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Application of power swing equation for the estimation of power imbalance

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***Abstract* — Electric power system is always subjected to different types of disturbances due to overload, tripping of generators, fault occur at any section of power system. Due to these disturbance, the system frequency will change and the power system becomes unstable which may lead to major blackout if not recovered quickly. In order to maintain the frequency, conventional under frequency load shedding scheme is commonly used. However, it has the problem that it does not estimate the power imbalance and lead to un-optimal load shedding. The result is either over-shedding, which affects power, or under-shedding, which leads to tripping of electricity service. In order to address this issue, this thesis proposes a power imbalance estimation module (PIEM) to accurately estimate the power imbalance in the power system that can be used provide efficient and reliable operation of power system under severe disturbances.**

***Index Terms*— Centre of Inertia Frequency, Power Imbalance Estimation Module, Optimal Load Shedding Module.**

I. INTRODUCTION

The electrical power system is a network of many electrical components which is used to supply, deliver electric power from one place to another place. The power system of electrical components can be broadly divided into the generators which is used to supply the power, the transmission network that carries the power from the generating station to the load centers and the distribution system that feeds the power to nearby towns, homes and industrial manufactures. Stability of a power system is its ability to return to normal or stable operating conditions after having been subjected to some form of disturbance. Conversely, instability means a condition denoting loss of synchronism [1]. Though stability of a power system is a single phenomenon, for the purpose of analysis, it is classified as steady state analysis and transient stability. Increase in load is a kind of disturbance. If increase in loading takes place gradually and in small steps and the system withstands this change and performs satisfactorily, then the system is said to be in steady state stability. Thus, the study of steady state stability is basically concerned with the determination of upper limit of machine's loading before losing synchronism, provided the loading is increased gradually at a slow rate. Frequency stability is a crucial consideration in power system operation and planning, particularly as a consequence of recent increase in load demand [2]. The frequency response of an islanded system is more severely disturbed when subjected to transient than the interconnected grid system. In order to avoid these power blackouts, conventional UFLS scheme is commonly applied. Conventional UFLS scheme has the problem that it does not shed the optimal loads. In order to address this issue, this thesis has proposed a power imbalance estimation module (PIEM) to estimate the power imbalance [3].

II. LITERATURE REVIEW

A blackout in a power system refers to the unavailability of electric power in an area for a short or long duration. These power blackouts can occur due to natural reasons as well as technical reasons. Natural reasons include animal contact with a live conductor, a vehicular accident resulting in damaged transmission poles, and trees falling on transmission lines due to stormy weather. Technical reasons include faults, damaged transmission or distribution lines, stability issues, overloaded transmission lines, cascading events, faulty equipment, and human error. The estimated unsupplied energy is another important factor leading to blackouts. Some of these reasons, like faults, are initiating contingencies; others are the subsequent consequences of those events which may result in instability and cascading, leading to a blackout. The top ten most severe power blackouts that have occurred in the last two decades, affecting millions of people, One of the most significant blackouts occurred in the United States and Canada on 14thAugust 2003. This blackout affected around 50 million people in eight US states and two Canadian provinces. Estimates show that this blackout interrupted around 63 GW of load, and more than 400 transmission lines and 531 generating units' at 261 power plants tripped [4, 5, 9]. It lasted for 96 hours (4 days) in various parts of the eastern United States [10] as shown in Table 2.1, resulting in an economic loss of approximately 4–6 billion USD [11]. Indonesia suffered a severe blackout in 2005 that affected100 million people for 7 hours [3]. The world's largest blackout happened recently on 31stJuly 2012 in India following a voltage collapse due to the overloading of transmission lines. It affected around 670 million people, hundreds of trains, and hundreds of thousands of households in 22 Indian states [8].

III. METHODOLOGY

This research proposes the power imbalance estimation module to overcome the limitations of conventional UFLS scheme. The power imbalance estimation module consists of following two steps.

(1) Center of inertial frequency (COIF) Module.
(2) Power imbalance Estimation Module.

