Technique to Develop Auto Load Shedding and Islanding Scheme to Prevent Power System Blackout

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Abstract—**Abnormal condition in a power system generally leads to a fall in system frequency, and it leads to system blackout in an extreme condition. This paper presents a technique to develop an auto load shedding and islanding scheme for a power system to prevent blackout and to stabilize the system under any abnormal condition. The technique proposes the sequence and conditions of the applications of different load shedding schemes and islanding strategies. It is developed based on the international current practices. It is applied to the Bangladesh Power System (BPS), and an auto load-shedding and islanding scheme is developed. The effectiveness of the developed scheme is investigated simulating different abnormal conditions in BPS.**

Index Terms—**Auto load-shedding, islanding, rate of change of frequency, under frequency load shedding.**

I. Introduction

RECENTLY, three blackouts occurred in Bangladesh due to the failure of the national grid. The first two failures occurred in the same day, in the morning and in the evening of November 15, 2007, the next day of the occurrence of hurricane Sidr. The third one occurred on December 14, 2007.

The digital fault data recorder (DFDR), installed at four locations of the grid, recorded frequency, current, and voltage of few cycles before the occurrences of the blackouts. The DFDR starts recording data only when the system frequency crosses the pre-specified lower or higher threshold values. The frequency record from a DFDR on the third blackout is shown in Fig. 1.

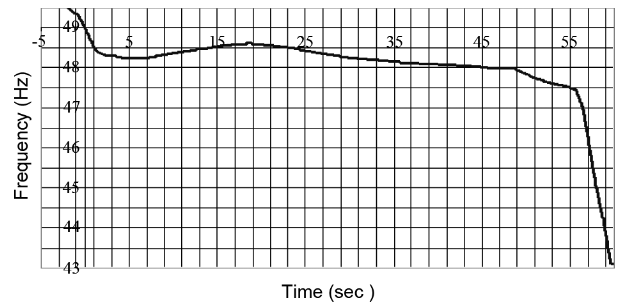

Fig. 1. Falling frequency during blackout on December 14, 2007 from DFDR records.

These three blackouts created a total system interruption of 110 GWh. The total loss in terms of loss of revenue and the loss of consumers due to interruption was 15.9 million USD. The restoration of the total system was not possible at a time; rather the system was brought to normal state integrating the total grid part by part. Neither the above revenue loss nor the interruption cost includes the partial disintegration of the system.

Emergency load-shedding for preventing frequency degradation is an established practice all over the world. The objective of load shedding is to balance load and generation. Since the amount of overload is not known at the instant of disturbance, the load is shed in blocks until the frequency stabilizes. Different techniques are available for implementing the load shedding scheme. The three main categories of load shedding schemes are [1]:

1) traditional;
2) semi-adaptive;
3) adaptive.

The traditional load shedding is mostly used among the three schemes [2], because it is simple and does not require sophisticated relays. The traditional scheme sheds a certain amount of load when the system frequency falls below a certain threshold. If this load drop is sufficient, the frequency will stabilize or increase. If this first load shed is not sufficient, the frequency keeps on falling at a slower rate. When the falling frequency reaches a second threshold, a second block of load is shed. This process is continued until the overload is relieved or all the frequency sensitive (FS) relays have operated [3]. The values of the thresholds and the relative amount of load to be shed are decided offline, based on experience and simulations. Traditional load shedding scheme has mostly conservative settings because of the lack of information regarding the magnitude of the disturbance [4]. Although this approach is effective in preventing inadvertent load shedding in response to small disturbances with relatively longer time delay and lower frequency threshold, it is not able to distinguish between the normal oscillations and the large disturbances of the power system. Thus, this approach is prone to shedding lesser loads at large disturbances.

The semi-adaptive load shedding scheme [5] uses the frequency decline rate as a measure of the generation shortage. The activation of this scheme depends on the rate of change of frequency (ROCOF) when the system frequency reaches a certain threshold. According to the value of ROCOF, a certain amount of load is shed. That is, this scheme checks the speed at which the threshold is exceeded: the higher the speed, the more load is shed. Usually, the measure of the ROCOF is evaluated only

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at the first frequency threshold, the subsequent ones being traditional. In this scheme, the ROCOF thresholds and the size of load blocks to be shed at different thresholds are decided offline on the basis of simulation and experience. But the scheme adapts to the system disturbance as the actual amount of load blocks to be shed is decided by the frequency droop (FD) relay depending on the rate of frequency change.

