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Proper sizing and placement of distributed power generation aids the intentional islanding process

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ABSTRACT

Blackouts occur in power networks after cascading failures which separate the network into some uncontrolled islands. These unintentional islands are mostly faced with a deficiency in active or reactive power balance leading to continuing failures and blackouts. Intentional or controlled islanding is one of the best solutions for preventing blackouts during cascading failures. Controlled islanding strategies can be based on different network features such as its topology and distribution of resources in a way that the imposed amount of load shedding will be minimized. Nowadays, the application of distributed generation (DG) units is increasing rapidly and such units can play a significant role in the process of intentional islanding.

In this study, a method for proper sizing and placement of DG units in order to aid the intentional islanding process by strengthening the static stability of newly created islands and minimizing the amount of imposed load shedding was analyzed. The proposed method was applied on an IEEE 39-bus network. Simulation results demonstrated the ability and efficiency of proper sizing and placement of DG units from an intentional islanding point of view.

1. Introduction

1.1. Motivation and approach

As applications of distributed generation (DG) units are increasing, numerous studies are being carried out on the interaction of these generation units with the power system. Since the scattering quality of DG units and their size play a significant role in the operation and security of power systems, proper sizing and placement of these units is one of the most important fields of study. Proper sizing and placement of DG units can be investigated in power systems with different aims such as minimizing network loss, improving network voltage profiles, decreasing investment and operation costs, etc.

One of the situations in which DG units can be useful is in the islanded operating conditions of power systems for preventing blackouts. In the process of subsequent events and lines tripping, known as cascading failures, that take place based on network weaknesses and the local action of protection relays, one of the best solutions for preventing blackouts is intentional islanding of a power network. Intentional or controlled islanding prevents failures to be extended to other parts of the power network and separates the network into islands which can balance their own loads and generation. In this condition, the presence of properly sized DG units at strategic locations in the network can strongly help to increase the stability of the newly created islands and the islanded operation of the network for preventing global blackouts. The authors of this current study were not able to find any previous studies evaluating the sizing and placement of DG units for purposes of aiding intentional islanding processes.

In this study, two main purposes were considered for proper sizing and placement of DG units in order to help the intentional islanding process and prevent cascading failures and blackouts. These main purposes were: (1) decreasing load shedding in the islanded operating condition; and, (2) increasing the static stability of created islands. In this way, different conditions of the network, including both normal and abnormal conditions with $N-1$ contingency scenarios, were considered and dominant islands of the network were recognized by implementing intentional islanding processes across all of the conditions and scenarios mentioned earlier. Next, the study focused on these dominant islands and the proper sizing and placement of the DG units. Finally, the proposed method was applied on an IEEE 39-bus network. The results demonstrated improvement in the condition of the islands after the DG units were installed and the ability of the method to achieve the desired goals.

1.2. Literature review and contributions

In power systems, many studies have been done and a variety of methods proposed for determining appropriate location and

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capacity of DG units from different points of view. These studies can be implemented in transmission, sub-transmission or distribution networks [1]. Some studies are focused on determining optimal placing and sizing of DG units in order to achieve systematic and technical goals such as minimizing active [1–6] or reactive [1,5] losses or loading of selected lines [1,4,5], mitigating congestion in transmission lines [6] and improving voltage profiles in the network [3–7]. Other studies propose algorithms for proper sizing and placement of DG units with economic goals in mind such as minimizing total system planning costs including DG investment, operation and maintenance costs [6,8] or maximizing profit in deregulated environments [6–8]. On the other hand, in order to solve the problem of proper sizing and placement of DGs and implementing it in the network, Distribution Network Operators (DNOs) and DG units' developers may have different objectives. Therefore, DG units' developers do not merely act in the same direction as the DNOs' goals. In [9], using a multi-objective OPF, it was shown that developers and DNOs would tend to connect DG in significantly different locations and capacities. Harrison et al. [9] examine the different incentives for DG developers and DNOs and how these influence the optimal connection of DG units within existing networks.

