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AN EARLY WARNING MECHANISM TO ENCOUNTER INTERCONNECTED POWER SYSTEMS CATASTROPHIC FAILURES

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Abstract- In order to provide an early warning procedure for the dispatchers in the control center such that some actions can be taken before encountering a catastrophic failure, a methodology is prpposed in this paper. As a Special Protection Scheme (SPS), power system splitting is the final action against wide-area blackout of interconnected power networks. This action is a comprehensive decision making problem that includes different complicated sub-problems. This paper proposes an approach for separation of the entire power system into several stable islands. The proposed method combines both the dynamic and static characteristics of interconnected power networks and determines the proper splitting schemes. The initial boundaries are determined by BFS algorithm. The presented algorithm applied to NPCC 68-Bus test system. Time domain simulation of the splitting strategy validates the capability of the proposed method.

Keywords: Early Warning, Special Protection Scheme (SPS), Coherency, System Splitting, BFS, Boundary Network.

I. INTRODUCTION

Early warning mechanism development for the power system, in case of controlled islanding provides the final remedial action against major incidence following severe disturbance and catastrophic failures. If there is no proper remedial action in time, immediately after occurrence of the large disturbance, it may lead to a catastrophic failures and power system blackouts [1].

The splitting algorithm of power system is determining the proper separation points for interconnected power networks when preservation of integrity of entire power system is inevitable [1, 2]. Achieving the proper islanding strategy that satisfies all steady state and dynamic constraints within islands is a complicated scenario. Major efforts needed to determine a splitting scheme with two following important characteristics: the speed and the proper action of separation scenario [3]. Although during last decade there were remarkable efforts on controlled islanding of power system, but there are some unsolved problems such as transient stability in the area of the system separation [4].

The proposed method combines the characteristics of topological structure of power systems and load-generation balancing within the islands. The slow coherency theory applied for calculation of the inter-area modes of the system as well as to cluster network machines and buses in different coherent groups as the primary islanding scheme. In the second step of the splitting strategy, a novel approach with spanning tree based breadth first search algorithm implemented to balance and minimize the net load and generation between the island tie lines.

The method searches for minimum load shedding in global and direct manner. Generators can be grouped according to the dynamic behavior of each generator due to specific disturbance [1, 5, 6] as well as the nonlinear interaction among them. In [1] and [6], slow coherency theory used to cluster generators. Slow coherency theoretically determines the weakest connection in a complex power network [1]. Normal form algorithm applied to determine the natural groupings that formed by machines in power system due to nonlinear interaction.

In [2, 3] and [7, 8] an interesting method based on OBDD (ordered binary decision diagram) is applied as a three-phase method to online search for splitting strategies for large scale power systems. In [9] a new approach presented using the continuation method to trace the loci of the coherency indices of the slow modes in the system with respect to variation in system conditions. Reference [10] proposes a new system-splitting scheme based on the identification of controlling group. Compared with the conventional coherent splitting schemes, this method is much more effective under complicated oscillation scenarios.

Reference [11] describes the use of Krylov projection method in the model reduction of power systems. Additionally, a connection between the Krylov subspace model reduction and coherency in power systems is proposed. System separation includes two primary aspects, "where to island?" and "when to island?" Paper [12] seeks to address the "when to island" aspect, which assisted by a decision tree (DT) approach. In [13] authors, develop a combined graph-theoretic-algebraic approach to detect island formation in power system networks under multiple line outages.

Power system operation state is divided into five operating state as indicated in Figure 1. According to this figure, the power system encounter with normal, alert, emergency, in extreme and restorative states. The early warning procedure may start either at alert state, emergency or in extreme. Many relevant papers discussed the control mechanism and stability of power systems. For example in [15] a Multi-objective Honey Bee Mating Optimization (MOHBMO) technique is used to damp power system oscillation by tuning the PSS parameters. Selecting the parameters of PSS, which simultaneously stabilize system oscillations. In the proposed syndicate tuning technique, two performances indicates as ITAE and FD are computed for the stability and performance at each of the given set of operating conditions of the system simultaneously, which leads to use multi objective technique.