Sometimes, blackout can be prevented in real time through controlled disintegration of a system into a number of islands together with generation tripping and/or load shedding [6], [7]. Disintegrating a grid system into a number of islands can be considered either as a last resort [8] or as a primary measure [9]. The basis for islanding is never unique and depends upon the utility in particular.

A large number of papers on the application of different load shedding techniques and islanding approaches for the stability and prevention of blackout of a power system is reported in the literature [4],[6],[8]–[11], particularly in the last two decades. However, to authors' knowledge, a global solution of the problem of blackout or instability of a power system describing the sequence and conditions of the applications of load shedding and islanding approaches has not yet been reported in the literature. Rather, each technique/methodology presents a solution of a particular condition relating to the stability of a system.

This paper presents a technique to develop a frequency dependent auto load-shedding and islanding scheme to bring a power system to a stable state and also to prevent blackouts under any abnormal condition. The technique incorporates the sequence and conditions of the application of different load shedding schemes and islanding strategies. The technique is developed based on the international current practices. It uses the magnitude and the falling rate of change of frequency in an abnormal condition to determine the relay settings offline. The paper proposes to implement the technique using only FS and FD relays. The technique is applied to the Bangladesh Power System (BPS), and an auto load-shedding and islanding scheme is developed. That is, a set of relay setting is determined using the proposed technique for BPS. The developed scheme is validated simulating different abnormal conditions in BPS. The simulation results are presented in [12].

II. Proposed Technique

Abnormal condition in a power system generally leads to a fall in system frequency. The usual solution to rescue the system from this sort of state is the load shedding. However, in some cases the load shedding may be unnecessary as the system makes itself stable by providing additional input from its stored kinetic energy or from the spinning reserve or by lowering the system frequency within acceptable limit. In some cases, the magnitude of load shedding may be inappropriate, that is more or less than required, to make the system stable by maintaining the system frequency within acceptable range.

In some cases, only load shedding cannot rescue the system from total collapse. In that case, the system may be disintegrated into a number of islands. The main advantages of islanding are 1) easier to minimize generation-load imbalance in an island than that in a large integrated system and 2) quicker to restore the system by integrating the islands than restoring the whole system from a blackout state [11].

The technique proposed in this paper is a heuristic one that considers all these issues and develops a comprehensive solution to the instability of a power system. The technique is based on three schemes: 1) traditional load shedding, 2) semi adaptive load shedding, and 3) disintegration of the grid. The traditional load shedding scheme is implemented through FS relays. The scheme is activated only when the system frequency, f, falls below a certain threshold value, f_{TH}. The implementation of other schemes requires FD relays.

A. Sequential Steps

The proposed scheme is implemented in steps, sequentially. The activation of number of steps depends on the state of the system. Different steps of the technique are as follows.

Step 1) System frequency and ROCOF are continuously monitored by FS and FD relays, respectively.

Step 2) The traditional load shedding scheme is activated if $f < f_{TH}$ and $|df/dt| < m_o$. The ROCOF based load shedding scheme is activated instead of traditional one, if $f < f_{TH}$ and $m_o < |df/dt| < M$. m_0 and M are ROCOF related threshold values. The magnitude of M is much higher than m_o. Grid disintegration scheme is activated only when $f < f_{TH}$ and ROCOF exceeds M. That is, disintegration scheme is implemented if $f < f_{TH}$ and $|df/dt| > M$.

Step 3) The system starts measuring time once the ROCOF based load shedding is activated. After the preset time delay (TD), k_1, if the system frequency is still below the threshold value, f_{TH}, the traditional load shedding scheme is activated.

Step 4) The system frequency is checked after another preset TD, k_2, where k_2 is greater than k_1. At this time, if the system frequency is lower than f_{TH}, and ROCOF is negative, then disintegration scheme is activated.

Step 5) Once the disintegration of grid scheme is implemented, generation is adjusted appropriately in each island if the islanded system frequency is higher than the rated. If in an islanded system $f < f_{TH}$ and $|df/dt| < m_i$, traditional load shedding scheme is activated. Here, m_i is the rate of change of frequency related threshold value of the ith island. However, if $f < f_{TH}$ and $|df/dt| > m_i$, then the ROCOF based load shedding scheme is activated.

Step 6) After implementing ROCOF based load shedding in an island, if the elapsed time is more than the preset TD, k_3 and the frequency is still less than threshold value the traditional load shedding scheme in that island is activated.

The sequence of implementation of different steps of the proposed technique is represented in Fig. 2 to illustrate the technique.

