Blackout Prevention by Auto Load Shedding and Islanding Scheme

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Abstract— **Abnormal condition in power system generally leads to a fall in system frequency, and it leads to system blackout in an extreme condition. This paper pSSresents a technique to develop auto load shedding and islanding scheme for power system to prevent blackout and to stabilize the system under any abnormal condition. The technique proposes the sequence and conditions for application of different load shedding schemes and islanding strategies.**

Keywords- Auto load shedding ,islanding ,blackout

I. INTRODUCTION

This paper presents a technique to develop a frequency depended auto load shedding and island scheme to bring power system to a stable state and to prevent blackout under any abnormal conditions. This technique incorporates the sequence and conditions of the application of different load shedding schemes and islanding strategies. This technique is developed based on the international current practice. It uses the magnitude and fall in rate of change of frequency in an abnormal condition to determine the relay settings offline. The paper proposes to implement the technique using frequency sensitive and frequency droop relays. The developed scheme is validated simulating different abnormal condition and simulated results are presented.

II. LOAD SHEDDING

Abnormal conditions in a power system generally lead to 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 its 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 technique proposed in this paper is a heuristic one that considers all these issues and develops comprehensive solution to the instability of a power system. The technique is based on three types load shedding

1. Traditional load shedding
2. Semi-adaptive load shed and
3. Adaptive load shedding

The traditional load shedding is implemented through frequency sensitive (FS) relays. The shed is activated only when the system frequency falls below a certain threshold value, fth. The implementation of other schemes required frequency droop (FD) relays.

III. SEQUENTIAL STEPS

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

Step 1: System frequency and ROCOF are continuously monitored by frequency sensitive (FS) and frequency droop (FD) relays respectively.

Step 2: The traditional load shedding scheme is activated if $f < f\ th$ and $|df/dt| < m0$.

Step 3: The df/dt based load shedding scheme is activated, if $f< f\ th$ and $m0< |df/dt| <M$. m0 and M are df/dt related threshold values. The magnitude of M is much higher than m0.

Step 4 : Grid disintegration scheme is activated only when $f < f\ th$ and df/dt exceeds M.

IV. DETERMINATION OF THRESHOLD VALUES

The first frequency threshold, fth is defined as when 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. 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 while the situation becomes critical, creating cascade effect at about 46-44 Hz.

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 fth may be determined through experience and simulations.

The threshold value of df/dt, mo is determined using a reduced model for a reheat unit. Considering constant system inertia, H, the methodology arrived at a solution that if 6 % of the system real power is disturbed. Although in a small system H does not remain constant when multiple synchronous machines are disconnected from the system. However, this can be the approach of determining mo.

This technique prefers to determine mo heuristically from a series of simulation results and it considers mo as the lowest vales of df/dt for which the system cannot be returned to the targeted steady state frequency range using traditional load shedding approach.

TANGEDCO (Tamil Nadu Generation and Distribution Corporation) practices load shedding if frequency falls less than 49.9 Hz and sheds 100MW of load for every 0.1Hz fall in southern grid. The fall in frequency without any corrective measure in shown in fig1. It is observed around 0.3Hz frequency is falling for every 1% of load addition.

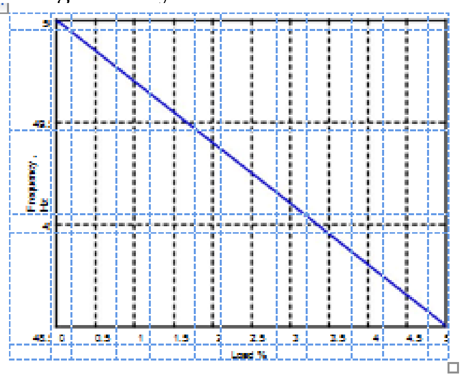

Figure 1. Fall in frequency without any corrective measure

V. DETERMINING THE MAGNITUDE OF LOAD SHEDDING

The magnitudes of load shedding of different steps of traditional scheme are not the same. The magnitude of load shedding of df/dt based scheme is also different from that of traditional one.

Various load shedding schemes recommendations is given in table 1.

Table 2 shows the steady state frequency and rate of change of frequency of loss of different magnitude of generation loss without any corrective measures.

