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

Md. Quamrul Ahsan, Abdul Hasib Chowdhury, S. Shahnawaz Ahmed, Imamul Hassan Bhuyan, Mohammad Ariful Haque, and Hamidur Rahman

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.

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

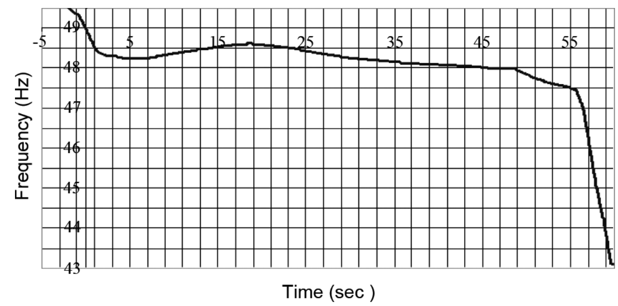

Fig. 1. Falling frequency during blackout on December 14, 2007 from DFDR records.

Manuscript received October 11, 2010; revised January 22, 2011 and April 05, 2011; accepted May 13, 2011. Date of publication July 05, 2011; date of current version January 20, 2012. The work was supported under a Bureau of Research, Testing and Consultation project of Bangladesh University of Engineering and Technology sponsored by the Power Grid Company of Bangladesh Limited. Paper no. TPWRS-00811-2010.

The authors are with the Department of Electrical and Electronic Engineering, Banngladesh University of Engineering and Technology, Dhaka 1000, Bangladesh (e-mail: hasib@eee.buet.ac.bd).

Digital Object Identifier 10.1109/TPWRS.2011.2158594

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.