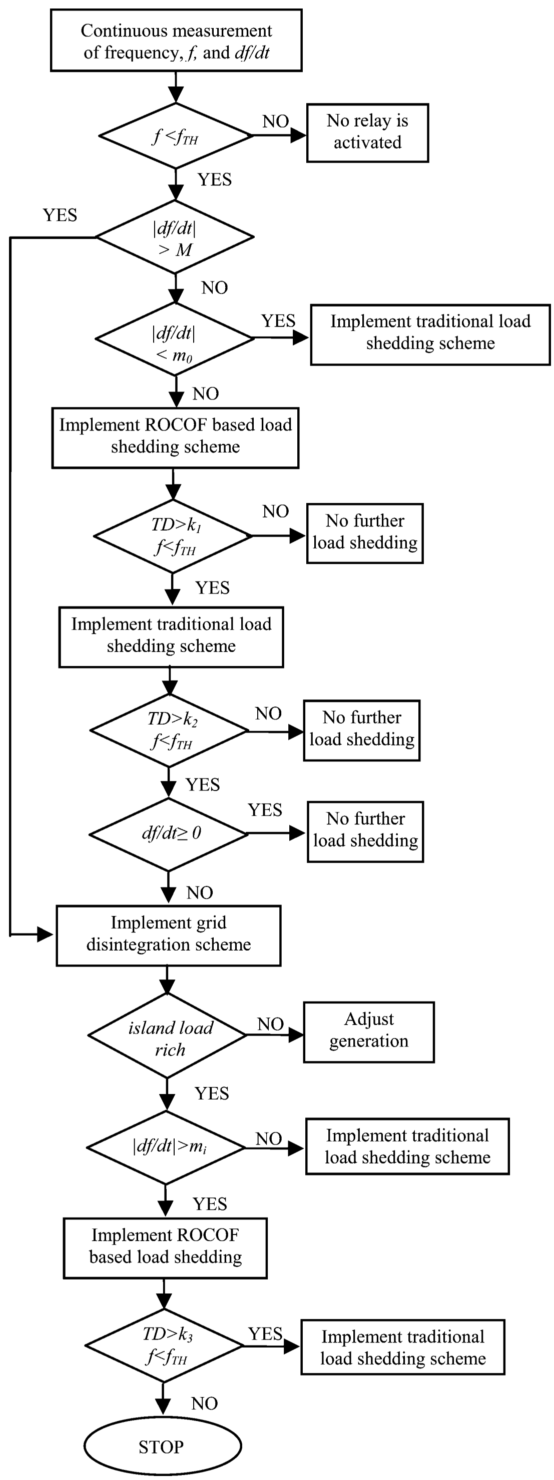

Fig. 2. Flow chart illustrating different steps of the technique.

B. Determination of Threshold Values

The first frequency threshold, f_{TH}, is a limiting frequency state of a power system. That is, the system cannot return to steady state condition without any load shedding relay activation if the frequency drops below f_{TH}. The equipment that are more sensitive to frequency drops are generators, auxiliary services, and steam turbines [2], [13]. Auxiliary services of a power plant are more demanding than generators in terms of minimum allowable frequency; in fact, they begin to malfunction at a frequency of 47.5 Hz (57 Hz in case of 60 Hz system), while the situation becomes critical, creating cascade effect, at about 46–44 Hz (55–53 Hz in 60 Hz system).

At any frequency state between nominal and f_{TH}, the system is supposed to be self-stable, without any relay activation, through its stored energy and or spinning reserve. However, stored energy and spinning reserve are very much system dependent. Therefore, the more accurate value of f_{TH} may be determined through experience and simulations.

In [4], the threshold value of ROCOF, m_0, is determined using a reduced model for a reheat unit. Considering constant system inertia, H, the methodology arrived at a solution that if 30% of the system real power is disturbed the system leads to exceeding the threshold value of ROCOF. Although in a small system H does not remain constant when multiple synchronous machines are disconnected from the system [3], however, this can be an approach of determining m_0.

The proposed technique prefers to determine m_0 heuristically from a series of simulation results and it considers m_0 as the lowest value of ROCOF for which the system can not be returned to the targeted steady state frequency range using traditional load shedding approach. The threshold value, m_i, corresponding to the ith island is also the lowest value of ROCOF at which state the ith disintegrated part of the power system cannot be returned to steady state condition, after islanding, with the traditional load shedding scheme.