In [16] designing and application of an optimal supplementary controller for damping of power swing in a weakly connected power system is investigated. The proposed stabilizer is a SSSC based controller that is designed based on a hybrid PSO and GSA algorithm. The behavior of proposed controller under different loading operating conditions is evaluated. The positive effect of PSS on LFO damping is obviously clear. Proper designing of PSS can increase the positive effect. Therefore, to enhance of the effectiveness, paper [17] presents a novel method to reduce LFO. Since the problem of PSS design can be considered as a multi-objective optimization problem, this paper proposes an improved Particle Swarm Optimization (IPSO) algorithm. A suitable and comprehensive fitness function is also introduced to cover the wide operating conditions.

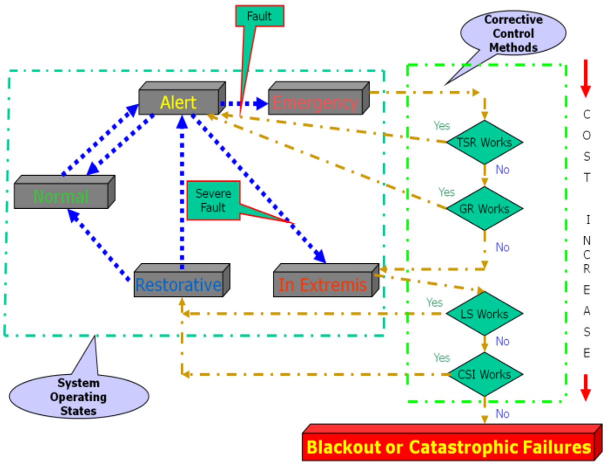

Figure 1. Power system operating states

II. COHENENCY THEORY AND SELECTIVE MODAL ANALYSIS

In this section, the mathematical background of slow coherency theory and selective modal analysis provided. There are many approaches to calculation of a set of selective modes of the system in a large dynamical system [14]. A coherency-based grouping approach requires the states to be coherent with respect to a selected set of modes σ of the system.

This approach allows coherency to be examine in terms of the rows of an eigenvector matrix $\boldsymbol{V}$ that can used to find coherent groups of states. The selection of the slowest modes results in slow coherent groups such that the areas of the system partitioned along the weakest boundaries. Detailed information can obtain in [1] and [25]. In this approach, disturbances modeled as initial conditions. Therefore, a linear system may be model as the following form:

$$\dot{X} = AX \quad , \quad X(0)=0 \tag{1}$$

where, the state x is an n-vector.

According to Equation (2) suppose σ is the selected set of modes of the system:

$$\sigma = \{\lambda_1, \lambda_2, ..., \lambda_r\} \tag{2}$$

where, λ_i is an eigenvalue of A associated with a dominant mode. The definition of coherency is that the states x_i and x_j are coherent with respect to σ if and only if the σ-modes are unobservable from z_k, where z_k defined as (x_i-x_j). This definition implies that coherent states have the same impact, as dominant modes on dynamics, which means the relative rows of V are identical. Modes with high frequency and high damping neglected in long-term studies. By concentrating only on the σ-modes the coherency study will be independent of the location of disturbance.

The power system model linearized about the equilibrium operating point. Neglecting the damping constants that do not significantly change the mode shape and the line conductance which are relatively small compared with the line reactance, a second order dynamic model can be obtain from Equation (2):

$$\ddot{X} = M^{-1}KX \quad , \quad X(0) = X_0 \tag{3}$$

where,

$$x_i = \Delta\delta_i\,,\; m_i = 2\times\frac{H_i}{\omega_r}\,,\; M = \operatorname{diag}(m_1, m_2, ..., m_n)$$

$$k_{ij} = V_i V_j B_{ij}\cos(\delta_i - \delta_j),\quad j \neq i\,,\; k_{ii} = -\sum_{\substack{j=1 \\ j\neq i}}^{n} k_{ij}$$

It has been observed that matrix K has a zero eigenvalue with eigenvector where, u=[11…1]^T. Furthermore, K is symmetric if B is symmetric which is true for transmission networks without phase shifters. In general, B_{ij} are positive and (δ_i-δ_j) are small, which implies that K is a negative semi-definite matrix and the eigenvalues of A are non-positive. Similar to the first order dynamic system, same implication is applicable in the second order dynamic system.

$$\begin{cases} x_1 = x \\ x_2 = \dot{x} \end{cases} \tag{4}$$

where,

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & I_n \\ A & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \tag{5}$$

