

# Slow Coherency Based Cutset Determination Algorithm for Large Power Systems

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**Abstract**—This paper provides an integrated algorithm to identify a cutset for a large power system for the application of a slow coherency based controlled islanding scheme. Controlled islanding is employed as a corrective measure of last resort to prevent cascading outages caused by large disturbances. The large scale power system is represented as a graph and a simplification algorithm is used to reduce the complexity of the system. Generators belonging to the same slowly coherent group are collapsed into a dummy node, and a graph partition library is used to split the graph into a given number of parts. Some extra islands formed by the partition library are merged into their adjacent large islands and the original cutset of the actual power system is recovered from the highly simplified graph. A software package was developed to test the efficiency of the algorithm, and dynamic simulations were run on the WECC system to verify the effectiveness of the cutset obtained. The WECC system has more than 15 000 buses and 2300 generators. Detailed steps to develop an islanding strategy for a specified contingency for a large system are described in this paper.

**Index Terms**—Controlled islanding, cutset identification, dynamic simulation in the WECC system, slow coherency.

## I. INTRODUCTION

POWER systems subjected to large disturbances may become transiently unstable leading to uncontrolled system separation because of cascading outages. Controlled islanding could help prevent the detrimental impacts of the large disturbance and contain the impact of the disturbance to a smaller island in which the service would be slightly degraded.

Prior research dealing with controlled islanding [1]–[3] provides a controlled islanding strategy using ordered binary decision diagram (OBDD) based method, in which three static constraints are set and an optimum cutset under the three constraints is found. However, neither an effective algorithm for large systems nor any dynamic simulation on large systems is shown. References [4]–[10] provide an alternative controlled islanding strategy based on slow coherency. Additionally, the effectiveness of the slow coherency based islanding strategy has been demonstrated using a WECC 179-bus system in papers [4]–[10].

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An approach to determine the cutset for a power system was discussed and presented, however no integrated general solution or algorithm for cutset determination was developed.

This paper develops a controlled islanding solution for large power systems. An effective and efficient integrated cutset identification algorithm for large power systems is developed and then verified by dynamic simulations on a WECC system representation, which has more than 15 000 buses and 2300 generators.

The paper is organized as follows: Section II introduces the concept of slow coherency and outlines its use in power system islanding; the steps needed to represent a power system network as a graph, and the objectives of the islanding strategy are also outlined; Section III describes the details of the cutset identification algorithm and a software package based on the algorithm is developed to test the efficiency of the method; Section IV demonstrates the dynamic simulation results on the WECC system using the cutset obtained from the software package developed in Section III and discusses the simulation results; finally, Section V provides concluding remarks.

## II. SLOW COHERENCY METHOD AND GRAPH REPRESENTATION OF POWER SYSTEMS

In the controlled islanding approach, a critical step to deal with the generator grouping is based on slow coherency identification [11]–[13]. Following a disturbance, the oscillation of generator angles within an area is much faster than that between areas. After the intra-area oscillations decay only inter-area oscillation exists and generators within the same area move together. These machines swinging together are said to be coherent with regard to the slow modes [12]; in other words, they belong to the same slow coherency group. In this paper, a dynamic reduction tool developed by EPRI, DYNRED [14], especially the “two time scale for generators only” option in DYNRED, is used to identify the slowly coherent groups of generators in a power system under a given operating condition.

Graph representation is then employed to simplify the structure of a power system. A traditional power system network representation contains lots of redundant information with regard to the determination of a cutset. Generally a graph representation utilizes only the following basic information of a power system structure:

- 1) nodes representing buses in the power system;
- 2) branches representing transmission lines and transformers;
- 3) weight of a branch equal to the active power flow in MW through the line or transformer representing the branch.

Note that the branch weight is directed, since the power flow in a branch is directed. Suppose the weight of a branch ( $I, J$ )

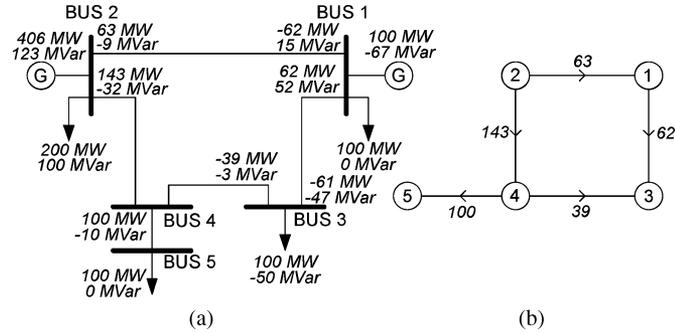


Fig. 1. Five-bus system and its graph representation. (a) Five-bus two-generator system. (b) Graph representation of the five-bus system.

is  $w_{ij}$ , then the weight should be  $-w_{ij}$  if the branch is written as  $(J, I)$ . In graph theory, the notion of the *degree* of a node is defined as the number of branches connected to that node. It could be a positive number or zero.

