Electrical Power and Energy Systems 45 (2013) 391–403

Contents lists available at SciVerse ScienceDirect

Electrical Power and Energy Systems

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

New algorithm based on CLPSO for controlled islanding of distribution systems

Amany El-Zonkoly *, Mostafa Saad, Reem Khalil

Arab Academy for Science & Technology, Faculty of Eng. & Tech., Miami, P.O. 1029, Alexandria, Egypt

ARTICLE INFO

Article history:
Received 20 April 2012
Received in revised form 19 August 2012
Accepted 29 August 2012
Available online 7 November 2012

Keywords:
Controlled islanding
Comprehensive learning particle swarm optimization (CLPSO)
Distributed generation (DG)
Power dispatch
Load shedding

ABSTRACT

Controlled islanding operation of distribution systems having significant penetration of distributed generation (DG) is becoming an important option for economical and technical reasons. Implementation of intentional islanding of DG improves the continuity of supply and reliability of power system. In this paper, comprehensive learning particle swarm optimization (CLPSO) is used to optimally partition the distribution system in case of main upstream loss. The objective is to find the optimal islanding scheme of distribution system to achieve minimum active power generation cost, minimum reactive generation cost and minimum cost of the un-served power while satisfying system operational constraints. The solution proceeds by splitting the system into islands after the loss of main upstream feeder. In each island, the power balanced is achieved through load shedding. An optimal dispatch of the generating units of each island is then carried out to achieve minimum active power generation cost. A power flow calculations are carried out to calculate the reactive power generated by each unit and to check the operational constraints of the system. Finally, the effects of controlled islanding with and without utility owned DGs on the system reliability indices is studied. The proposed algorithm is applied to two radial and meshed test systems.

1. Introduction

DG systems have been widely focused on by many researchers. As a result of DG penetration, power system can be split into several isolated subsystems prior to or following a catastrophe to avoid blackouts. Intentional islanding can improve the continuity of the power supply to local loads which improve the quality of supply and hence the reliability of the system [1–8].

However, one of the important aspects in classical distribution system protection is the prevention of islanding. For that purpose many anti-islanding techniques were introduced by researchers [9]. Moreover, the PV (photovoltaic) installations oriented IEEE Standard 929-2000 [10] allows the islanding, but the inverter that interconnects the PV panel with the grid must be disconnected otherwise islanding must be prevented due to the following reasons:

- The voltage and frequency in the island are not controlled by the utility which may cause damage to customer equipment.
- Restoration of the island may be disturbed because of lake of synchronism between the island and the grid.
- Islanding can lead to potential risk of life for utility line workers if a line remains energized, while it could be assumed to be disconnected from all energy sources.

On the other hand, the IEEE Standard 1547-2003 [11], which addresses the topics of intentional islanding and DG interconnection, proposes to consider the intentional islanding topic in its future revisions. Therefore, attempts have been made to overcome the islanding prevention reasons. Some control techniques that enable safe islanding operation of DGs were proposed [12,13]. With suitable load shedding and generators dispatch, both voltage levels and frequency of the island could be maintained constant. To connect back the local survived islands to the restored grid, paralleling synchronizing switches located at the points of interconnection is needed. Finally, it is becoming essential for line workers to strictly follow the procedures of line maintenance and repair [12,13].

In this paper, in order to apply the intentional islanding, an off-line study is carried out to determine the optimal islanding configuration and the optimal active power dispatch and load shedding following islanding. An island can be formed due to faults causing the upstream feeder breakers connecting the distribution network to the main grid to open. Once the island is detected, a decision must be taken either to allow the anti-islanding scheme or the intentional islanding scheme to active. According to the voltage magnitudes measured at the DG terminals, the fault can be

Abbreviations: DG, distributed generation; UGs, utility owned distributed generation; PSO, particle swarm optimization; CLPSO, comprehensive learning particle swarm optimization; SASUI, system average service unavailability index; SAIDI, system average interruption duration index; EENS, expected energy not supplied; ECOST, expected interruption cost per hour; IEAR, interruption energy assessment rate.

* Corresponding author. Tel.: +20 1007384174.
E-mail address: amanyelz@yahoo.com (A. El-Zonkoly).