Assume V to be an σ-eigenbasis matrix of A, and $\Lambda = \operatorname{diag}(\lambda_1, \lambda_2, ..., \lambda_r)$. Based on $AV=\lambda V$, it is easy to obtain the following equation:

$$\begin{bmatrix} 0 & I_n \\ A & 0 \end{bmatrix}\begin{bmatrix} V & 0 \\ 0 & V \end{bmatrix}=\begin{bmatrix} 0 & V \\ AV & 0 \end{bmatrix}=\begin{bmatrix} V & 0 \\ 0 & V \end{bmatrix}\begin{bmatrix} 0 & I_r \\ \Lambda & 0 \end{bmatrix} \tag{6}$$

which means that:

$\begin{bmatrix} V & 0 \\ 0 & V \end{bmatrix}$ is a σ-eigenbasis matrix of $\begin{bmatrix} 0 & I_n \\ A & 0 \end{bmatrix}$.

From the definition, x_i and x_j are coherent if and only if the *i*th and *j*th rows of *V* are identical. This implies that to examine the coherency of the second order system such as that of Equation (2), only the σ-eigenbasis matrix of *A* is required.

Usually in the real dynamic network of a real system, the coherency definition may not be satisfied exactly. Thus, if this definition applied to a real system, there will be, in general, more coherency groups than the number of modes in σ, which means that there are too many groups to be use in islanding. As a result, an approach to finding near-coherent groups will be present such that the total number of near-coherent groups is equal to the number of modes in σ. The areas formed by these near-coherent groups are still coherent with small perturbation.

III. EARLY WARNING DEVELOPMENT ALGORITHM

The proposed algorithm designed such that preserves the primary dynamic based islanding feature and obtains global minimum load shedding solution. The concept of the new proposed algorithm illustrated in Figure 2. In the figure, the primary boundaries between each coherent group of generators and buses, which is the result of primary grouping algorithm, presented. Suppose that area A has common boundaries with area B and C.

The passive boundary network between each area with other adjacent area called boundary network. The lines that connect each area to the others called boundary lines, and the buses that are connected to these lines called boundary buses. Each area connected to the adjacent areas by the boundary lines. All load buses on the trees that originated from boundary buses and expanded to the adjacent areas, while they have no direct connection to a generator bus, are members of boundary network. For example in Figure 2, the lines and buses that indicated with dashed lines belong to a boundary network.

It should be notice that boundary network only includes the load buses and there is no generator bus. The idea is that it is possible to select some buses of the adjacent areas and bring them into the other islands. This has done by directly minimizing of total load-generation imbalance within islands. For each spanning tree originated from boundary buses, all branches of spanning trees are determined and introduced as a candidate case for the adjacent area. In Figure 2, B1, B3, B8, B11, and B15 buses are adjacent buses. For example if the algorithm determines that B11 should be transfer from area B to area C, and B8 brought to the area A, according to minimum load shedding algorithm. In this situation the lines L7, L8 instead of L1, L2, and L10, L11 instead of L4 should be trip off respectively. For this case L1, L2 and L4 should be remove from switching lines list and L7, L8, L10 and L11 should be add to new switching lines group to form new islands.

The maximum number of buses that can be transfer into the adjacent areas called penetration bus and can be select by the user. The upper limit of penetration buses depends on the network structure and number of initial islands and can be determine by the dimension of electrical distance matrix between each boundary bus and machine bus. This matrix called the boundary bus electrical distance matrix (BEDM). BEDM is a matrix that determines the electrical distances between each adjacent or boundary bus and each generator in the other islands.

It is evident that if the boundary of islands changes due to new algorithm, then the number of tripping lines also must be change. The maximum acceptable numbers of new lines within each area that can be tripped off, and called maximum cutting line and can be select by dispatcher. A spanning tree based breadth first search algorithm used to determine all possible combinations of buses that can be interchange between all areas. By knowing that the numbers of adjacent buses in a real islanding scenario are small, the maximum number of possible combinations considerably decreased and it is possible to find the global solution for minimum load shedding.