In the graph representation of a power system, only connections and the power flows through those connections are required. All the other information, such as generators, loads, transformers, FACTS devices and different voltage levels etc, are not necessary. Therefore, it is much simpler to analyze the highly simplified graph representation of a power system than to directly analyze a complex power system itself. For instance, a five-bus two-generator system [10] shown in Fig. 1(a) can be represented as a graph shown in Fig. 1(b).

After the identification of the slowly coherent generator groups and the graph representation of the power system network, the problem of determination of a cutset based on slow coherency for a large power system boils down to finding a cutset in a graph under the following constraints.

- 1) The system is split into given number of islands based on disturbance location and user definition.
- 2) Generators being identified as belonging to the same slowly coherent group are located in the same island.
- 3) The load/generation imbalance is minimized. Additional constraints which check for reactive reserve capability in each island or black start capability in the event of a blackout can also be included without any loss of generality.

### III. CUTSET DETERMINATION ALGORITHM

#### A. Graph Simplification

Generally, a large power system contains more than 10 000 buses and a larger number of branches. For example, the test system used in this paper representing the WECC system contains more than 15 000 buses and 18 000 branches. The computational burden to find a cutset in such a large system will be significant. In order to reduce the computational burden graph simplification is considered.

In [10], three kinds of simplifications are used: removal of degree one nodes, removal of degree two nodes and coarsening. Coarsening is a method to compact a node and all its adjacent nodes into a new node. Coarsening not only reduces the system complexity significantly, but also results in the loss of some connectivity information. In this paper, a more comprehensive sim-

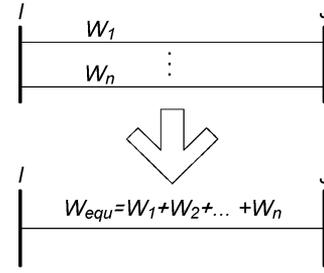


Fig. 2. Equivalence of parallel lines.

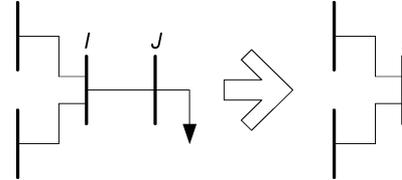


Fig. 3. Removal of degree-one-node.

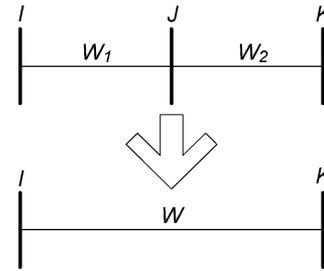


Fig. 4. Removal of degree-two-node.

plification scheme without coarsening, that takes into account the physical construct of the power system network is introduced.

1) *Equivalence of Parallel Lines*: As shown in Fig. 2,  $n$  ( $n \geq 2$ ) branches connect bus  $I$  with bus  $J$ . Each branch has a separate weight  $w_k$  which is equal to the active power in MW through the  $k$ th ( $1 \leq k \leq n$ ) line. After simplification, only one branch is preserved in the graph and the weight of this equivalent branch is  $w_{equ} = w_1 + w_2 + \dots + w_n$ .

2) *Removal of Degree-One-Nodes*: As shown in Fig. 3, bus  $J$  can be removed, when bus  $J$  connects to only one bus (bus  $I$ ) and bus  $J$  is a PQ bus, or bus  $J$  is a PV bus but not grouped in slow coherency identification. Branch  $(I, J)$  cannot be cut in islanding, because a one node island will be formed if branch  $(I, J)$  is cut.

3) *Removal of Degree-Two-Nodes*: As shown in Fig. 4, bus  $J$  can be removed, when bus  $J$  connects to only two buses (bus  $I$  and bus  $K$ ), and no active power is injected at bus  $J$ . Since no active power is injected into bus  $J$ ,  $w_1$  is equal to  $w_2$ . There is no difference in removing branch  $(I, J)$  or branch  $(J, K)$ . Branch  $(I, J, K)$  is replaced with a new equivalent branch  $(I, K)$ . The weight of the new branch is  $w = w_1 = w_2$ .

