

Detection of Frequency Deviation and Under/Over Frequency Protection by Load Shedding Using MATLAB/SIMULINK

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Abstract -This paper represents measurement of frequency, design steps for digital frequency relays, effectiveness of under/over frequency relays as well as tripping requirements of frequency relays. Matlab/simulink is user friendly software and is useful to simulate normal and faulty conditions of the electrical power system. In recent days, most of electromechanical relays are replaced by the digital relays because of their high speed, compact size, high accuracy and variable settings. In this paper, performance of digital under/over frequency relays are tested on 132 kV power system network, that contains synchronous generator with distribution generation on MATLAB/SIMULINK.

Key words - stability, over/under frequency, digital relays, load shedding, distributed generation

I. INTRODUCTION

The major problems of electrical power system network are because of power system instability. Frequency, angle and voltage instability are three fundamental instability problems [1]. Power system protection and stability coordination are big challenges for researchers [2]. Certain faults like over load, transmission line tripping contingency and reversal power cause instability problems [4]. Few types of relays such as over/under frequency, over current, over voltage, earth fault, reverse power relays are used to protect typical portion of a power system.

If the overloading condition persists for a long duration then a part of power system may face a problem of instability as well as the generator and their prime mover may begin to slow down. Mismatch between the load and generation can cause the frequency deviation. Which may ultimately leads to loss of power. If the frequency deviation is in excess then the entire power system may face very serious trouble which may be responsible for start the condition of cascade tripping [6]. To save the power system against such serious problems, under frequency relays are used. When there is mismatch between the load and generation, the power system frequency varies within a wide range depending upon the level of mismatch. The frequency relay operates depending upon its setting and level of mismatch. After a set time, transmit trip signal to the circuit breaker to start load shedding. This is helpful to bring back power system parameters under safe limit.

Now a days, most of the electromechanical and solid state relays are being replaced by digital relays. Digital relays can able to perform different functions such as, protection, measurement and control simultaneously. Wide range controlling and high sensitivity are also specific advantages of the digital frequency relay [7]. Simulation tools like MATLAB, PSCAD, MIPOWER, ETAP assist researchers for more easily grasped actual operation of power system. matlab provide power system analysis toolbox, which does not have protection relays module. In this paper, the design of a digital frequency relay is built on MATLAB/SIMULINK.

II. DETECTION OF FREQUENCY

Frequency relays are used to protect the power system against variations in frequency. In any condition of power system, power frequency should remain stable. For maintaining stability, first step is measure or detect frequency variations. A signal frequency measuring technique proposed by C. Buque et al. [3] is used in this paper for measuring frequency. This is based on counting the number of zero level crossing with unit time interval. This numbers indicate the frequency of a given signal.

As shown in the fig.1 voltage signal from the potential transformer is send to the zero crossing detection block. Time delay is applied to output of zero crossing detection block and give the signal to integrator circuit. Integrator integrate the signal and send the signal to the sample and hold circuit if signal exceeds the threshold value. Sample and hold circuit hold the signal till the next zero crossing. Output of the sample and hold circuit is multiplied by integer 2.inverse of this value gives the signal frequency.

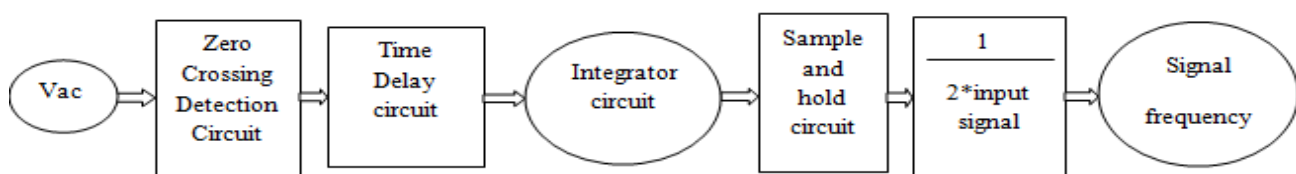


Figure 1. Frequency measurement

This frequency is compared with the nominal system frequency (50 or 60 Hz) to find the actual frequency deviation of the power system.