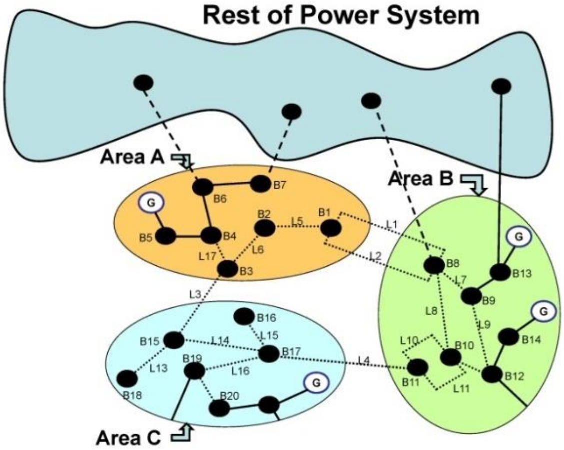

Figure 2. Power mismatch balancing concept

The value of minimum load shedding for each scenario can be calculated directly as:

$$\min\ LS=\sum_{i=1}^{n-Islands}\left|P_{G-Island}(i)-P_{L-Island}(i)\right| \tag{7}$$

In Equation (10) $P_{G\text{-}Island}(i)$ and $P_{L\text{-}Island}(i)$ are total generation and the load of *i*th island respectively that are obtained from Equations (8) and (9). *LS* is the total load shedding of the islanded system.

$$P_{G-Island}(i)=\sum_{k=1}^{Island-Gen}\left(P_G(k)\right) \tag{8}$$

$$P_{L-Island}(i)=\sum_{h=1}^{Island-Load}\left(P_L(h)\right) \tag{9}$$

where, $P_G(k)$ and $P_L(h)$ are the generation of the machine *k* and load of bus *h* in each island, respectively.

For each splitting pattern and each island, the total sum of generation and load calculated by Equations (8) and (9). The generators of each island remain in the same island, and the total generation of each island is constant and does not change with the different islanding patterns. In the contrary, the loads of each island can be varying from primary case by the transferred buses to the other areas.

IV. RESULTS FOR POWER SYSTEM SPLITTING

This section contains the main results related to application of novel algorithm on NPCC 68BUS system that is a benchmark for power system islanding studies. The system data of the interconnected test system has given in [4]. The single line diagram of the test system is indicated in Figure 3.

The primary task for interconnected power networks splitting is the determination of interarea oscillation modes based on its basic inherent nature. In Table 1 all modes and frequency of the NPCC 68 bus system is indicated. Among all modes, table 2 shows the inherent interarea modes of the test system. According to the table, there are five interarea oscillation modes in this system. Figures 4-8 show the participant of system machines in each mode. According to these figures almost all machines is participate at existing of the above modes and therefore, there are interarea oscillation modes of the test system.

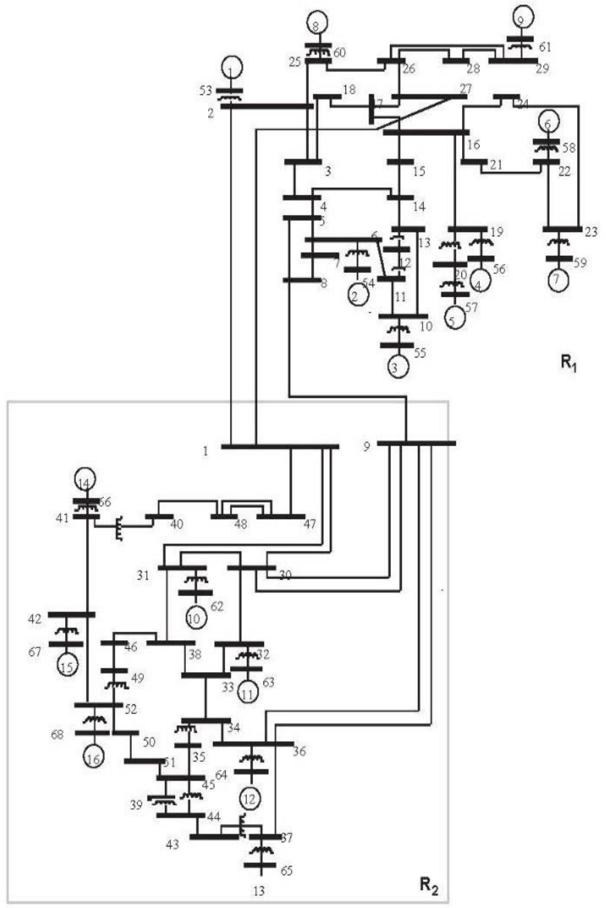

Figure 3. NPCC 68-bus system with primary six areas [3]