4) *Removal of Step-Up Transformers*: In power systems, power flows from generators are transferred to high voltage networks through step-up transformers, therefore the tripping of a step-up transformer will probably cause generators connected to that transformer to lose synchronism. It is necessary to remove

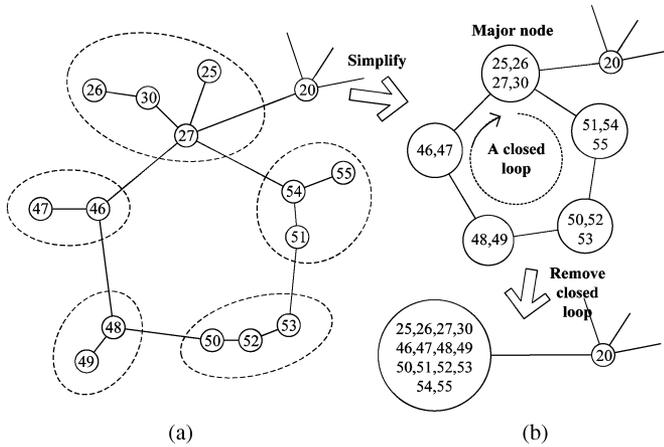


Fig. 5. Closed loop formation process and its simplification.

step-up transformers from the cutset. A step-up transformer is removed by merging the two or three buses that the transformer connects to. Merging two or three buses at different voltage level is not a problem because in a graph representation the associated two or three nodes have no difference.

5) *Removal of Closed Loops*: Some closed loops may form due to the previous simplifying procedures and due to the tree collapse procedure which will be introduced in Section III-B. Fig. 5 is an actual closed loop from the WECC system, which is formed after simplification, in which the bus numbers are re-defined. In Fig. 5(a), the numbers in the circles represent the bus number, and a group of numbers in the ellipses represents a virtual node that is formed by merging several nodes in the simplification procedure.

A closed loop is defined as three or more nodes connected to each other; each node connects two different nodes except one that is defined as major node connects to more than two nodes. Generally, a non-major node in a closed loop contains less than 100 nodes. A closed loop should not be cut in islanding. If one line inside the closed loop is cut, the closed loop will become a straight line and have no effect on the islanding; if more than one line within a closed loop is cut, small islands will be formed, which is not expected. A closed loop is replaced with a single node in the simplification process, as shown in Fig. 5(b).

**B. Tree Collapse**

Since generators belonging to the same slowly coherent group should not be separated into different islands, these generators can be collapsed in to a large virtual node to reduce the system complexity. Beginning from a generator node in the graph, a minimum spanning tree that contains all the generators in that group can be formed; subsequently a new generator node is created to replace the minimum spanning tree; finally all the branches connected to the nodes of the minimum spanning tree are replaced and connected to the new generator node. This procedure is called tree collapse.

Tree collapse is essential to the cutset determination algorithm and guarantees that generators being identified as belonging to the same slowly coherent group are located in the same island. The idea of using tree collapse in islanding was first introduced in [10]; however, in this paper the tree collapse

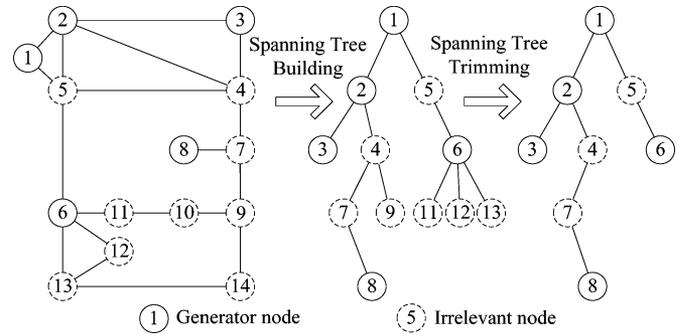


Fig. 6. Demonstration of spanning tree building and trimming algorithm.

algorithm developed is both effective and efficient in handling large power systems.

The effectiveness and efficiency of the tree collapse algorithm depends on three aspects: 1) the selection of the beginning node of the spanning tree; 2) the spanning tree building algorithm; 3) the minimum spanning tree trimming algorithm.

The minimum spanning tree should not only include all generators in the group but also contain as few irrelevant nodes as possible. The spanning tree building algorithm uses the breadth first searching (BFS) algorithm [15], which is a widely used and efficient algorithm in graph theory. The BFS algorithm begins from a node and visits all its adjacent nodes; then for each of these nearest nodes, it visits their un-visited adjacent nodes and so on. In order to contain as few irrelevant nodes as possible and search faster, a generator node with maximum degree is selected as the beginning node of the spanning tree.

Since the spanning tree building algorithm is a general algorithm, the efficiency of the tree collapse algorithm essentially depends on the minimum spanning tree trimming algorithm. A demonstration of spanning tree building and trimming procedure is shown in Fig. 6, in which all the generator nodes are supposed to be in the same group. As a first step, a spanning tree is created from a 14-node graph, and then four of the seven irrelevant nodes are removed to form the minimum spanning tree. The other three irrelevant nodes are retained to build the minimum spanning tree which is expected to contain all the generator nodes in the graph. Note that nodes 10 and 14 are not involved in the spanning tree, because all the generator nodes have been visited before visiting these two nodes. When all the generator nodes have been visited, the spanning tree building process stops.