III. MODELING OF OVER/UNDER FREQUENCY RELAYS

Digital frequency relay constructed with two blocks 1) Frequency measuring block (FMB) 2) Frequency detection block (FDB) as shown in figure. Frequency detection block is also classified in to two element delay element and hold element

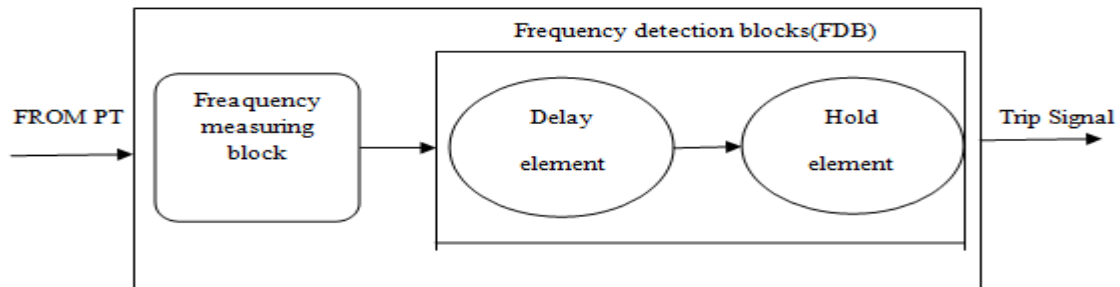


Figure 2. Block of digital frequency relay

As shown in Fig. 2, Frequency measuring block calculate the system frequency from signal of potential transformer. Frequency measuring block transmit measured frequency to delay element of the frequency detection block. Detection block transmit the signal to circuit breaker based on under and over frequency limit.

A. Frequency measuring block:-

Frequency measuring block used voltage signal of the system from PT for measure the frequency. X_1 is first zero crossing and X_2 is the second zero crossing of the voltage signal as shown in figure. X is the total time of one complete cycle. To calculate X , zero crossing difference between X_1 and X_2 ($X_2 - X_1$) is multiplied by factor 2. Inverse of this value gives the frequency of the signal as shown in below equation and fig. 3.

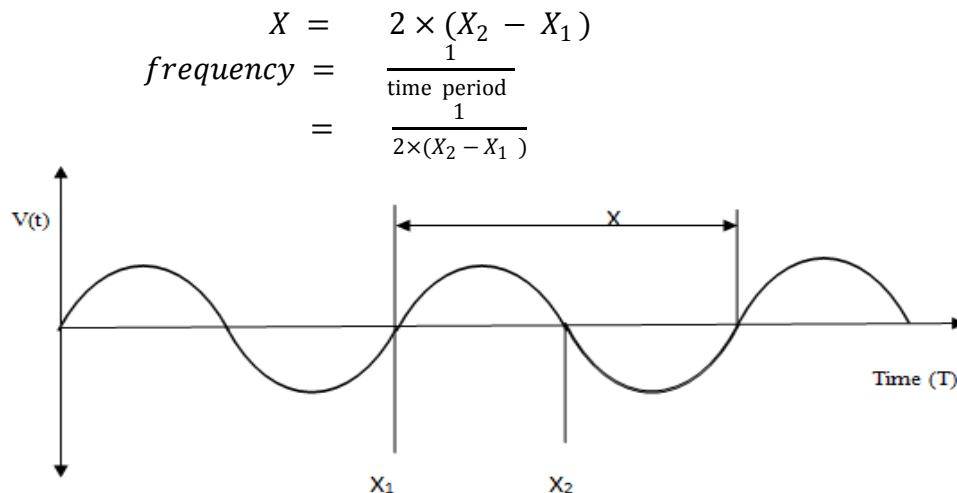


Figure 3. Frequency measurements of input signal

1. Delay element:-

Relay send a false signal to the circuit breaker in the temporary or transient fault condition. So, the main reason of implement delay block is to stop the relay from transmitting a false tripping signal to the circuit breaker. The frequency measuring block output is sent to an action block (switch or switch4). In the normal condition output of action block is 0 and in the faulty condition output of the block is 1. This value is integrated by the integrator block. The output signal of the integrator is compared with threshold. Threshold value is set same as required delay time. In normal condition output of the delay element is 1 otherwise 0.