Table 1. All modes and frequency of the NPCC 68-bus system

No	Modes	Frequencies	No	Modes	Frequencies
1	0-0.0004*i*	6.6897e-005	17	0-7.2003*i*	1.146
2	0-0.0004*i*	6.6897e-005	18	0+7.2003*i*	1.146
3	0-2.3166*i*	0.36869	19	0-7.5018*i*	1.194
4	0+2.3166*i*	0.36869	20	0+7.5018*i*	1.194
5	0-3.1518*i*	0.50162	21	0-7.7049*i*	1.2263
6	0+3.1518*i*	0.50162	22	0+7.7049*i*	1.2263
7	0-3.7614*i*	0.59865	23	0-7.9849*i*	1.2708
8	0+3.7614*i*	0.59865	24	0+7.989*i*	1.2708
9	0-4.9376*i*	0.78584	25	0-9.2278*i*	1.4686
10	0+4.9376*i*	0.78584	26	0+9.2278*i*	1.4686
11	0-5.9915*i*	0.95358	27	0-9.2364*i*	1.47
12	0+5.9915*i*	0.95358	28	0+9.2364*i*	1.47
13	0-6.4605*i*	1.0282	29	0-9.468*i*	1.5069
14	0+6.4605*i*	1.0282	30	0+9.468*i*	1.5069
15	0-7.0364*i*	1.1199	31	0-10.998*i*	1.7504
16	0+7.0364*i*	1.1199	32	0+10.998*i*	1.7504

Table 2. Inrearea modes and frequencies of NPCC 68-bus system

Mode No	Eigenvalue	Frequency (Hz)	Damping	Mode Type
1	0-0.0004i	0.000067	0	Interarea
2	0-2.3166i	0.3678	0	Interarea
3	0-3.1518i	0.5016	0	Interarea
4	0-3.7614i	0.5987	0	Interarea
5	0-4.9376i	0.7858	0	Interarea

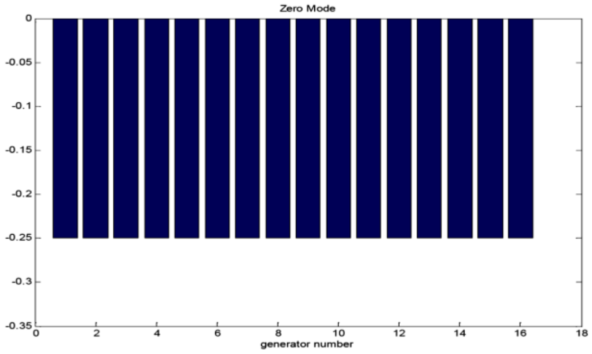

Figure 4. Generators participant on interarea mode number 1

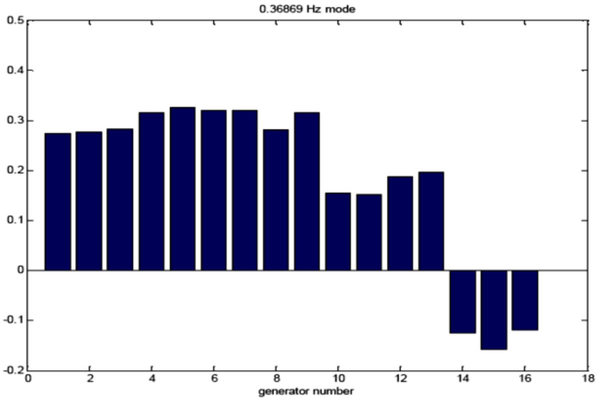

Figure 5. Generators participant on interarea mode number 2

Table 3 and Figure 9 illustrate some of possible case with their corresponding load shedding. In this table, the primary and final load shedding magnitude is indicated. If the dispatchers decide to split the entire power system into two islands according slow coherency theory, the amounts of load shedding for some of (*MPB*, *MCP*) presented with respect to the number of possible status.

For example in the status of (*MPB*, *MCP*) = (6, 6) in the figure there are 150 feasible scenarios in which the amount of load shedding is less than the base situation. In total for (*MPB*, *MCP*) = (6, 6) there are 521 possible combinations of bus configuration. Figure 9 indicates that with the increasing of MPB and MCP the load-shedding scenario improved in general. The minimum load shedding reduces to 3.3% of the total load. The minimum values of load-generation imbalance with respect to number of penetration bus and maximum cutting lines for the two islanding case indicated.

In this case, the minimum load shedding is obtained when maximum penetration bus is 6 and maximum cutting line is 4 respectively. So, the minimum amount of load shedding obtained for (*MPB*, *MCP*) = (6, 4) status.