In the trimming algorithm, the critical step is to judge which irrelevant nodes are not necessary. The details of the trimming algorithm are as follows.

- 1) Determine and record the position of all the generator nodes in the spanning tree.
- 2) Visit a generator node and all its parent nodes and mark them as visited, until a previously visited node is met.
- 3) Repeat step 2 until all generator nodes and their parent nodes have been visited.
- 4) Remove all the nodes that have not been visited in the visiting process.

The trimming algorithm sequentially visits the spanning tree three times. This feature is used since a sequential visit can be

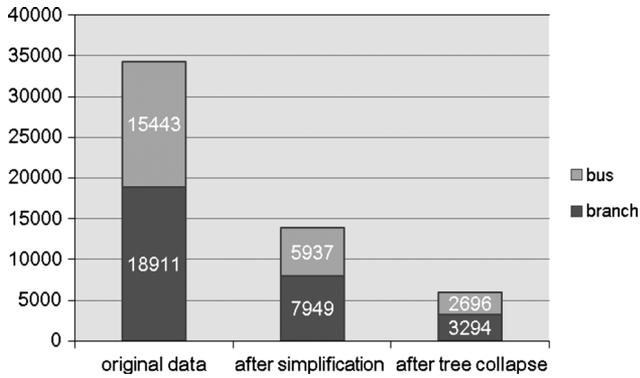


Fig. 7. System size before and after simplification.

implemented with great efficiency. No nested loop is used here, since it generally results in significant computational burden. In the third sequential visiting process, all the nodes that have not been visited in the second visiting process are deemed unnecessary nodes for the minimum spanning tree and should be removed. The tree collapse process replaces the minimum spanning tree with a new dummy node. Branches between a node outside the spanning tree and a node inside the spanning tree are replaced with a new branch that connects to the outside node and the new dummy node; branches between two inside nodes of the spanning tree are removed.

By replacing the minimum spanning tree with a new generator node and modifying all the branches that connected the minimum spanning tree to the new node, the tree collapse procedure is completed.

### C. Effectiveness and Efficiency of the Algorithm

After graph simplification and tree collapse the system complexity is significantly reduced. As shown in Fig. 7, the system size is reduced to 40% and 19% after simplification and tree collapse respectively when the WECC system is tested for separation into two islands identified by the slow coherency grouping. In Fig. 7, the numbers inside the box represents the number of buses and branches of the system.

Both the graph simplification algorithm and the tree collapse algorithm are computationally efficient. A C++ code based on corresponding algorithms is tested on the WECC system, which has 15 443 buses and 18 911 branches. The two algorithms as coded take less than 1 s of computation time on a PC with the following specification: Intel Core2 6700 2.66-GHz CPU and 2 GB memory.

### D. Partitioning and Pre-Processing

Partitioning a graph into several isolated parts is one of the fundamental problems in computer science and has a number of applications in engineering. Several papers have been published and several widely used graph partitioning libraries are available online [16]–[18]. In this paper, a general multi-way balanced graph partitioning library, METIS v4.0 [17] is employed to split the simplified graph into a given number of parts. METIS is prone to split a weighted graph into  $n$  equal parts, with the weight of cut lines of each part minimized.

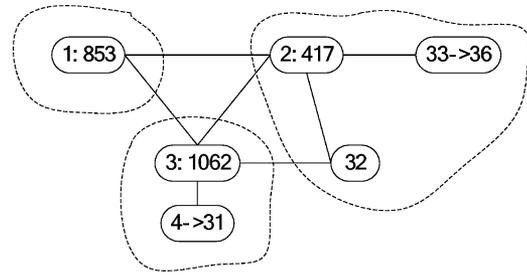


Fig. 8. Island merging demonstration.

The graph is simplified as expected to guarantee that the partitioning results satisfy the three constraints identified before. Except for the three constraints, some extra conditions that are stipulated by users may be satisfied to obtain better dynamic performance after islanding. The conditions include: 1) tripping a specific transmission line or a transformer; 2) guaranteeing that a transmission line or a transformer is not being tripped; 3) retaining a bus in an expected island.

All of these requirements are implemented through pre-processing before converting a power system into its graph representation. The prerequisite is that these conditions should be realizable, which means that these lines, transformers or buses must be located at the border of the slowly coherent groups.

Tripping a specified branch is realized by removing the equivalent branch in the graph in advance and setting the two nodes that the branch connects as belonging to two different groups. Similarly, to guarantee that a specified line or transformer is not tripped, the two nodes that the branch connects are merged in advance in graph pre-processing. In order to retain a bus in an expected island, that bus is marked as a generator node and its grouping property is modified so that it will be merged into the expected island in the tree collapse procedure.