The technique proposes in Section II-A that if traditional and ROCOF based load shedding approaches fail to bring a system into a steady state condition from an abnormal state, islanding is the last resort to rescue the system. Step 2 of this subsection also presents that if ROCOF is very high, islanding should be the first step instead of following the traditional and ROCOF based load shedding approaches. The threshold value, M, for such a case is determined heuristically, based on experience and simulation results.

Note that all the above threshold values are determined offline.

C. Determination of Magnitude of Load Shedding and Time Delays

The magnitudes of load shedding of different steps of traditional scheme are not the same, and each step is implemented with certain time delay. The time delay corresponding to a step may be different from that of another step. The magnitude of load shedding of ROCOF based scheme is also different from that of the traditional one. Several load shedding solutions are available worldwide. A collection of them is presented in [1].

The sensitivity of the system frequency to the change of loads located at different places in the system is evaluated. In [14], it is reported that the shedding of loads near the lost generator is more effective. Also frequency response characteristics of the system are evaluated for generator capacity outages of different magnitude of different locations.

The load shedding of traditional and ROCOF based semi adaptive schemes are presented in Table I. The magnitude of load shedding in each step, x_1, x_2, x_3, and x_4, are evaluated offline on the basis of simulation results and experience of

TABLE I
TIME DELAY AND MAGNITUDE OF LOAD SHEDDING

Types of load shedding	Frequency state	Time delay and magnitude of load shedding
Traditional	$f \geq f_{TH}$	No load shed
	$f < f_{TH}$ and $\left\lvert \frac{df}{dt} \right\rvert < m_o$	Step 1: x_1 % of load Step 2: x_2 % of load (after a delay of y_1 cycles) Step 3: x_3 % of load (after a delay of y_2 cycles)
Semi adaptive	$f < f_{TH}$ and $m_o < \left\lvert \frac{df}{dt} \right\rvert < M$	x_4 % of load

the operational engineers. Current world practices can be the basis of simulations. The TDs, y_1 and y_2, are also evaluated from simulation results. The minimum value of TD is however hardware dependent.

D. Formation of Island

It is widely reported in the literature [10] that islanding is an approach of preventing blackout in an extreme abnormality. But the question is what are the buses where the network should be disconnected to form an island.

The formation of islands is not unique. Graph partitioning [15]–[17], minimal cutset enumeration [18], and generator grouping [19]–[21] are the major approaches of islanding. The essence of these approaches is to find the weak link/links among different zones of a power system. However, if the system is radial in nature, it is easier to identify the bus/buses where the system can be disintegrated by carefully inspecting the mismatches between loads and generations of different zones.

E. Procedure of Determining Settings of Different Types of Relays

The activation frequency/frequencies with appropriate time delays of FS relays, i.e., relay settings, are evaluated. For the evaluation of these relay settings, all probable events, like different types of faults, withdrawal of different amount of generations, and additions of different amount of loads, are simulated. Due to the occurrence of each event, the system frequency is monitored. Then the falling frequency should be stabilized within the range of target frequency through appropriate load shedding. The appropriate amount of load shedding may be obtained from different trials of shedding loads of different amount at different locations. That is, at what frequency level and locations of load are more effective in terms of system stability should be determined heuristically through trials. It should be noted that the target range of frequency, acceptable frequency range of normal operation, should be pre-defined from the experience of load dispatch center (LDC).

During simulation of events for the stability analysis, one should experience that the operation of only FS relay is not enough to make the system stable in case of many events. In those cases, the activation of FD relays is also required. The settings of FD relays are also evaluated through simulation of different events and then shedding loads. It should be noted that the amount of load shed is sensitive to the settings of FD relay. That is, the activation of FD relay at higher frequency, that is at earlier time, requires lesser amount of load shed than that is required for the activation at lower frequency. It may also be noted that in most of the cases, the operation of FS relay is required after an operation of FD relay.

For few events only load shedding schemes are not enough for the stability of the system. In those cases, the solution to keep the system in a stable state is to disintegrate the whole power system into different regions. The regions are identified as either load rich or generation rich. The identification is required to decide whether the load should be shaded or generation. Once again, the activation frequency and frequency slope threshold are determined through event simulations.

III. APPLICATION OF THE PROPOSED TECHNIQUE

The technique described in Section II is applied to BPS. It is a small system with an installed capacity of 5250 MW and an annual peak demand of around 4300 MW. The transmission system of BPS has formed an integral grid of two voltage levels of 132 and 230 kV. It supplies electricity to the whole country, geographically divided into two regions by the rivers Padma and Jamuna. That is, the transmission system has two major regions connected through two tie line, known as East-West Interconnector -1 and -2.