The description of each module is explained as below:

In a grid connected mode, the COIF module uses grid frequency (f_{grid}), and sends it to the PIEM module. However, in case of generator tripping or grid disconnection, the COIF module determines the center of inertia frequency f_{COI} as below [29]

$$f_{COI} = \frac{\sum_{i=1}^{N} Hifi}{\sum_{i=1}^{N} Hi}$$

Where,

f_{COI} = frequency of the center of inertia (Hz),

H_i = Inertia constant ith generator (Hz),

f_i = Frequency of ith generator (Hz),

The COIF Module transmits this frequency to the PIEM Module via a communication link. This module will determine the power imbalance due to any load variation. The COIF Module transmits this frequency to the PIEM Module via a communication link. This module will continuously monitor the generator tripping event by checking the status of the generator breaker. This may occur due to the failure of malfunction of generators differential protection or transmission line tripping. In such case, the power imbalance is estimated using the power swing equation.

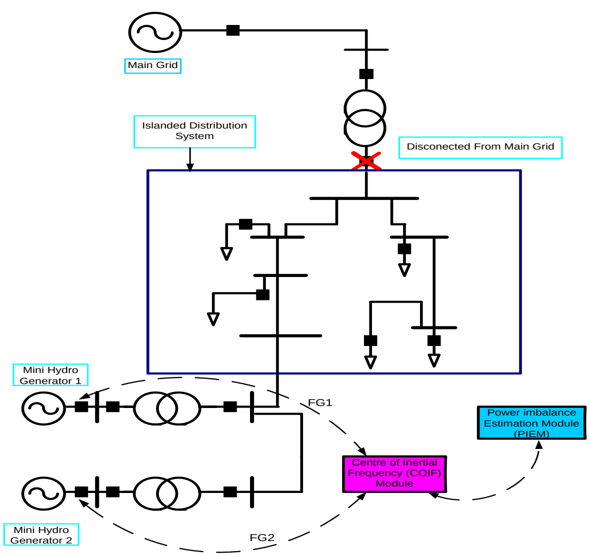

Figure.1. Proposed islanding distribution Network Layout

IV. Simulation Model

The overall test system modeled in PSCAD/EMTDC software is shown in Figure 4 shows the test system with application of power swing equation by using to calculate the estimated power by using (PSCAD/EMTDC) software.

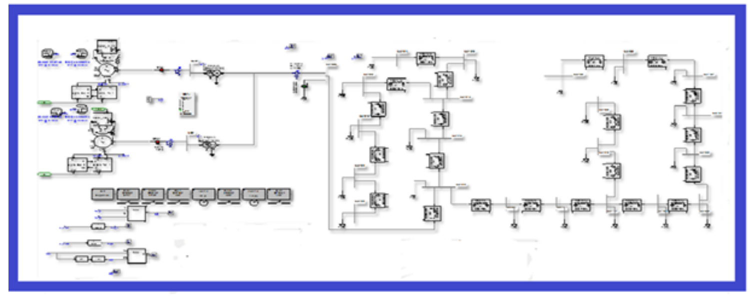

Figure.2. shows calculate the estimated power by using PSCAD/EMTDC software.

V. Simulation Results and Discussion

This research includes the simulation results of case studies of various power imbalances occurred in the system. The performance of the power imbalance estimation module is investigated for all these cases. Table 4.1 provides the details about the case studies.

Case Studies Description
Case 1 Response of PIEM at 0.3 MW power imbalance
Case 2 Response of PIEM at 0.6 MW power imbalance
Case 3 Response of PIEM at 0.9 MW power imbalance

Case 1 Response of PIEM at 0.3 MW power imbalance

In this case, an overload scenario is simulated in which system is subjected to sudden increment of 0.3 MW Load. Due to this, system frequency starts decreasing. At this stage, proposed power imbalance estimation module (PIEM) is used to estimate the power Imbalance by using swing equation. The response of the proposed PIEM is shown in Figure 2.