### E. Island Merging

A graph partition library does not always give a practical splitting solution. When a graph to be partitioned is complex, for instance a graph that has more than 5000 nodes and 5000 branches, METIS typically gives more than the expected number of islands [19]. That is, except for the slowly coherent groups of islands, some small extra islands may be formed. An island merging algorithm is invoked to refine the islanding results.

Considering each island as a node of a new graph, the connections between islands can be obtained. Assume  $n$  is the targeted number of islands (the number of slowly coherent groups identified) and  $N$  is the actual number of islands formed. Label these islands from 1 to  $N$ . Fig. 8 is an actual graph splitting result from METIS, in which  $n = 3$  and  $N = 36$ . The notation 1:853 means that island #1 contains 853 nodes. The notation 4->31 means that all the 28 islands, from island #4 to island #31, are connected to the same adjacent island.

There are some characteristics in the islands formed by METIS: 1) the  $n$  largest major islands contain a major portion of the nodes in the graph, while other ( $N - n$ ) minor islands contain a minor portion; 2) each minor island connects to at least one major island, and no minor island connects to another

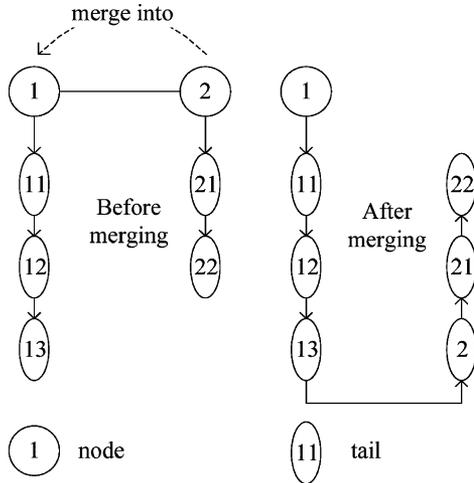


Fig. 9. Node merging and original cutset recovery.

minor island; 3) most minor islands connect to only one major island, and a few minor islands connect to more than one major islands.

According to above characteristics, it is possible to merge minor islands with their adjacent major islands. In this paper, the simplest method is used, in which each major island merges all its adjacent minor islands that have not been merged. Some better methods may be available, for example in Fig. 8, the minor island #32 can be merged into either island #2 or island #3 depending on the load/generation imbalance of the two islands.

After island merging, the cutset and grouping results for each node in the simplified graph can be obtained. Note that the slowly coherent grouping results give only the grouping results for the generator nodes.

#### F. Original Cutset Recovery

In the highly simplified graph, one line which connects two nodes may be equivalent to several lines which connect to several nodes in the original network. The cutset obtained in the final step corresponds to the simplified graph. Consequently, it is necessary to recover the physical lines corresponding to the cutset result in the original network.

A solution to accomplish this objective is to record the simplified node numbers in the graph simplification and tree collapse process by adding a tail for each node. In the tail, all the merged node numbers are recorded. As shown in Fig. 9, consider the case when node 2 is simplified by merging node 2 into its adjacent node 1. In the merging process, both node 2 and its tail nodes 21 and 22 are added as tail nodes of node 1. In the tree collapse procedure, all the nodes in the tree and their tails are added as the tails of the new created dummy node.

Since the grouping results of all nodes in the simplified graph are known, the grouping results in the original graph can be obtained through the tail information. If a node belongs to a certain island in the simplified graph, then that node and all its tail nodes belong to that island in the original graph. It is possible to find out to which island a certain node belongs in the original system. Following this process the cutset in the original physical



Fig. 10. Location of the three 500-kV lines tripped.

system is obtained: a branch that connects two nodes in different islands belongs to the cutset.

The imbalance power of each island can also be obtained from the cutset. Since the power flow is balanced before islanding, the imbalance power of an island is equal to the power flow summation on the lines within the cutset that connect to the island.

## IV. DYNAMIC SIMULATION

The details of the cutset identification algorithm have been introduced comprehensively, and the efficiency of the code based on the algorithm has been demonstrated. In this section, the detailed steps of how to build an islanding strategy for a given contingency are shown with dynamic simulation on the WECC system. These steps include the demonstration of how the lines involved in the contingency are included in the cutset, how to address the problem of low voltages after islanding, and how to avoid generator instability. All the dynamic simulations in this section are performed using TSAT, which is a transient security assessment tool developed by Powertech Labs Inc. [20].

#### A. Simulation Data and Contingency Description

The WECC system data used in dynamic simulation represents the 2009 summer peak load case. The system data consists of 15 549 buses, 2385 generators, 12 667 lines, and 5848 transformers. The overall generation capacity is 166.3 GW and the load is 160.9 GW.

The WECC system consists of 21 areas. The northern areas, such as B.C. Hydro, Northwest, and Alberta, are generation rich areas; most southern areas, especially areas in California including PG&E and Southern California, are load rich areas. About 3000 MW of power is delivered from the North to the South through the tie lines between Oregon and California, which consists of three 500-kV transmission lines, as shown in Fig. 10.

