence problem. So the solutions obtained from these algorithms are mostly local optimal solution which makes a huge error between actual value and the estimated value of a quantity. Moreover, some of the restrictions like the objective function should be differentiable and continuous are usually imposed on the traditional algorithms. These restrictions can be well handle by artificial intelligence (AI) techniques for distribution state estimation	WLS
Lin et al. [4]		BC-DSSE
Wang and Schulz [5]		BC_DSSE
Pau et al. [7]		BC_DSSE
Haughto and Heyd [9]		Linearized DSSE
Medeiros Junior et al. [10]		WLS
Naka et al. [8]	In these papers the authors have used PSO for estimation of system states. The PSO algorithm has good exploration capability but it has poor exploitation capability to find the global optimal solutions	PSO
Nanchian [11]		
Proposed Method	A hybrid fuzzy adaptive charged system search algorithm based state estimation in distribution networks has been proposed to balance the exploration and exploitation capability of the CSS algorithm as well as to estimate the system states more accurately	FACSS

Please cite this article in press as: S. Prasad, D.M. Vinod Kumar, Hybrid fuzzy charged system search algorithm based state estimation in distribution networks, Eng. Sci. Tech., Int. J. (2017), http://dx.doi.org/10.1016/j.jestch.2017.04.002