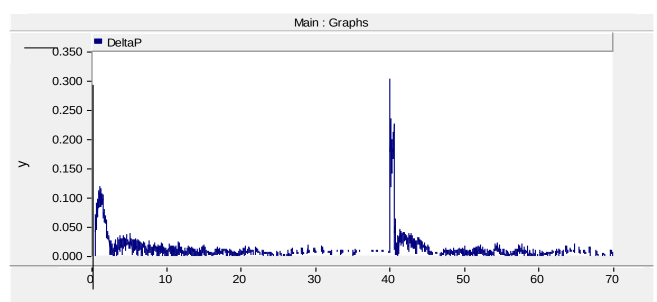

Figure.3.Response of PIEM module for 0.3 MW power imbalance

Case 2 Response of PIEM at 0.6 MW power imbalance

In this case, an overload scenario is simulated in which system is subjected to sudden increment of 0.6 MW Load. Due to this, system frequency starts decreasing. At this stage, proposed power imbalance estimation module (PIEM) is used to estimate the power Imbalance by using swing equation. The response of the proposed PIEM is shown in Figure 5.

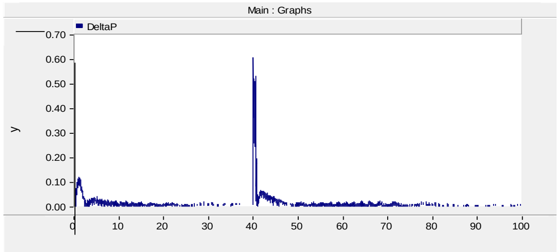

Figure 4.Response of PIEM module for 0.6 MW power imbalance.

Case 3 Response of PIEM at 0.9 MW power imbalance

In this case, an overload scenario is simulated in which system is subjected to sudden increment of 0.9 MW Load. Due to this, system frequency starts decreasing. At this stage, proposed power imbalance estimation module (PIEM) is used to estimate the power Imbalance by using swing equation. The response of the proposed PIEM is shown in Figure 6.

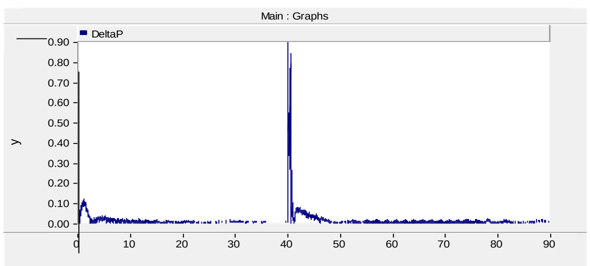

Figure 5.Response of PIEM module for 0.9 MW power imbalance

The simulation result of the PIEM module by using the power swing equation has been investigated for different power imbalances cases ranging from 0.3 MW to 1.5 MW. It has been observed that proposed PIEM module accurately estimates the power imbalance in the system. This estimates can be used in the load shedding techniques to disconnect accurate amount of load in order to stabilize the system and to overcome the limitations of conventional UFLS schemes.

VI. Conclusion

This research has presented the modeling of the power imbalance estimation module (PIEM) based on power swing equation to accurately estimates the power imbalances in the power system blackouts. The proposed PIEM module was based on the frequency, rate of change of frequency, and utilization of power swing equation. Two modules were used namely Centre of inertial frequency (COIF) module, and power imbalance estimation module (PIEM). The COIF module. Transmits the frequency to the PIEM module via communication link. Based upon this information, the PIEM module estimates power imbalance between the generation and load demand by using power swing equation.

The effectiveness and robustness of proposed PIEM modules has been investigated for sudden load increment of 0.3 MW to 1.5 MW cases on different buses on test system. The results of the proposed PIEM module for various power imbalance cases have shown that it accurately estimates the power imbalance for all cases. Thus, it has been proved that PIEM module can be used in the load shedding techniques to accurately estimate the power imbalance in order to disconnect accurate amount of load which is necessary to stabilize the system and to overcome the limitations of conventional UFLS schemes.

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