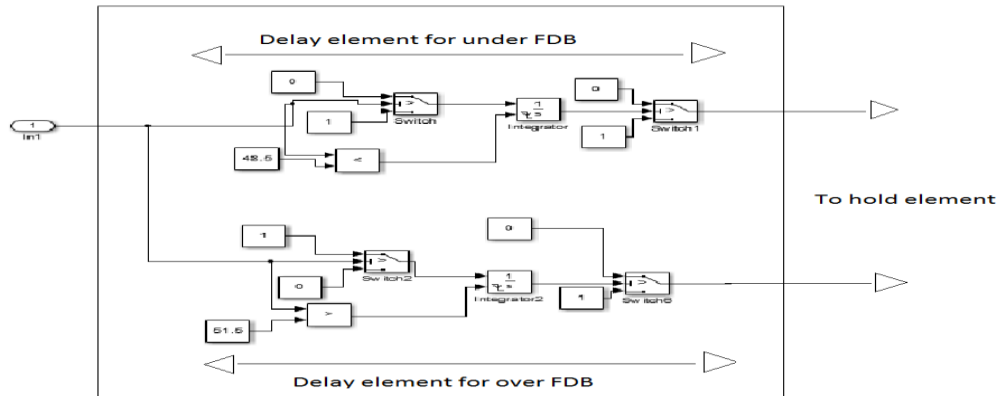


Figure 6. Logic diagram of delay element

2. Hold element:-

Relay sent trip signal to circuit breaker when permanent fault occurs. If For a few second stable condition is occurs after the permanent fault then relay again send signal to close the circuit breaker. This maloperation is prevented by using hold element in the detection block. So, hold element is used to keep the relay in stable state after the relay transmit trip signal to circuit breaker.

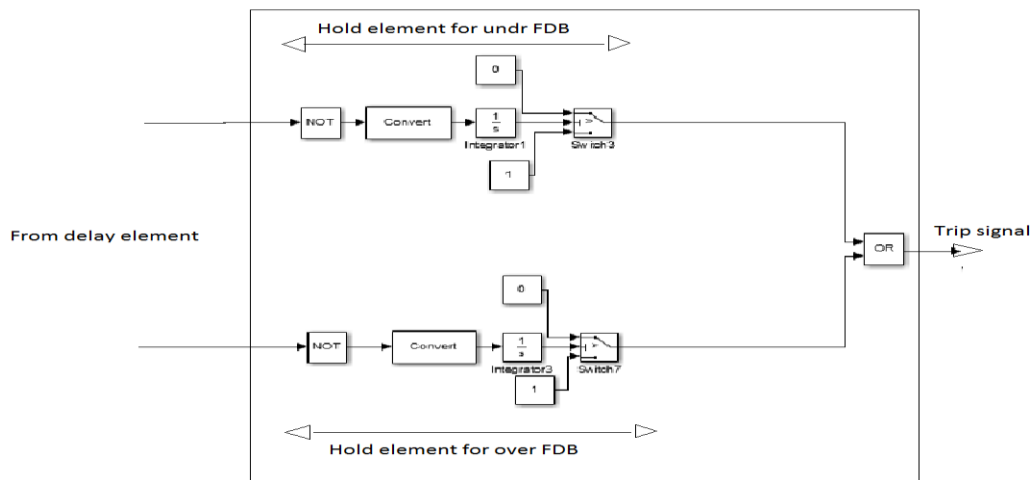


Figure 7. Logic diagram of hold element

Output of delay is convert (0 to 1 or 1 to 0) and transmitted to the integrator block. Output of the integral exceeds '0' value then hold block output is change from '1' to '0'. The integrator output exceeds the threshold of '0' it will never come back to that value because integrator can't reset in the hold element.