The contingency analyzed consists of tripping these three 500-kV lines. If no action is taken, uncontrolled islanding occurs and some generators will lose synchronism within 5 s. Fig. 11(a)–(c) shows the relative generator angle, generator speed and bus voltage magnitude after contingency respectively. The vertical traces in Fig. 11(a) and (b) are caused by

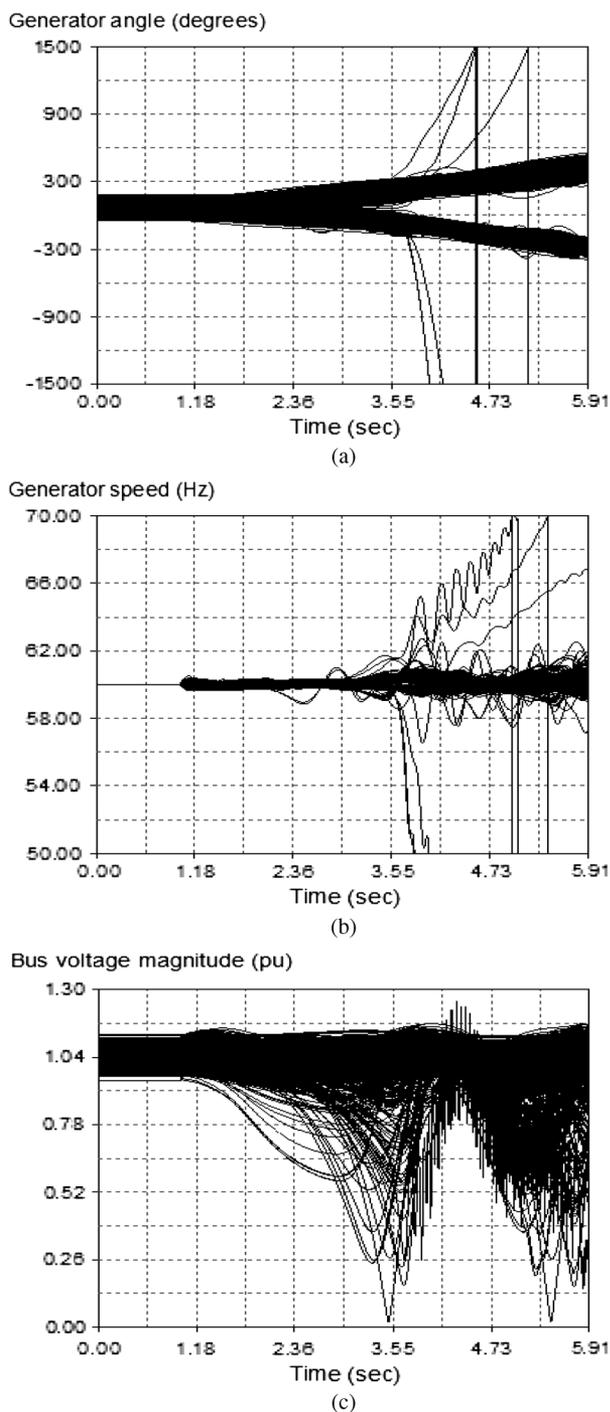


Fig. 11. System post-contingency performance without islanding. (a) Generator angle plots after contingency. (b) Generator speed plots after contingency. (c) Bus voltage magnitude plots after contingency.

the simulation tool. When the value of a parameter is greater than the default upper limit, a vertical trace is shown.

### B. Building Up a Simple Islanding Strategy

This method is used to support offline operations planning. Before obtaining a feasible islanding strategy, candidate cutsets would be identified and tested using dynamic simulation. The cutset that performs best in time-domain simulations in terms of dynamic performance will be selected as the feasible cutset; and

an islanding strategy will be implemented based on the feasible cutset.

As a first step, the slowly coherent grouping results of generator are obtained, in which 2385 generators are identified as belonging to two slowly coherent groups. There are 959 generators that belong to the North group and 1426 that belong to the South group.

The WECC system is thus split into two islands after the contingency. In each island, generators belong to the same slowly coherent group. The two islands also have minimum load/generation imbalance. These are static requirements. The dynamic performance of the islanding strategy will be tested using dynamic simulations conducted using TSAT.

Secondly, some generator buses located at the border of the slowly coherent groups may need to be moved as the slow coherency identification process *does not* consider the contingency. In the case tested, there are four generator buses located in the encircled area in Fig. 10 belonging to the North group. In order to include the contingency into the cutset, the four generator buses are moved to the South group before identifying the cutsets. Generator buses at the border of slowly coherent groups are movable. Theoretically, the slow coherency identification of generators is associated with eigenvectors of the slow modes identified [12]. A generator bus belonging to one slowly coherent group would be separated into another group when the system operating condition varies or the network topology changes.