The BPS grid network is inherently radial in nature. Fig. 3 shows the BPS grid in terms of a number of regions. The figure clearly shows that the regions are like islands connected radially to the Dhaka region. The status of different islands in terms of generation capacity and loads of a typical day is given in Table II. The table shows that most of the islands are load rich. A load rich island is the one whose available generation is less than the load and generation rich island has available generation more than its load.

A. Frequency Response Characteristic of BPS

The frequency response is investigated in two different ways: 1) changing the load at 33 kV buses one at a time and 2) forcing capacity outages.

Changing load shows that the change in system frequency for the same amount of load shed at different 33 kV load buses is different. It is observed that loads close to power plants have faster and greater impacts on the change in system frequency. Furthermore, since a particular load bus has a particular amount of connected load, its contribution towards increasing system frequency by load shedding is limited by the amount of that load. Depending on the above observations, all the 33 kV substations are categorized into five types as presented in Table III. That is, the category of a substation is defined depending on its proximity to major power plants and the magnitude of connected load.

Transient stabilities of BPS are investigated for generator capacity outages from 5% to 35% of existing generation (in steps of 5%) or sudden load addition from 5% to 40% of existing load (in steps of 5%). A steady state load flow analysis was done only once before the transient stability studies are run. It may be noted that a sudden load addition by 40% is the maximum possible addition in view of the present maximum demand.

This study shows that for up to 7% generation deficit, the system frequency stabilizes itself without any load shedding

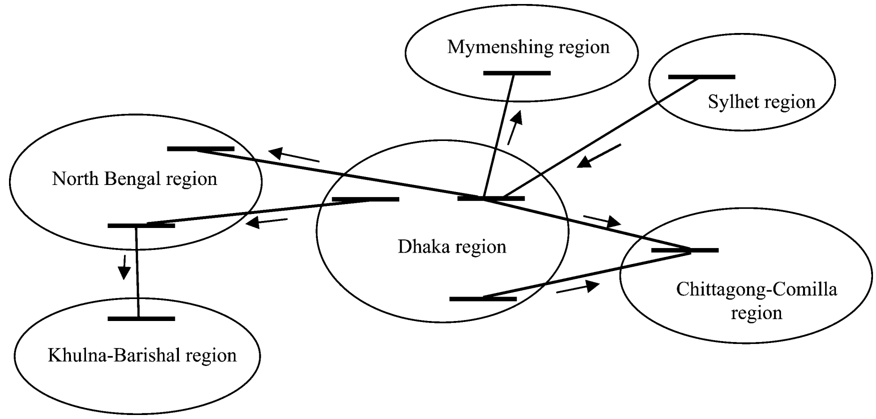

Fig. 3. Radial nature of Bangladesh Power System.

TABLE II
STATUS OF DIFFERENT RADIALLY CONNECTED REGIONS OF BPS

Description of the island	Available generation (MW)	Demand (MW)	Status of the island
Dhaka region	2390	1450	Generation rich
Ctg., Comilla, Noakhali region	233	698	Load rich
Sylhet region	308	176	Generation rich
Mymenshing region	133	250	Load rich
North Bengal region	421	645	Load rich
Khulna-Barishal region	205	464	Load rich

TABLE III
CATEGORIZATION OF SUBSTATIONS OF BPS

Substation type	Proximity to major power plants	Load size*
T_1	Close	Large
T_2	Close	Medium
T_3	Far	Large
T_4	Far	Medium
T_5	Far	Very large

* Medium – 20 to 40 MW, Large – 40 to 80 MW, Very large – >80 MW

above 49.1 Hz. The maximum rate of change of frequency for this condition is less than 0.2 Hz per second. Therefore, the minimum value of targeted frequency and the threshold f_{TH} is set at 49.1 Hz and the first ROCOF threshold, m_0, is chosen to be 0.2 Hz per second.

Table IV shows a simple calculation of load to be shed instantaneously to stabilize the system keeping a generation deficit of 7%. For example, a sudden generation loss of 35% (1435 MW) the amount of load shed necessary is 1250 MW so that generation deficit remains within 7%. This simple calculation is used to assess qualitatively the amount of instantaneous load shed necessary to reach the target frequency range.