3. Complete circuit:-

Delay element and hold element is connected as shown in the fig. 8. output of hold element is applied to the nor gate and then send to the circuit breaker.

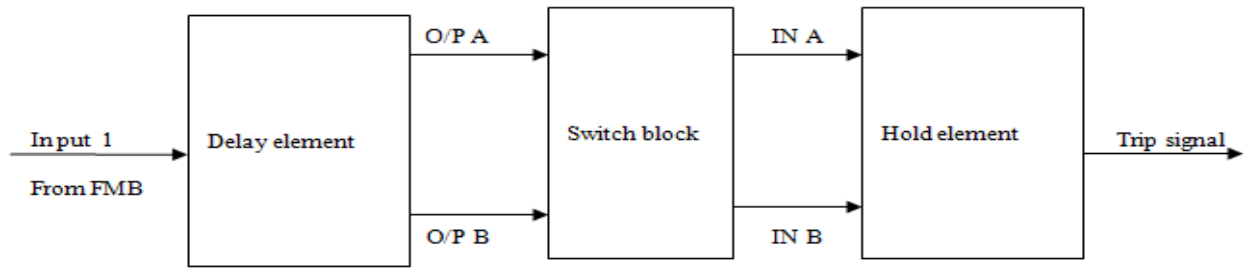


Figure 8. Diagram with hold and delay element of under/over frequency detection block

To stop the false tripping during transient, switch block is fed between hold element and delay element as shown in fig. 8.

IV. POWER SYSTEM MODEL

The single line diagram of power system model is shown in the figure. The system shown in fig. 9 is tested under various conditions such as normal operation and load variations. Here, utility load is fed by the main grid whereas local load is fed by the distribution generation (as shown in the fig. 9). Variable load changes as per the change of demand. Voltage signal is derived from the potential transformer connected at the bus 2. This voltage signal is sent to the frequency measuring block of digital frequency relay. Output of the digital relay frequency detection block is sent to the circuit breaker of the variable load. If under frequency problem occurs, then variable load is shed by opening the circuit breaker 2. Frequency relay is effectively implemented in islanded mode for the protection of distribution generation as shown in fig. 9. Frequency relay also has ability to detect the islanding condition of this system.

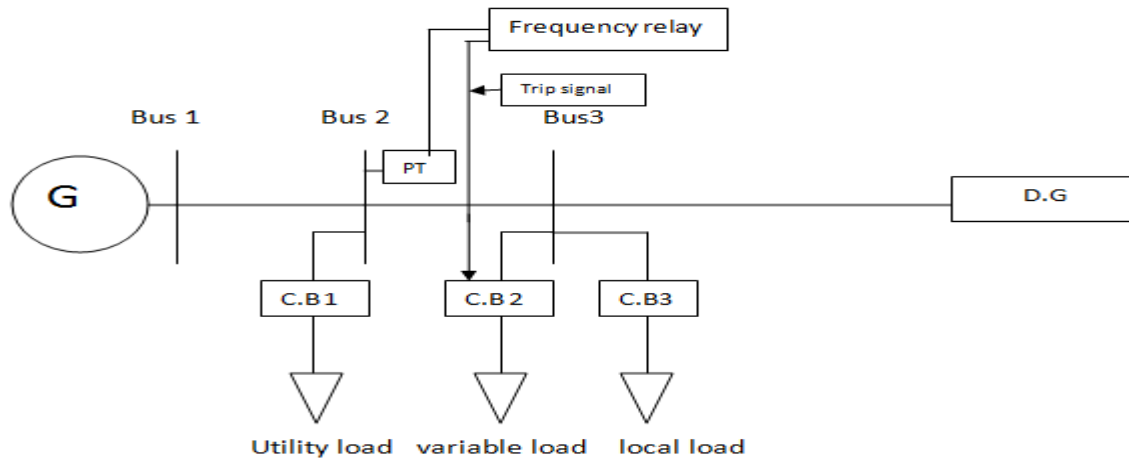


Figure 9. Single line diagram of the power system

V. MATLAB MODEL OF POWER SYSTEM

As shown in fig. 10, 150MVA, 132KV synchronous machine is used for testing the designed relay. 10 MVA, 132 KV distribution source is fed the system. Frequency relay is set at 51.5 HZ over frequency limit and 48.5 HZ for under frequency limit. Under frequency problem is occurs, frequency relay sent the trip signal to the circuit breaker and variable load is isolate from the system when the frequency goes below 48.5HZ. After the predetermine load shedding frequency will be restored.