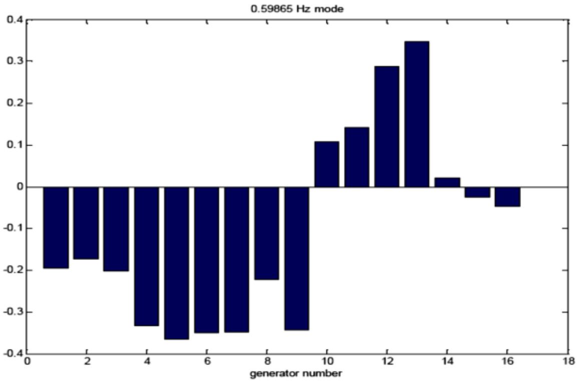

Figure 6. Generators participant on interarea mode number 3

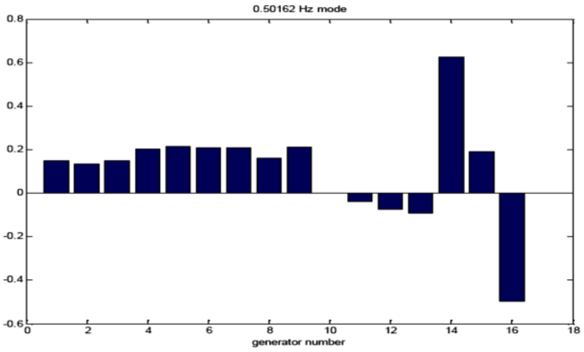

Figure 7. Generators participant on interarea mode number 4

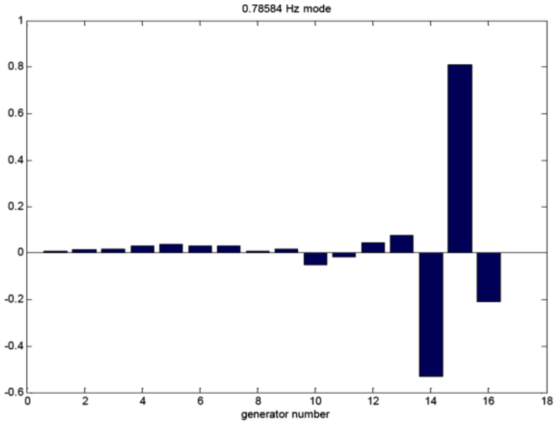

Figure 8. Generators participant on interarea mode number 5

Above this optimum point, the amount of load that has shed can not be further improved. In this figure, the upper surface shows the value of load shedding at base case and the lower one indicates the minimum load shedding respect to the (*MPB*, *MCP*).

Table 3. Possible contribution of the boundary bus in splitting scenario

No	To Island	From Island	Boundary Bus	Transferred Bus	Best Case	Primary LS (pu)	New LS (pu)	New / Primary LS
1	2	1	50	51	5	19.65	10.52	46.44
2	2	1	50	45-51	4	19.65	10.53	46.41
3	2	1	50	35-45-51	2	19.65	13.2	32.82
4	2	1	50	39-45-51	3	19.65	13.2	32.82
5	2	1	50	44-45-51	1	19.65	15.28	22.24
6	1	2	51	50	6	19.65	21.65	-10.18

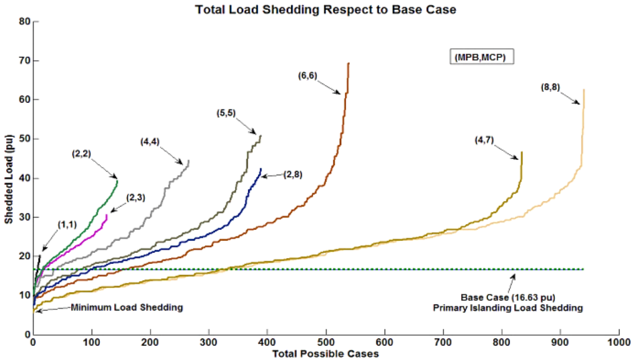

Figure 9. Load-generation balancing for two-area case

Table 4 shows that the amount of load shedding depends on the number of transferred buses and maximum cutting lines. From table 4 it can be seen that according to primary islanding strategy and without implementation of new algorithm, 16.63 pu of total 184.2 pu load should be shed which is 9% of total system load. Application of new algorithm decreases amount of total load shedding to 10.5 pu that is only 5.8% of total load.