The identified cutset should include the contingency lines, contain as few lines as possible, have low imbalance power, and provide good dynamic performance.

### C. Performance Evaluation of Islanding Strategies

The performance of an islanding strategy is evaluated using both static and dynamic indices. Static performance requires that a cutset contain as few lines as possible and have minimum imbalance power. Dynamic performance examines generation tripping, load shedding, voltage performance and frequency performance after islanding. Dynamic performance of an islanding strategy is tested by dynamic simulations.

An actual cutset used in this section contains the three 500-kV contingency lines and 17 other lines. Using this cutset, the WECC system is split into two islands: one located in the North and the other in the South, as shown in Fig. 12. The characteristics of each island are shown in Table I, in which the number of generators in each island is shown. Besides, zero impedance lines have been removed and three winding transformers are converted to three equivalent two winding transformers.

### D. Dynamic Simulation and Discussions

In the simulation, the contingency occurs at 1.0 s; 0.3 s later, the islanding strategy is deployed and the 17 lines that form the cutset are opened.

After islanding, the system is separated into two isolated sub-systems: the North island and the South island. Generators in the North island will accelerate as the North island is generation rich; while generators in the South island will decelerate as

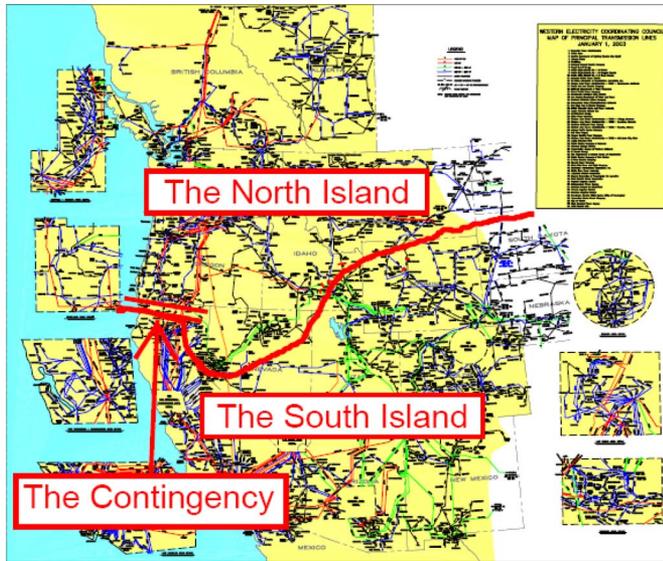


Fig. 12. Location of the cutset and contingency.

TABLE I  
ISLAND INFORMATION

Island	Nodes	Generators	$P_{gen}$ (MW)	$P_{load}$ (MW)	Imbalance Power (MW)
North	7284	955	55174	49704	3379.0
South	8043	1430	111173	111440	-3379.0

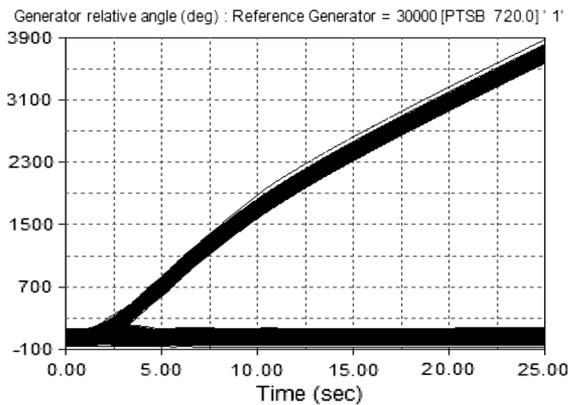


Fig. 13. Generator relative rotor angle plots after islanding.

the South island is load rich. Accordingly, the generator relative rotor angle after islanding will form two distinct groups as shown in Fig. 13. The swing bus is in the South island, so that the relative rotor angles of generators in the South island remain almost constant after settling down, while those in the North island increase at nearly constant speed.

Generator speeds in the South island are lower than 60.00 Hz due to the island being load rich; while those in the North island are higher than 60.00 Hz due to the island being generation rich, as shown in Fig. 14. Generators in both the South and the North islands oscillate during the first 10 s after islanding and reach a new stable operation point finally.