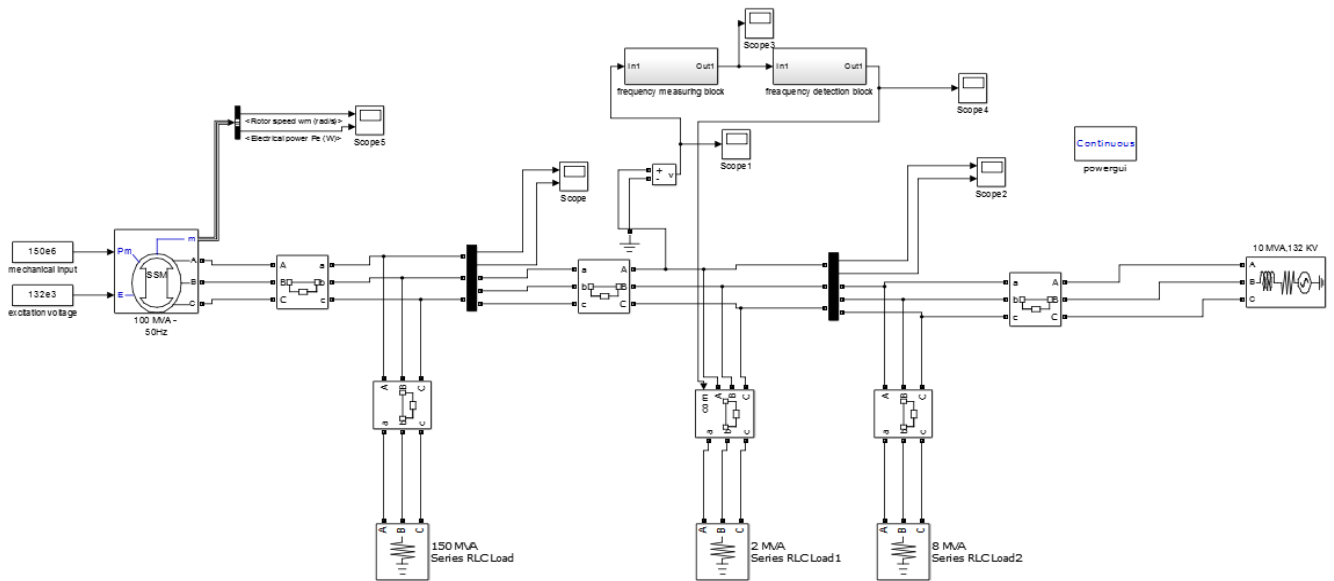


Figure 10. Implementation of frequency relay in power system on MATLAB/SIMULINK

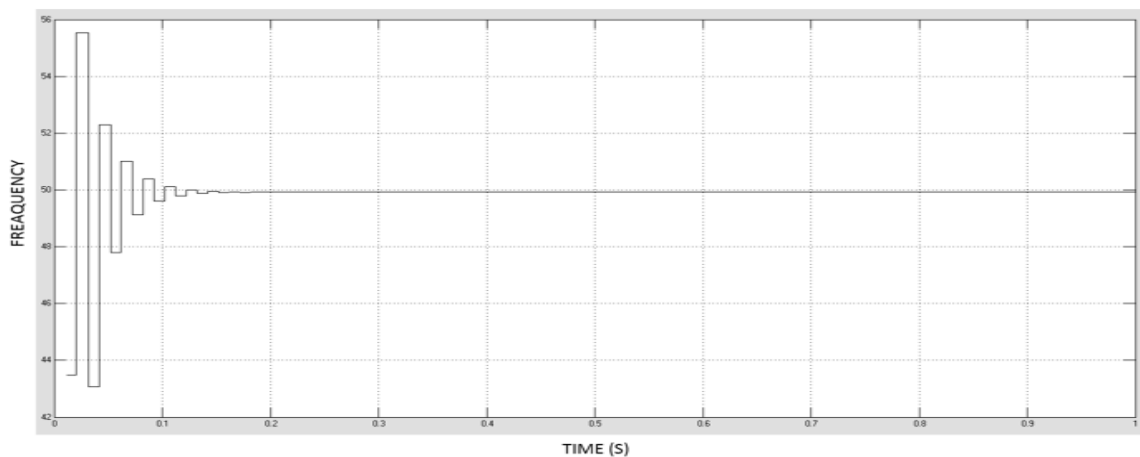
VI. SIMULATION RESULTS

The relay is tested under three cases 1) Normal operation, 2) Under frequency operation and 3) Over frequency operation. In the normal case generation power is equal to the consumption power. So, there is no frequency deviation and frequency is within a limit. Generation power is less than the consumption power in under frequency case. If frequency goes below the relay setting, relay send trip signal to the circuit breaker. In the over frequency case generation is larger than consumption. Hence, frequency may go above the relay setting and ultimately relay will send trip signal to the breaker.

A. Case 1 (Normal Operation):-

During the normal operation, variable load is assumed to be 2 MVA. The frequency and relay status as per MATLAB simulation are shown in fig. 11. As shown in fig. 11, relay does not trip because frequency of the power system is under safe limit.