For the verification of the effectiveness of the presented method a solid three phase fault is occurred on line connecting bus 49 to 52 closed to bus 49 at t=1.0 second and is cleared after 0.3 seconds by removing the faulted line. Time domain simulation shows that the interconnected system is unstable if there is no corrective control action. To prevent from wide-area blackout and catastrophic failure, automatic islanding strategy should be execute as soon as possible. For this fault, the studied power system is transiently unstable and islanding strategy should be executed. Because of the considerably reduction of huge initial search space by the new strategy the total spent time to find a proper splitting is reduced below 0.4 second for all cases. It means that we can run the splitting strategy almost 0.7 second after initial disturbance (0.4 second + fault clearing time).

The islanding algorithms should be applied to the faulted system as soon as possible. The dispatching center decided to split the integrated power network into two islands, two second after removing the faulted line. The splitting strategy is executed at t = 3.3 seconds. Based on time domain of simulation results the primary islanding strategy is unstable with long term simulation if there is not any load-shedding scenario.

Table 4. Load shedding values and the number of transferred buses and maximum cutting lines

No	To Island	From Island	Boundary Bus	Transferred Bus	To Island	From Island	Boundary Bus	Transferred Bus	Case Number	Primary LS (pu)	New LS (pu)	New / Primary LS
1	5	6	27	1-47	4	6	50	51	181	16.63	7.70	53.68
2	5	6	27	1-47	4	6	49	46-38-33	180	16.63	9.44	43.20
3	4	6	49	46-38-33	4	6	50	51	225	16.63	9.63	42.07
4	5	6	27	1	4	6	50	51	172	16.63	9.73	41.47
5	5	6	27	1-47	3	6	48	47	177	16.63	10.04	39.62
6	3	6	48	47	4	6	50	51	219	16.63	10.23	38.49
7	5	6	27	1-47	4	6	49	46	178	16.63	10.56	36.36
8	4	6	49	46	4	6	50	51	221	16.63	10.75	35.33
9	5	6	8	9	5	6	27	1-47	62	16.63	11.03	33.66
10	5	6	8	9	4	6	50	51	72	16.63	11.22	32.53
11	5	6	27	1	4	6	49	46-38-33	171	16.63	11.47	30.99
12	3	6	48	47	4	6	49	46-38-33	218	16.63	11.97	28.01
13	5	6	27	1-47	-	-	-	-	12	16.63	12.07	27.41
14	4	6	50	51	-	-	-	6	22	16.63	12.26	26.27
15	5	6	27	1	4	6	49	46-38	170	16.63	12.59	24.25
16	5	6	8	9	4	6	49	46-38-33	71	16.63	12.96	22.05
17	5	6	8	9	5	6	27	1	61	16.63	13.06	21.44
18	5	6	48	47	4	6	49	46	216	16.63	13.09	21.28
19	3	6	48	47	4	6	49	46-38	217	16.63	13.09	21.27
20	5	6	8	9	3	6	48	47	68	16.63	12.96	22.05

This implied that some islands of the separated system are unstable respect to frequency stability point of view. Application of the proposed algorithm not only reduces the amount of load shedding during power system splitting but also creates stable islands.

Table 5 only shows the results of the primary separation of interconnected power system and results of the power system splitting with the new algorithm, according to degree of coherency of inter-area modes into two and six islands. To the test system, all initial islands that formed by the coherency-based algorithm are unstable without load shedding, except the strategy that splits the system into three primary islands. By application of the new proposed method all initially formed islands are stable and the minimum possible load shedding has achieved.

In general, the islanding strategy should be execute as soon as possible if the dynamic assessment program predicts the system out of speed condition. In this paper for the examination of robustness of the new splitting strategy, the strategy executed two seconds after fault clearing which is very large time window in islanding problem. Results show that the islands formed by the new strategy are stable for all the cases. Table 5 also summarized and compared the results of the splitting based on the primary slow coherency algorithm and new proposed scheme. It should be mention that many of the practical aspects of given network, such as tie line availability, has considered in the algorithm. The dispatcher can select arbitrary unavailable tie line by the algorithm. In fact, this is some of the advantages of the proposed method for the flexible selection of the candidate's lines for contribution at the islanding scenarios.

In addition, it is possible to system engineers to consider owns experiences at the system separation, for example if the dispatchers decide to remain a specified bus at a given island, it is implementing by the algorithm easily. The number of islands determined by the dispatchers and the automatic islanding program finds the proper islanding strategies for each given fault. From Table 5 it can be seen that the machines configuration in each islands respect to primary islanding pattern remain unchanged and only the load buses of islands may be transferred to the other area, hence the first two columns of Table 5 are same for primary and new splitting case.