Additionally, generation tripping and load shedding are required to maintain synchronism after islanding. Some generators may lose synchronism after islanding and have to be tripped

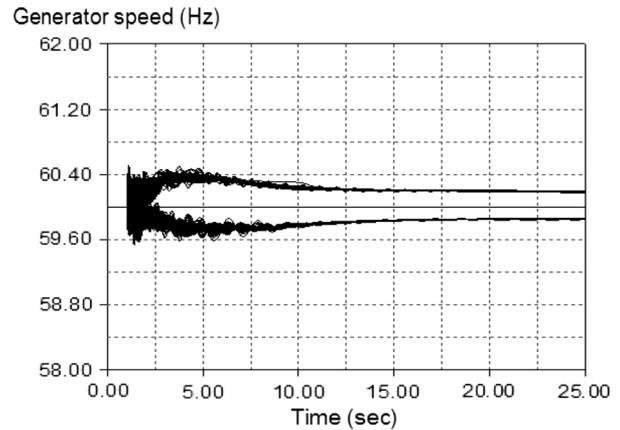


Fig. 14. Generator speed plots after islanding.

following the execution of the islanding strategy. Generation runback is another option to maintain the system frequency in an acceptable range and avoid transmission line overloading in the generation rich islands. Both generation tripping and generation runback are performed immediately after the islanding occurs. Generation tripping is implemented automatically by relays. The governor models represented will compensate for the load-generation imbalance and automatically adjust the required amount of generation. Load shedding is generally automatically implemented by under voltage load shedding relays or under frequency load shedding relays.

In this case, the under frequency load shedding relays will not be triggered because the frequency in the South island is still high enough after islanding. Generally in the WECC system, an under frequency load shedding relay will be triggered when the bus frequency is lower than 59.1 Hz for more than 14 cycles [21].

As shown in Fig. 14, the stable frequency of the South island after islanding is 59.84 Hz, and that of the North island is 60.18 Hz. The acceptable frequency range for the WECC system is 59.4 Hz to 60.6 Hz [21]. The post contingency frequencies in both the South and the North islands are within the safe operation range.

In the simulation, 0 MW of load was shed, 15 generators with a total generation of 205.74 MW were tripped, and three generators were run back by a total generation of 157.5 MW based on governor action. Compared to the total generation of 166.3 GW, the generation tripping or runback is a small portion (0.22%). All the generation tripping and generation runback occurred in the North island.

Fig. 15 shows that neither extreme low nor extreme high voltages occurred after islanding. The voltage oscillation decayed in 10 s. Fig. 16 shows that bus frequency is well behaved also. After islanding, no severe oscillations occur within either the South island or the North island indicating that the islanding strategy implemented provides good dynamic response.

## V. CONCLUSION

It has been shown in this paper that the slow coherency based integrated cutset determination algorithm is effective and efficient for large power systems. The whole calculation took less

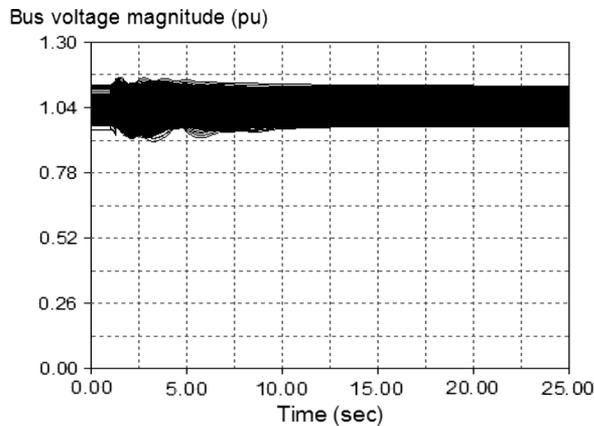


Fig. 15. Bus voltage magnitude plots after islanding.

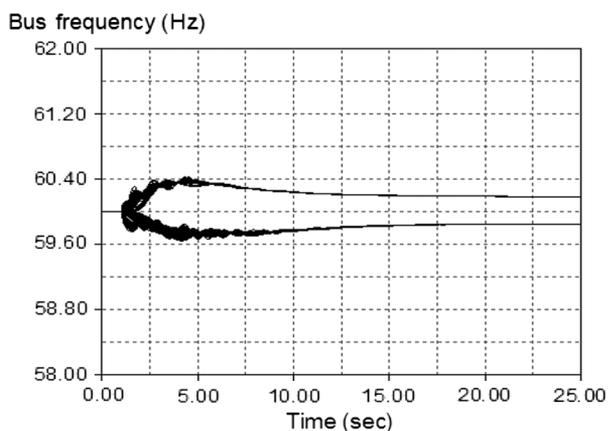


Fig. 16. Bus frequency plots after islanding.

than 3 s to determine a cutset for a power system with more than 15 000 buses using a 2.66-GHz PC and is intended for an offline operations planning environment.

Dynamic simulations conducted on the WECC system for a specified contingency have demonstrated that the islanding strategy based on the cutset obtained is effective. After the contingency, the case without any corrective action will result in uncontrolled islanding and some generators will lose synchronism within 5 s; while the case with the proposed islanding scheme can separate the system into two pre-designed islands and prevent the system from losing synchronism.

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