TABLE IV
AMOUNT OF REQUIRED LOAD SHED CALCULATION

System load, MW (D)	Conditions		Load shed required, MW (x)
4100	Generation loss ($P_{g\,loss}$), %	35	($x=1.07\,P_{g\,loss}-0.07D$) 1250
	Load addition ($P_{L\,add}$), %	40	($x = P_{L\,add} - 0.07D$) 1353

B. Determination of Relay Settings

It is considered that the system frequency would be raised to 49.1 Hz through auto load shedding scheme in the event of sudden generation loss and/or sudden load increase. After this, it is expected that the operators of central load dispatch center (CLDC) would take control of the situation following their line of action as presently practiced through manual control of some on-demand feeders in different areas.

To determine the FS relay setting, simulations were repeated with four sets of FS relay settings:

1) (49, 48.8, 48.6) Hz;
2) (49.1, 49.0, 48.9) Hz;
3) (48.6, 48.4, 48.2) Hz; and
4) (48.7, 48.6, 48.5) Hz.

At first, each set was tested independently with only FS relays connected to major 33 kV substations. Amount of load shedding at each threshold of a set was determined by simulating with different amount of load shedding.

Fig. 4 presents the frequency responses of BPS with only FS relay based load shedding. It is observed that the system can retain stability for a 40% load addition only when the setting is (49.1, 49.0, 48.9 Hz) with 15% load shed at each threshold for this set. It is observed from the figure that this setting cannot raise the system frequency to the targeted 49.1 Hz when severer disturbance like a 32% generation capacity outage occurs.

A FD relay is considered usually to retain stability when it is not otherwise achievable using only FS relay specially for larger disturbances. For BPS, these disturbances can be sudden load additions by more than 40% or cascaded or one time outages of more than 32% of generation capacities in a typical peak load condition.

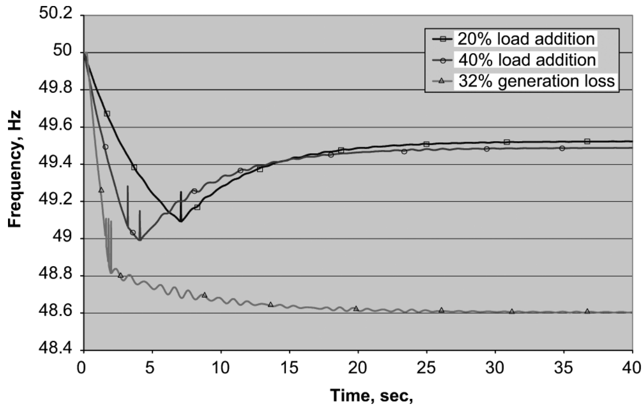

Fig. 4. Frequency responses of BPS with only FS relay based load shedding.

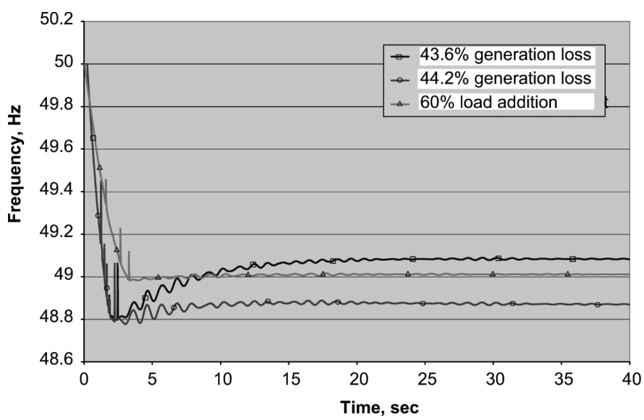

Fig. 5. Performance of combined FS and FD relay scheme on BPS.

TABLE V
FS Relay Settings

Relay type	Time delay, cycles	Frequency threshold, Hz	Load shed amount, %
FS_1	7.5	49.1	15
		49.0	15
		48.9	15
FS_2	7.5	48.8	90

TABLE VI
FD Relay Settings

Relay type	Time delay, cycles	Frequency threshold, Hz	Load shed amount, %		
			|df/dt| = 0.2, Hz/sec	|df/dt| = 0.3, Hz/sec	|df/dt| = 0.4, Hz/sec
FD_1	20	49.5	0	30	20
FD_2	20	49.5	30	20	0
FD_3	20	49.5	10	20	20
FD_4	20	49.5	0	0	50
FD_5	20	49.6	0	0	90

TABLE VII
FD Relay Settings for Islanding

Relay type	Time delay, cycles	Frequency threshold, Hz	|df/dt| threshold, Hz/sec	Lines to be tripped
FD_6	20	49.5	0.6	Both ckts. of East-West Interconnectors

After series of simulations and considering the system frequency responses, FD relay setting at all the five substation types are determined.

