Electric Power Systems Research 95 (2013) 214–224

Contents lists available at SciVerse ScienceDirect

Electric Power Systems Research

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

Islanding Control Architecture in future smart grid with both demand and wind turbine control

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ARTICLE INFO

Article history:
Received 15 December 2011
Received in revised form 15 August 2012
Accepted 9 October 2012
Available online 3 November 2012

Keywords:
Control architecture
Demand
Distributed generation
Island operation
Wind turbine

ABSTRACT

In recent years, a large number of Distributed Generation units (DG units) such as Wind Turbines (WTs) and Combined Heat and Power plants (CHPs) have been penetrating the distribution systems. Meanwhile, an intentional island operation of distribution systems is proposed as a potential measure against power supply outages by continuously running DG units during system emergencies. However, there are some challenging security issues for an island operation, such as the power imbalance during the islanding transition and the coordination of feeder protection systems. To tackle the former issue, which is the focus of this paper, available resources including both DG units and demand should be fully utilized as reserves. The control and coordination among different resources requires an integral architecture to serve the purpose. This paper develops the Islanding Control Architecture (ICA) for future smart grid, based on the Islanding Security Region (ISR) concept. With the ISR, system operators can assess beforehand if an island operation can be successful for a given distribution system at its current operating state. In case of unfavorable assessment, control measures will be suggested to coordinate different resources, aiming at pulling the system back into the ISR to ensure a successful island operation on time.

1. Introduction

Distributed Generation (DG) has become a global interest for the research and development of electric power systems [1,2]. In the European Union (EU), DG is one of those priorities for the development of the SmartGrid concept [3]. For instance in Denmark, a high penetration level of DG units, such as Wind Turbines (WTs) and Combined Heat and Power plants (CHPs) has been observed in the power system, and the market share of the electricity production of the central power plants has been greatly reduced by more than 40% as of 2004 [4].

Meanwhile, it is foreseeable that more DG units will emerge in future power system. In Denmark, the "visionary Danish energy policy 2025", published by the Danish government in early 2007 establishes the following targets by 2025 [5]:

- Reduce the use of fossil fuels by at least 15% compared with today;
- Effectively counteract rises in overall energy consumption, which must remain static.

To accomplish the targets, the share of renewable energy must be raised to at least 30% of total energy consumption by 2025, and more efficient energy generation and consumption technologies must be applied. Therefore, it is recommended that 50% of total electricity demand in Denmark by 2025 should be supplied by Wind Turbines (WTs) [6], and the role of distributed Combined Heat and Power plants (CHPs), especially those powered by renewable fuels, will be strengthened to further enhance the energy efficiency in Denmark [7].

As there are more renewable and other energy efficient DG units present in the Danish distribution systems, it has been of great interest to fully utilize them to maintain the security of power supply during all circumstances including emergencies that have occurred in the upstream grid. One possible solution is to perform a controlled island operation as investigated in the Cell Controller Pilot Project [8]. In fact, the island operation has also been actively studied within the MicroGrids concept [9–11] and either tested or implemented in practice [12–14]. Meanwhile, an IEEE standard P1547.4 for islanding guide has just recently been published [15].

There are many challenges during an islanding transition, including the power imbalance issue, which is the focus of this paper. Power imbalance may lead to system frequency instability, and finally blackout of the islanded system, due to the loss of adequate power reserves from the external grid. Thus, the DG units in the islanded system should be utilized to re-establish the power balance and avoid customer interruptions accordingly. Intentional

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0378-7796/$ – see front matter
http://dx.doi.org/10.1016/j.epsr.2012.10.004

island operations of selected distribution systems with DG units could be of high potential to enhance system reliability. When there is a gradually aggravated stressed situation caused by a certain constraint/emergency in the system, the Transmission System Operator (TSO) can island several distribution systems to prevent a blackout of the whole transmission system, while the islanded systems can still maintain stability by utilizing their DG units [8].

Another possible source of reserve could be the demand. Traditionally, an Under Frequency Load Shedding (UFLS) scheme of large scale industry loads is employed for reserve purpose. In fact, some types of household appliances that can be disconnected fast and whose short disconnection does not influence the function of equipment or comfort for the consumer can also be used for reserve. A research project upon the Demand as Frequency controlled Reserve (DFR) has revealed this potential application [16]. This is even more beneficial for the system with more intermittent DG units, like WTs, which may not provide adequate reserve. However, once a large amount of DG units and demand resources exist within distribution systems and they are required to serve island operations, a control architecture must be developed to ensure optimal coordination and integration of elements of different natures, and to cope with the risks and uncertainties involved.