Up to 0.2s, frequency varies because of starting transient but frequency still in the limit of the relay setting. So, frequency relay does not send trip signal to the circuit breaker.



(a)

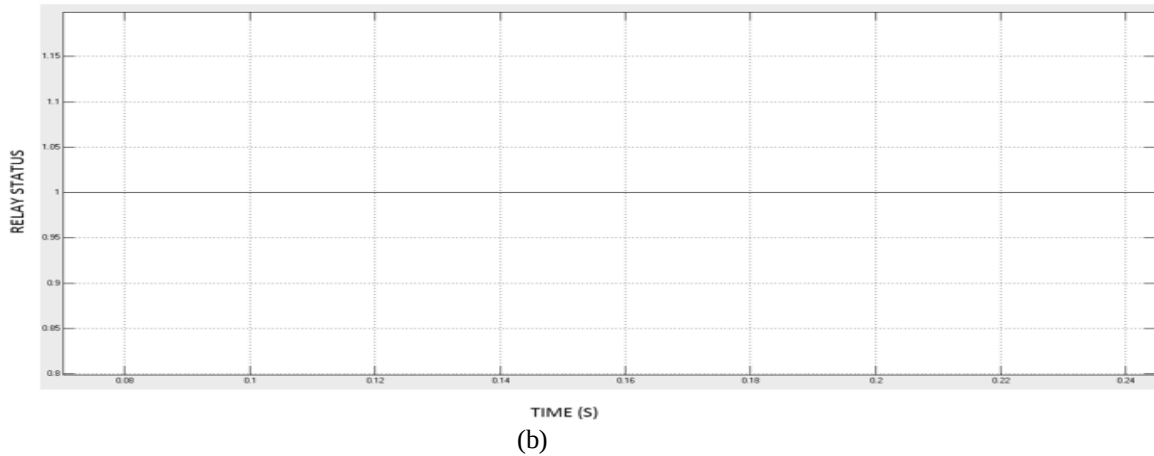


Figure 11. Performance of the relay a) Frequency b) status of trip signal

B. Case 2 (Under frequency condition):-

In this case, variable load is increased from 2 MVA to 30 MVA. Because of increase of load, the system frequency goes down (here 48.49HZ) below the under frequency limit of 48.5 Hz. Hence, the relay sends trip signal after the set time limit (here the limit is kept to 0.4s) to the circuit breaker as shown in fig. 12. Because of tripping of the variable load, frequency comes within a limit. In this way, the system frequency is restored to its safe limit (between 48.5 HZ and 51.5 HZ).