The threshold slope for activating the FD relays are determined considering the disturbances which have a lower degree of severity so that more severe disturbances causing a steeper slope can also be accommodated. For BPS, the simulations show that among the disturbances causing instability, sudden load additions are less severe than cascaded outages of generators. It should be noted that the activation frequency can conveniently be set at 0.5 Hz less than the nominal frequency e.g., 49.5 Hz for a 50 Hz power system.

So the threshold slopes for FD relays has been decided considering the minimum one obtained from the frequency curves produced by transient stability simulations for sudden load additions up to 40% without any FS or FD relay.

Fig. 5 shows the performance of combined FS and FD relay scheme on the BPS system under a typical peak load condition. It shows that if FD relays are implemented in combination with FS relays at major 33 kV buses, BPS can sustain stability for disturbances of sudden load addition up to 60% or for disturbances of sudden (all at a time) outages of generators up to 43.6% with the frequency settling above 49 Hz. The figure also shows that the developed load shedding scheme cannot raise the system frequency to the target frequency of 49.1 Hz for a sudden generation loss beyond 43.6%, for example 44.2% in this case.

In a situation where the system stability cannot be achieved through the above relay settings, the disintegration of the regions is the only solution for making the system stable. That is, if a situation arises such that the falling frequency cannot be halted through the implementation of FS and FD relay based load shedding scheme, then the load rich and generation rich portions of the system need to be separated from one another by tripping all the 132 kV and 230 kV lines among them.

The disintegration of regions can be achieved by installing FD relays at both ends of the concerned lines and keeping their frequency slope threshold ($|\mathrm{df}/\mathrm{dt}|$) at 0.6 Hz per second. This threshold value is obtained from various simulations. After several simulations, it was found that disintegration of Eastern and Western regions of BPS is the most suitable solution.

The relay settings of different types of relays for the frequency dependent load shedding scheme obtained after extensive simulations are presented in Tables V– VII. Note that in this study, load in a substation is considered a resource to be used to retain system stability; 45% of the load is allocated for load shedding using FS relay and 50% of the load is allocated for load shedding using FD relay.

The first column of Table VI indicates FD relay types corresponding to different types of substations as specified in Table III. The table clearly shows that the settings of each category of FD relay are different from the others.

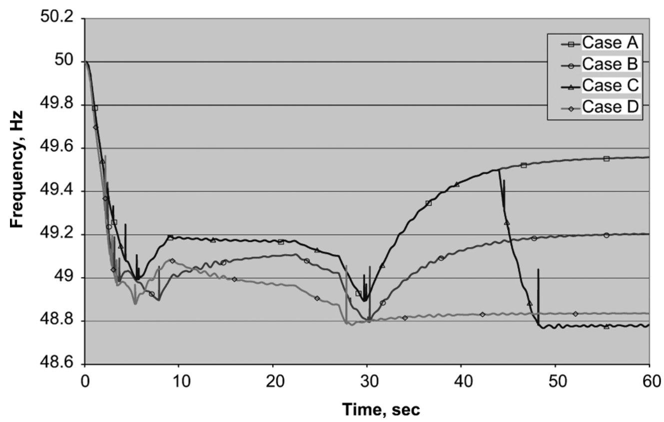

Fig. 6. Performance of the load shedding scheme under different case scenarios.

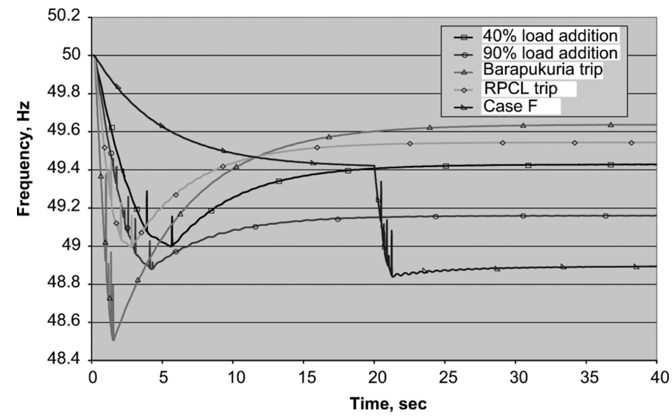

Fig. 7. Performance of the load-shedding scheme in 500 MW load and reduced network condition.