TABLE I. VARIOUS LOAD SHEDDING SCHEME RECOMMENDED

Recommended by	Frequency threshold, Hz	Load Shed, %
P Kundur	49.3	10
	49	15
	48.3	20
R M Maliszewky et al (1971)	49.6	3.3
	49.5	3.3
	49.4	3.3
	49.25	5.0
	49.15	5.0
	49.05	5.0
P M Anderson (1999)	49.6	6.25
	49.3	6.25
	49.1	6.25
	48.8	6.25
P M Anderson (1999)	49.6	4.8
	49.4	4.8
	49.3	4.2
	49	4.0
	48.8	3.6
	48.5	3.0
VN Chuvychin et al (1996)	0.1 steps between 48.5 and 46.5	4 in 20 steps

TABLE II. VARIATION OF FREQUENCY AND ROCOF WITHOUT ANY CORRECTIVE MEASURE

Generation Outage, %	Steady state frequency, Hz	|df/dt|, Hz/sec
10	49.44	0.05
20	48.75	0.12
30	47.86	0.2
40	46.68	0.32
50	45.01	0.48
60	42.52	0.71

VI. PROPOSED LOAD SHEDDING SCHEME

Various magnitudes of load shedding and different threshold levels for ROCOF are considered. After extensive testing of different values, a load shedding scheme is proposed. The proposed scheme for load shedding is shown in table 3. Flowchart for the proposed load shedding scheme is shown in figure 2

TABLE III. PROPOSED SCHEME FOR LOAD SHEDDING

S.no	Time delay, cycle	Frequency threshold, Hz	Load shed amount, %			
			Rocof < 0.2	Rocof 0.2 to 0.3	Rocof 0.3 To 0.4	Rocof > 0.4
1	0	49.1	15			
2	0	49.0	15			
3	0	48.9	15			
4	20	49.5			30	20
5	40	49.5		30	20	
6	60	49.5		10	20	20
7	80	49.5				40

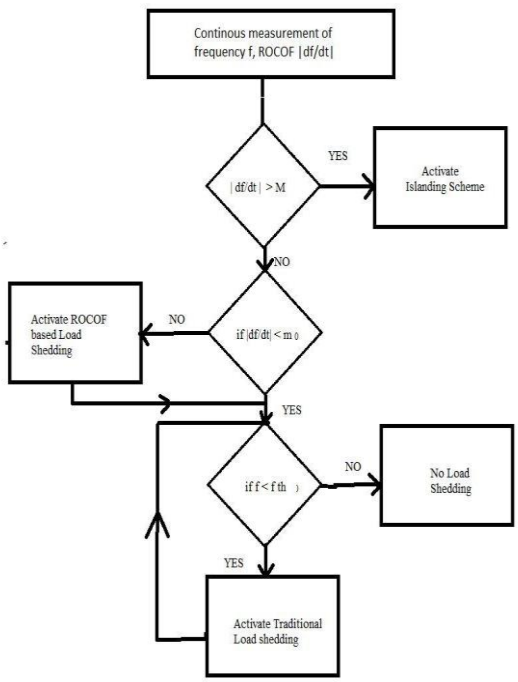

Figure 2. Flow chart for the proposed scheme of Load shedding

VII. SIMULATION OF ABNORMAL SCENERIO

To evaluate the performance of proposed scheme during cascading events, various scenarios are developed.

A. *Traditional load shedding scheme*

The loss of generation which causes the system overload, requires the same amount of load shedding to recover to 50Hz frequency. For example, a 30% loss of generation is equal to 42.9% of system overload but the resulting unbalance can be corrected by shedding 30% of the connected system load.

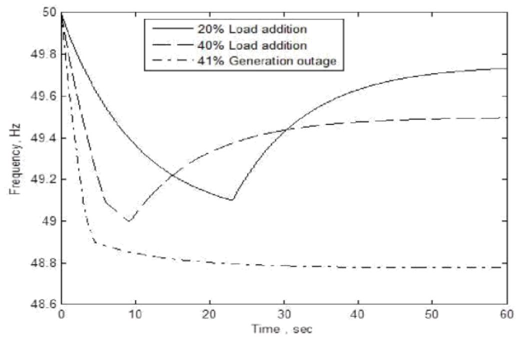

Figure 3. Frequency responses of the system with only traditional load shedding scheme

A 20% of load addition causes the system frequency to fall. The frequency falls at the rate of 0.095 Hz/sec. Once the frequency falls below the threshold frequency 49.1, 15 % of connected load is shed. Immediately after the load the load shed, the system frequency improves and stabilizes around 49.73.

A 40% of load addition causes the system frequency to fall. The fall in frequency is sharper and falling at the rate of 0.19 Hz/sec. It falls below the threshold frequency, 49.1 and 15% of connected load is shed. The system frequency fails to improve as the load shed is not adequate enough to improve the system frequency. As the frequency falls further and below the second threshold frequency 49.0, another of quantum of 15% of connected load is shed. Immediately the system frequency improves and stabilizes around 49.5.