0142-0615/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ijepes.2012.08.076

Nomenclature

Symbols

pbest	particle's best position
gbest	the best position discovered by the whole population
v_i^d	the velocity of the *d*th dimension of the *i*th particle
x_i^d	the position of the *d*th dimension of the *i*th particle
x_i	the position of the *i*th particle
v_i	the velocity of the *i*th particle
fi	the particles' *pbests* that the *i*th particle should follow
w	the adaptive inertia weight
iter	the iteration number
max-iter	the maximum iteration
c	the accelerating constant
$pbest_{fi(d)}^d$	the corresponding dimension of any particle's *pbest* including its own *pbest*
P_{ci}	the learning probability of the *i*th particle
ps	the swarm size
m	the refreshing gap
$C_i(P_i)$	the generation cost of the *i*th DG unit
P_i	the active power generated of the *i*th DG unit
NUG	the number of utility owned DG units
NG	the total number of DG units
NL	the number of buses that contain loads
NIG	the number of investor owned DG units
a_i, b_i, c_i	the operating cost parameters of *i*th DG unit
τ_i	the price of energy purchased from the investor-owned DG units
Q_i	the reactive generation of the *i*th DG unit
$QCST_i^Q$	the payment for reactive power from the *i*th DG units
Pr_i	the priority weighted cost of load at bus *i*
Psh_i	the amount of load shedding at bus *i*
$\lvert V_i \rvert$	the voltage magnitude at bus *i*
δ_i	the voltage angle at bus *i*
Y_{ij}	the element of bus admittance matrix
θ_{ij}	the angle of bus admittance matrix element
PD_i	the real power demand at bus *i*
QD_i	the reactive power demand at bus *i*
P^{min}, P^{max}	the minimum and maximum limits of active power generation, respectively
Q^{min}, Q^{max}	the minimum and maximum limits of reactive power generation, respectively
V^{min}, V^{max}	the minimum and maximum limits of bus voltage, respectively
P_k, Q_k	the active and reactive power flow in the *k*th feeder
S_k^{max}	the *k*th feeder complex power flow capacity limit
Pun_k^i	the demand for load point *k* per interval *i*
PD_k^i	the demand for load point *k* per interval *i*
ND	the total number of customers
NI	the number of intervals
d_i	the failure duration of a load point per interval *i*
L_k	the average load at load point *k*
SD	the simulation duration
c	the per unit interruption cost

classified into an internal or an external fault. Also, from the system data it can be identified if the load supplied in the isolated part of the system is less than or greater than the DGs power output.

The anti-islanding scheme is to be activated and the DGs must be disconnected in two cases. The first case is when the fault is classified as an internal fault (inside the distribution area). The DGs are then connected back after clearing the fault and restoring the main grid. The second case is when the fault is an external one but the DGs power output is greater than the distribution network loads. The DGs are then connected back after being re-dispatched.

Intentional islanding is allowed to take place if the fault is classified as an external fault and the distribution network loads are greater than the maximum power that can be supplied by the DGs on one condition which is load shedding. As proposed in this paper an immediate load shedding of the less important loads must take place after islanding to overcome the problem of power unbalance and hence the problem of voltage and frequency deviation of the island. Fig. 1 illustrates the cases of anti-islanding and islanding activation.

Many researchers have investigated the islanding problem. In [2], authors proposed a network reconfiguration strategy which allows the distribution network to separate into a certain number of autonomous islands, supplied by local DG, in case of permanent fault within the grid. Most researchers who addressed the intentional islanding problem tried to minimize the load shedding during islanding condition [3–7]. Others were aiming to reduce the cost of active generation of DGs [13] or to achieve safe islanding [14]. In [15], authors investigated the effect of intentional islanding on the reliability indices of a system with and without DG. Both [2] and [14] considered radial systems with pre-specified switches locations. The reconfiguration of the network is carried out by trying several options of opening and closing switches. The proper islanding scheme was also found by applying evolutionary computation methods [3,4,16]. In each of the previous cases, the number of islands was pre-specified. In addition, none of them considered the cost of DG reactive power service provision.

In this paper, a CLPSO based algorithm is proposed to find the optimum islanding scheme of distribution network. The proposed algorithm is to find the proper lines to be disconnected to minimize the active and reactive generation cost and the cost of un-served power while satisfying the system operational constraints. The number of islands is not pre-specified, but left for the algorithm to determine. A bus-branch incidence matrix model is used to determine the branches included in each island. After splitting the system into islands, generators re-dispatch, load shedding and power flow calculations are performed to determine the active and reactive power generation of each DG unit, the amount of loads needed to be shed to achieve safe islanding and to check the steady state operational constraints of the system. The proposed algorithm is applied to a 33 bus radial test system in addition to the 45 bus meshed, 66 kV network of Alexandria, Egypt. For each system, the reliability indices are calculated during islanding with and without utility owned DGs (UGs) penetration.

2. Comprehensive learning pso

PSO emulates the swarm behavior and the individuals represent points in the D-dimensional search space. In PSO each particle learns from its best previous position (*pbest*) and from the best position discovered by the whole population (*gbest*) simultaneously. However, because all particles in the swarm learn from the *gbest*, particles may easily be attracted to the *gbest* region and get trapped in a local optimum if the search environment is complex with numerous local solutions. To improve the original PSO, all particles' *pbests* are used to update the velocity of any one particle.