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Intentional islanding using a new algorithm based on ant search mechanism

Mohammad Reza Aghamohammadi *, Ali Shahmohammadi

College of Electrical Engineering, Power and Water University of Technology, Tehran, Iran

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ABSTRACT

Cascading failures and blackouts are the most significant threats for power system security. If the process of cascading failure proceeds by further line tripping, the system will face uncontrolled islanding. Establishment of uncontrolled islands with deficiency in MW or Mvar power balance are the main reasons for system blackout. In order to reduce the risk of blackout due to islanding, intentional or controlled islanding has been considered as a preventive strategy. In this paper, for identifying proper islanding scenarios in network, a new search algorithm based on the ant search mechanism is proposed. The security constraints considered for finding islanding scenarios are load–generation balance and line overloading which are implemented using linear programming and DC load flow. The proposed algorithm has been applied on IEEE 39-bus network with promising results showing the ability of the algorithm for finding proper islanding scenarios quickly.

1. Introduction

Security is a vital requirement for power systems which can be defined as its ability for preventing blackout following initiation of cascading failures. The process of cascading failures is the main mechanism for pushing power system toward blackout. Cascading failure is a complicated process consisting of a sequence of events such as line tripping, which take place due to network weaknesses and local function of protection relays.

In recent years, numerous ways for reducing cascading failure risks have been identified, including: more coordinated emergency controls. In general terms, these suggestions are attempts to improve coordination of power system design and operation to decrease cascading failures caused by line overloading. In [1], a decentralized load shedding approach has been presented that mimics wide-area approaches to provide emergency protection against excess frequency decline which also provides protection against line overloading, and hence minimizes cascading failure risk. A key feature of the proposed load shedding scheme is the use of local frequency rate information to adapt the load shedding behavior to the size and location of the experienced disturbance.

Modeling cascading failures is crucial for analyzing power system blackouts. A malfunction of a power system shows usually itself as a blackout. In [2], a new approach for blackout modeling based on ignoring the details of particular failures and focusing on the study of global behaviors and dynamics of time series with approximate global models has been presented. Concepts such as criticality and self-organization have been applied to characterize blackout data, suggesting that the frequency of large blackouts is governed by non-trivial distribution functions such as power laws.

In the process of cascading failures, outage of a heavily loaded line or tripping of a large generator may lead the system to collapse immediately. It is very important to maintain power flow solvability when unsolvable cases occur. Load shedding can prevent a system blackout in these situations. In [3], a framework based on two sub-problems using LP based OPF has been presented for determining a load shedding strategy for the restoration of power flow solvability and improvement of VSM.

In the process of cascading failure, if line tripping proceeds further, power network splitting into uncontrolled islands will be inevitable. The uncontrolled islands always suffer from load–generation imbalance which may cause angle, voltage or frequency instability leading to blackout.

In order to prevent cascading outages, in [4] a technique based on graph theory has been presented for generation shift from one generator to another. This method is suitable for both credible and non-credible contingencies. The proposed method also provides important additional information i.e. the transmission lines (links) to be switched off to detect islands of a power system in addition to preventive control strategies.

Forced establishment of uncontrolled islands is dominant characteristic of power system dynamic during the process of cascading failures which is recognized as the main cause for blackout. In order to avoid uncontrolled separation of power network and reducing the risk of blackout, intentional islanding has been considered as a preventive action in defense strategy of power systems.

* Corresponding author. Tel.: +98 21 77312176; fax: +98 21 73932591.
E-mail address: aghamohammadi@pwut.ac.ir (M.R. Aghamohammadi).

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System splitting known as controlled islanding is intentional separation of entire network into two or several islands by tripping properly selected lines.

After system splitting, the whole power system will be under islanding operation and each island including its own load and generation should be able to preserve its balance and remain stable. In such situation, although the power system is operating in an abnormal degraded state, however, customers are continuing to be served [5].

In order to apply the strategy of controlled islanding, three tasks should be carried out sequentially.

1. Recognizing the proper operating instant at which applying intentional splitting is inevitable otherwise the system will be separated into uncontrolled islands.
2. Identifying the proper islands for intentional network separation such that each island will be able to preserve its power balance and stability.
3. Implementation of the planned islanding scenario in a proper way without any dynamic and transient consequence causing large oscillation and instability for islands.