In Table 5, the results of islanding based on new algorithm are compared with the primary islanding scheme. From the table it can be see that the numbers of disconnecting lines increased in some cases. The capability of the algorithm is that, only by changing of some boundary buses we can create stable islands and obtain better load shedding results.

Figure 10 shows the frequency deviation of the islanded power system with new algorithm. The figure indicates that new algorithm creates two stable islands in which the frequencies of all islands are within acceptable limits. The figure clearly indicates the separation of entire power network into two independent islands. A three-dimension plot of islanded power network has shown in Figure 10. The figure provides a good view of the speeds of all machines within the islands. Group 1 contains 13 generator, generators (Gen$_1$-Gen$_{13}$) and group two includes 3 generators namely Gen$_{14}$-Gen$_{16}$. The last generator group is very large equivalents of the other power system.

The obtained results prove the capability and effectiveness of the proposed method. One of the advantages of the proposed method is that it usually changes the boundary of the primary islands and changes the lines that should be remove. In slow coherency based islanding the lines that should be remove, are usually inter-area tie lines, which have more switching problem when they removed or closed. The new algorithm changes the switching lines that are probably short lines. The short lines are well suited for switching action and restoration scenario.

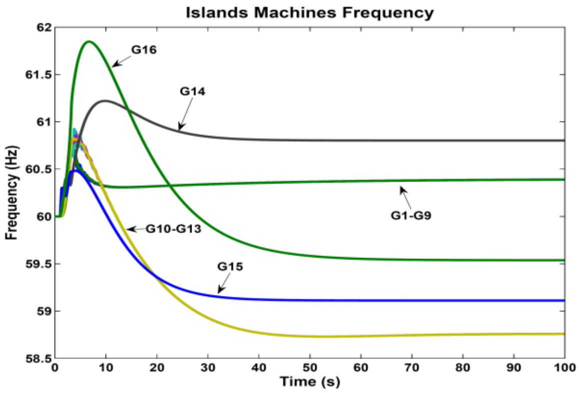

Figure 10. Machines speed of proper-islanded system into five islands

Table 5. Splitting points with primary and new proposed islanding algorithm

No. of Islands	Island Machines	Island Buses (Base)	Island Buses (New)	Splitting Points (Base)	Splitting Points (New)
2 Islands Case	G1-G13	Others	Others	B40-B41, B50-B51, B49-B52	B43-B44, B35-B34, B40-B41, B49-B52
	G14-16	B41, B42, B50, B52, B66, B67, B68	B41, B42, B50, B52, B66, B67, B68		
6 Islands Case	G1-G7	Others	Others	B41-B42, B47-B48, B47-B48, B46-B49, B50-B51, B1-B2, B2-B25, B52-B42, B1- B27, B26-B27	B41-B42, B47-B48, B47-B48, B46-B49, B46-B49, B35-B45, B43-B44, B1-B2, B2-B25, B17-B27, B8-B9, B1- B30, B1-B31, B52-B52
	G8-G9	B25, B26, B28, B29, B60, B61	B25, B26, B28, B29, B60, B61		
	G10-G13	B1, B9, B30, B31, B32, B33, B34, B35, B36, B37, B38, B39, B43, B44, B45, B46, B47, B51, B62, B63, B64, B65	B1, B9, B30, B31, B32, B33, B34, B35, B36, B37, B38, B39, B43, B44, B45, B46, B47, B51, B62, B63, B64, B65		
	G14	B40, B41, B48, B66	B40, B41, B48, B66		
	G15	B42, B67	B42, B67		
	G16	B49, B50, B52, B68	B49, B50, B52, B68		

V. CONCLUSIONS

In this paper, a novel strategy based on simultaneous application of both static and dynamic characteristics of an interconnected power system presented for proper islanding of power networks. The methodology calculates the splitting points of the integrated power system considering the frequency stability of the islands as well as minimum load shedding within areas. The presented method searches by spanning tree based BFS algorithm in the boundary of primary feature of clustered islands specified by the slow coherency theory. The algorithm determines the best splitting points such that the total shed load minimized and stability of the islands is preserved. The proposed approach finds the proper islanding pattern in a very fast and accurate manner. The algorithm can overcome the inherent time-consuming nature of the islanding schemes and is suitable for real time separation of power systems.

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BIOGRAPHY

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