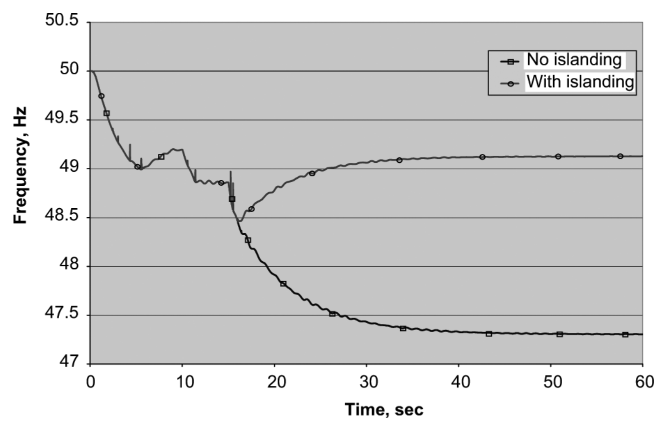

Fig. 8. Performance of combined FS and FD relay with islanding scheme.

C. Validation of Developed Auto Load Shedding Scheme

The relay settings presented in Tables VI and VII are tested simulating different scenarios.

1) Cascading Events: To evaluate the performance of the scheme during cascading events, various scenarios are developed. Fig. 6 shows the performance of the load shedding scheme under some of the scenarios namely case A, case B, case C, and case D. In brief, case A refers to cascaded outage of 15 generators in a span of 1340 cycles resulting in 25.95% generation outage. Case B refers to cascaded outage of 18 generators in a span of 1340 cycles resulting in 37.9% generation outage. Case C refers to cascaded outage of 18 generators in a span of 2190 cycles resulting in 37.9% generation outage. Case D refers to sudden addition of load by 5% and the cascaded outage of 18 generators in a span of 1350 cycles resulting in 37.9% generation outage.

Fig. 6 shows that the load shedding scheme could prevent the continuous fall in system frequency, stabilize, and improve it. That is, the load shedding scheme can stabilize system frequency around 49 Hz and prevent system blackouts during severe cascading generation outages and load increase during peak load conditions of BPS.

2) Emergency Situations: The performance of the load shedding scheme during an emergency situation of only 500 MW system load and reduced network condition is presented in Fig. 7. Such a system condition occurred because of disintegration of some of the parts of the BPS through the operation of circuit breakers as a result of simultaneous faults at different locations during Hurricane Sidr in November 2007. It is observed that the load shedding scheme could stabilize the system frequency for up to 90% load increase during this emergency condition. The scheme performed well during generator outage of 66 MW. The scheme could also stabilize the frequency at 49.64 Hz with a generator outage of 89 MW.

Case F refers to a situation where the system frequency falls to 49.42 Hz in 20 s due to a 10% increase in load, and at this state of frequency generation outage of 66 MW occurs. Even at this abnormal grid condition, the load shedding scheme stabilizes the system frequency at 48.89 Hz which is an acceptable frequency state.

3) Scenario Requiring Disintegration: The FD relay setting for disintegration of regions is tested for a cascaded generation outage of 47.5%. In this case, Khulna-Barishal and North Bengal regions, shown in Fig. 3, are disintegrated from the rest of the four regions. That is, two islands are formed: one with Khulna-Barishal and North Bengal regions and other one with the rest of the four regions. Fig. 8 depicts the system frequency fall without islanding and the frequency state of the island of four regions at different instants, eventually raised to the target frequency range. It clearly reveals that the disintegration of the regions along with load shedding could stabilize the disintegrated islands.

IV. Conclusion

Abnormal condition in a power system created through fault or sudden load addition/withdrawn or forced capacity outages or all at a time generates a huge loss to the utility as well as to the consumers. The loss reaches to an extreme if the abnormal condition leads to a system blackout.

This paper presents a technique in which an auto load shedding and islanding scheme can be developed for a system to bring it to a stable operating state under any abnormal condition. The proposed technique is developed based on the magnitude and the rate of change of the falling frequency during abnormal condition. It requires traditional and/or ROCOF based load shedding schemes to bring a system into a stable state from an abnormal state. However, in an extreme condition, the grid is disintegrated forming islands and brought the individual island into stable condition. The implementation of the technique is simple requiring only FS and FD relays. The technique presents the sequence and conditions of implementation of different load shedding schemes and islanding strategies. The paper proposes a couple of strategies of the activation of load shedding scheme so that the amount of load shedding is minimum.

The technique is applied to BPS and an auto load shedding and islanding scheme is developed. The scheme is tested simulating different scenarios including three recent blackouts in BPS. The simulation results show that the scheme is capable of handling any abnormal condition in a power system.

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