However, regarding tasks 1 and 3, less works have been reported [6]. When islanding scenario is identified and decided, the most important task is implantation of the scenario by proper tripping of lines between islands. In this respect, the order of line tripping is very important and dominating for islands stability.

Most reported works are mainly focused on task 2 concerning identification of proper islanding scenarios for network splitting [7–11].

Detecting islands and determining asynchronous groups of generators have been investigated in [12–14]. Enhancing the functions and operation schemes of relays for reducing their contribution in system blackout has been worked in [11,15]. However, still for recognition of controlled islanding strategies to prevent blackouts, limited studies have been reported [5,16–19]. Algorithms based on the technique ''Ordered Binary Decision Diagram'' (OBDD) have been used to determine proper splitting strategies [5,16,17,20]. In [16], a three phase method has been used to determine proper islanding scenario in the network. In Phase-1, a much simpler reduced network of the original power network is constructed by graph theory; then in Phase-2, the verification algorithms based on OBDDs can efficiently narrow down the strategy space and can give enough splitting strategies satisfying ''load–generation balance'' constraints. In Phase-3, by using power-flow calculations the possibility of line overloading is checked, and final proper splitting strategies will be given. Also in [5] a two phase method has been used to find proper islanding schemes. The method narrows down the strategy space using highly efficient OBDD-based algorithm in the first phase, then finds proper splitting strategies using power-flow analysis in the reduced strategy space in the second phase. In [17], in addition to load–generation balance constraint and overloading constraint in transmission lines, some other constraints such as synchronism between generators in each island and stability of islands after splitting are considered for finding proper islands. In this reference, a three phase method has been used to satisfy these constraints in order to find proper islands. In the first phase, power network will be split into separated sub networks; in the second phase, the constraints of load–generation balance and groups of synchronized generators will be checked. Finally in the third phase, constraints of overloading in transmission lines and stability of separated islands will be checked.

The main aims of network islanding can be listed as follows;

1. Isolating the vulnerable parts from other parts in order to avoid propagation of weak areas' problems to other parts.
2. Splitting the whole system into small subsystems for easy handling in dynamic and emergency conditions.

After splitting, each island including some loads and generators, must be able to maintain its stability and power balance by controlling its generators in a permissible limit and applying load curtailment.

In this paper, a new algorithm based on ant search mechanism is proposed for identifying controlled islanding scenarios. Here, it is assumed that the first task has been done and decision for islanding has been taken; so concerning the second task, and in order to identify proper islanding scenario, this approach is proposed. The third task is not considered in this paper and it is the subject of another study.

2. Intentional and controlled islanding

In the process of power system dynamic caused by cascading failures, some parts of network may experience angle, frequency or voltage instability. In such situation, trying to maintain system integrity and operate the system entirely interconnected is very difficult and may cause propagation of local weaknesses to other parts of the system. In critical conditions which continuation of cascading failures threats integrity of whole network and may split it into uncontrolled islands, intentional separation of power system into controlled islands is recognized as an effective defense strategy.

Intentional controlled islanding of power systems is based on the following advantages:

1. Separating weak and vulnerable areas from stable parts of the system.
2. Easy handling and control of small subsystems with respect to the whole system.

After formation of islands, load–generation imbalance, line overloading, voltage, angle and frequency instabilities, are the phenomena which can threat the stability and integrity of each island.

Therefore, islands must be formed in such way to be able to manage and maintain static and dynamic stability of their own region independently. For this purpose, each island must have adequate resources of active and reactive power and sufficient control facilities like load shedding and generation reserve.

The number of islands that should be established in the network is better to be as less as possible, however, it depends on the system condition at the instant of islanding, including network structure, spread of vulnerability into network, slow coherent groups of generators and available control facilitates in the network. As mentioned above, the process of intentional islanding consists of three phases including decision making for islanding, identifying proper islanding scenario and implementing islanding scenario. Decision depends on the criticality of operational conditions. Whenever system operator recognizes system inability for preserving its integrity, a proper islanding strategy can be applied as a defensive solution. In this paper, based on the hypothesis of having decided to split the network into controlled islands, a probabilistic algorithm for identifying the proper islanding scenario is proposed. The proposed approach is able to identify a variety of islanding scenarios satisfying basic criteria. In addition, it enables operator to implement some other constrains like minimum number of boundary lines between islands which cannot be easily handled in the main process of island identification. Also, provision of variety of islanding scenarios enables operator to effectively implement his engineering understanding and experience in the process of adoption of proper islanding scenarios.