Yet other studies focused on power system failures and blackouts. Some of these focused on enhancing functions and operation schemes of relays for reducing their contribution in system blackouts [10,11]. Others proposed methods for detecting islands and determining asynchronous groups of generators [12–14]. As mentioned earlier, in the context of cascading failures and blackouts, intentional islanding has been proposed as a preventive strategy. Aghamohammadi and Shahmohammadi [15] discussed three basic tasks which should be carried out sequentially in order to apply the strategy of intentional islanding. These tasks are:

1. Recognizing the proper operating instant at which applying intentional islanding is inevitable; otherwise, the system will be separated into uncontrolled islands leading to cascading failures and global blackout.
2. Identifying the proper islands in the network for intentional network separation such that each island would be able to preserve its power balance and stability.
3. Implementing the planned islanding scenario properly without any dynamic or transient consequence causing large oscillations and instability for the islands.

Among all of these studies, in the context of intentional or controlled islanding, few have reported concerns about tasks 1 and 3 [16], while most of them focused mainly on task 2 [15], [17–21]. Aghamohammadi and Shahmohammadi [15] proposed a new algorithm based on ant search mechanism to identify proper islands in the network for intentional islanding. The first task they assumed would have been completed, after which their new algorithm would be used. Neither did they evaluate the third task, but rather left it for independent studies.

Considering all of the studies in the context of intentional islanding, much more research should be carried out to consider all aspects of this critical action. Many elements and characteristics of a power system can affect the process of intentional islanding. For example, as in modern power networks, the use of DGs is increasing rapidly, these units can play a significant role in the process of intentional islanding. The interaction of DG units and intentional islanding of power networks is seldom studied. Calderaro et al. [22] present an optimization sectionalizer planning problem to apply intentional islanding in a distribution network in presence of DG units for minimizing both the power losses and the unsupplied loads. The feasibility of the proposed solution depends on the smart degree of the distribution system. In fact, the application of the solution is based on the communication of the switch status to the protection distribution system. Sizing and placement of DG units from an intentional islanding point of view has never been investigated in any of these studies. In this paper, appropriate sizing and placement of DG units was studied in order to help the intentional islanding process as a preventive method for decreasing the blackout risk in power networks and strengthening the stability of these newly created islands. Here, it is assumed that the first task for applying controlled islanding has been completed and a decision for islanding has been taken; so concerning the second task, this approach is proposed in order to strengthen islanding scenarios by proper sizing and placement of DG units. This strengthening occurs by increasing the static stability of the created islands and decreasing their load shedding in each islanding scenario.

After finding proper size and place for DG units in the network, it is important to encourage DG connections at locations and capacities obtained in theoretical studies. In order to achieve this goal, regulators are aiming to incentivize developers and DNOs to connect DG units to improve network environmental performance and efficiency [9]. Hence, after the theoretical studies for proper sizing and placement of DG units, there should be another independent study concerning the problem of implementing these theoretical results in the network and encouraging developers to act based on these results. In this paper, only the first section, concerning theoretical studies for proper sizing and placement of DG units, is investigated while the second section, dealing with DNOs and developers, is not in the scope of this paper and requires an independent study like the one presented in [9].

1.3. Paper organization

The rest of this paper is organized as follows. Section 2 provides basic model used for intentional islanding and clarifies the aspects in which DG units can affect created islands. In Section 3, sizing and placement of DG units for helping the intentional islanding process is investigated and different scenarios considered for this study are explained. Section 4 demonstrates numerical results of applying proposed method on an IEEE 39-bus network and compares islands' conditions before and after sizing and placement of DG units and finally, Section 5 provides some relevant conclusions obtained from the study reported in this paper.

2. DG units and intentional islanding of power networks

Since the purpose of this study was to analyze the effects of proper sizing and placement of DG units on created islands after intentional network separation, the intentional islanding process itself was not the main concern, though the algorithm for applying intentional islanding [15] in different scenarios was used. Principles of this algorithm are stated in the following section.

2.1. Principles of the intentional islanding algorithm

The algorithm for intentional islanding [15] is able to find any number of islanding scenarios with respect to the integrity and static stability criteria. In this algorithm, two basic criteria for static stability of islands were considered: load–generation balance and line overloading constraints. Intentional islanding was modeled as a linear programming optimization problem with the objective function of minimizing load shedding in each created island, as stated in Eq. (1), subject to some operational constraints which are based on DC load flow, as stated in Eqs. (2)–(7), as follows:

$$Min: \quad LS^k = \sum_i P_{Ls}^{i,k} \tag{1}$$