Another challenge regarding the island operation is how to find the appropriate time to island or how the system operator can ensure that the islanded system is still stable when suffering a loss of the external grid. This could be solved by the security region concept, which can provide the system operator with global information about a feasible island operation region. The security region concept was first proposed in [17], and further developed in [18], mainly for online system security monitoring, assessment and optimization.

Thus, this paper intends to develop a control architecture to coordinate different DG units and demand during the islanding transition operation, based on a new Islanding Security Region (ISR) concept [19].

The rest of the paper is organized as follows: in Section 2, the Islanding Control Architecture (ICA), the ISR concept, and the DFR technology are described. Section 3 presents the results based on a distribution system study, including the influence of DFR on ISR, a 3-Dimension (3D) ISR with WT, and the implementation test of one designed coordination scheme. Section 4 draws some main study conclusions and discusses the future work.

2. Methods

2.1. Overview

For a given distribution system with islanding possibility, a dedicated ICA is proposed as shown in Fig. 1. This ICA is based on the ISR, introduced later in this section. There are three stages within the ICA:

- Stage 1: the monitoring, supervision, and islanding security assessment;
- Stage 2: the control, coordination, and islanding security re-assessment;
- Stage 3: the post-islanding transition.

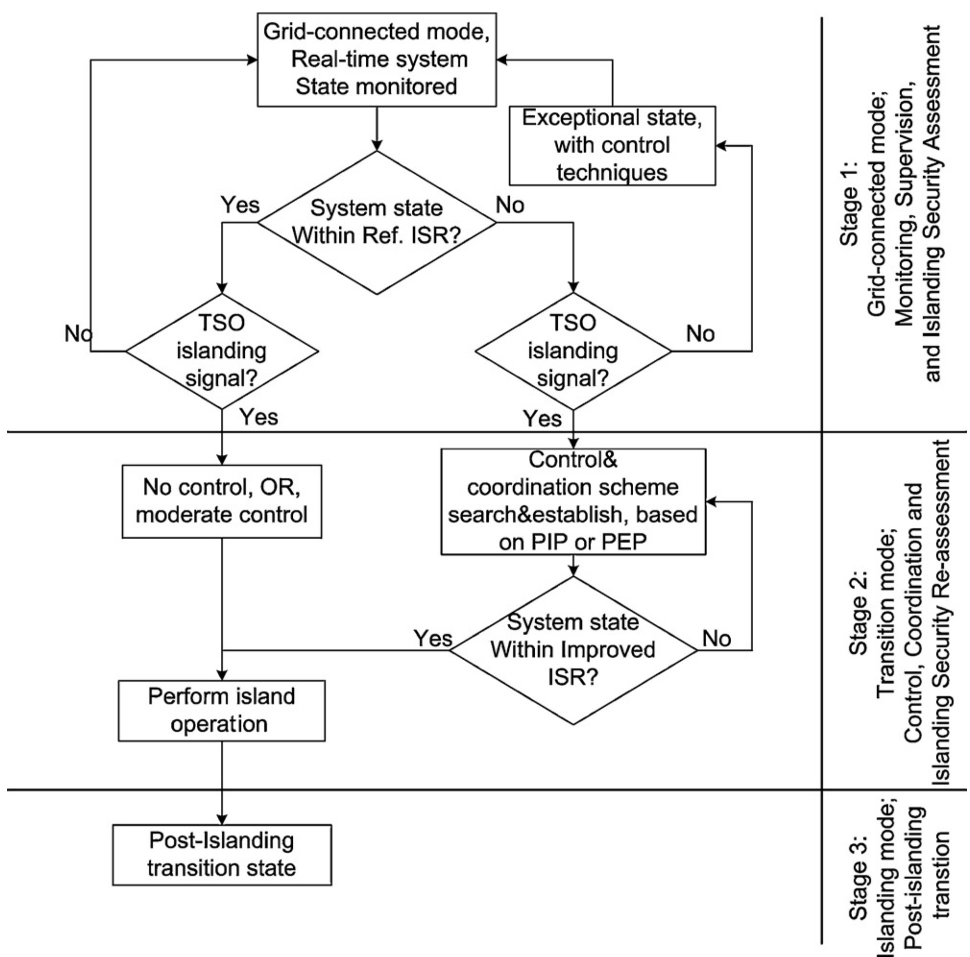

Fig. 1. Islanding Control Architecture for intentional islanding transition.