A 41 % of generation outage causes the system frequency to fall. The fall in frequency is sharper than earlier cases and falling at the rate of 0.33 Hz /sec. It falls below the threshold frequency 49.1, 15 % of load is shed. It fails to stop the fall in frequency. As the frequency falls below the second threshold level of 49.0, a second quantum of 15% of connected load is shed. It again fails to stop its fall. As the frequency falls below the third threshold level, a third quantum of 15% load is shed. The fall in frequency is arrested and it stabilizes around 48.5

B. *B df/dt based load shedding scheme*

A 43.6% of Generation outage causes the system frequency to fall and it falls at the rate of 0.37 Hz/sec. As the system frequency falls below the threshold frequency of 49.5 Hz , 30% load is shed after a delay of 20 cycles. As the fall in frequency continues for another 20 cycles, another 20% load is shed. As the fall in frequency continues for another 20 cycles, another 20% of load is shed. The system frequency stabilizes at 49.63.

A 46.2% of generation outage causes the system frequency to fall and it falls at the rate of 0.41 Hz/sec. As the system frequency falls below the threshold frequency of 49.5 Hz, 20% of load is shed after a delay of 20 cycles. As the fall in frequency continues for another 40 cycles, another 20% of load is shed. As the fall in frequency continues for another 20 cycles, another 40% of load is shed. The system frequency stabilizes at 49.7

A 60% load addition causes the system frequency to fall and it falls at the rate of 0.29 Hz/sec. As the frequency falls below the threshold frequency of 49.5 Hz, after a delay of 40 cycles, 30% of connected load is shed. But the frequency continues to decline and after a delay of 20 cycles, 10% of load is shed. The system frequency stabilizes at 49.0.

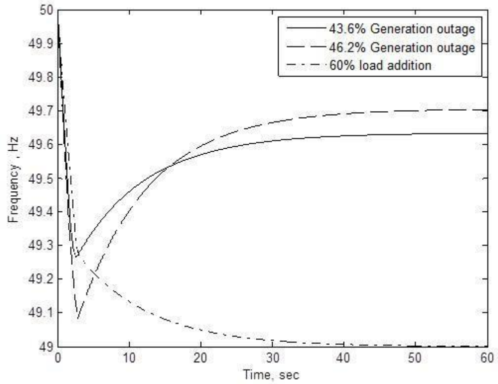

Figure 4. performance of combined traditional andf/dt load shedding

C. Cascaded generation outage

Cascaded outage of two generators in a time span of 1340 cycles. On outage of generation, the frequency falls . On implementation of load shedding, it improves till the second outage of generation occur. The system frequency falls further and improves on further load shedding.

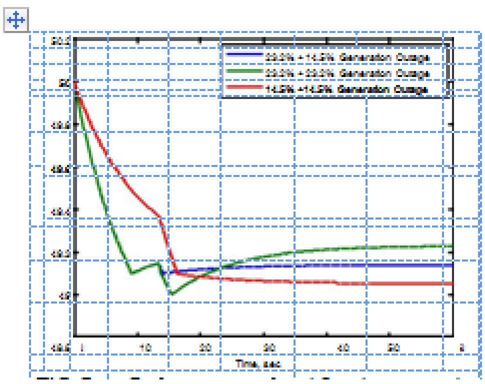

Figure 5. Performance of LS scheme under cascaded generation outage

D. Islanding scheme

Islanding or disintegration of the system to prevent blackout can be done either as a first resort or as a last resort. For a very larger disturbance, traditional load shedding and df/dt based load shedding will not prevent blackout. In that case, it is better to disintegrate the system immediately without even attempting for load shedding. If the fall in frequency is sharper than 0.6 Hz/sec, islanding is recommended as first resort. If the frequency fall is not sharper, traditional and df/dt based load shedding is attempted to stabilize the system frequency. Even after load shedding, if the system frequency fails to stabilize, islanding is considered as last resort. In the base paper, the system is disintegrated on geographical basis. In this paper, optimal islanding is adopted which ensures minimum load will be shed in island formation.

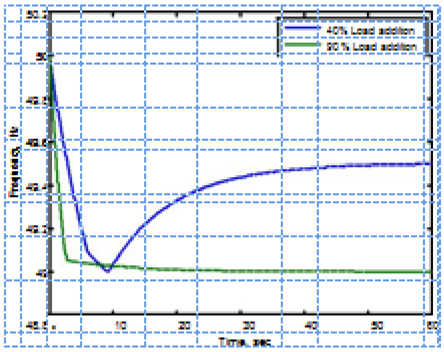

Figure 6. Performance of LS scheme under Islanding scheme

VIII. SUMMARY

UFLS scheme, ROCOF based load shedding and islanding of the system is implemented. Various abnormal cases are simulated and frequency gets stabilized and blackout is prevented.

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