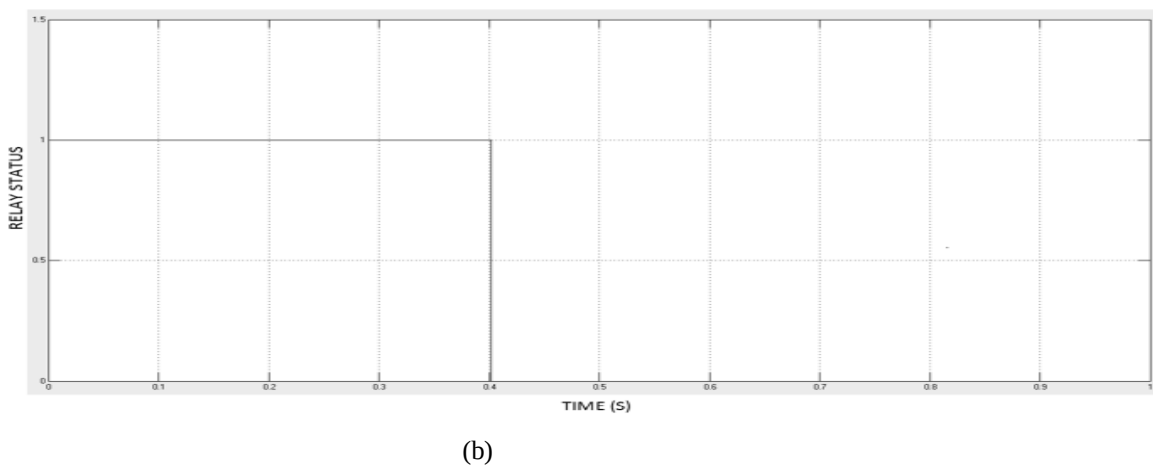
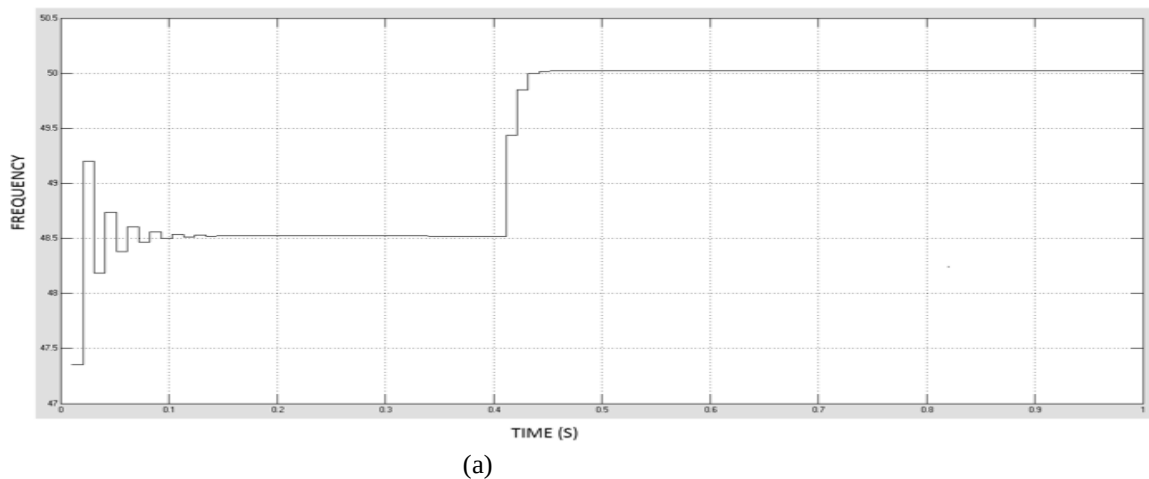


Figure 12. Performance of the relay a) Frequency b) status of trip signal

C. Case 3 (Over frequency condition):-

If generation is more than load, over frequency condition occurs. If the frequency increases beyond the limit, relay sends trip signal to circuit breaker to disconnect appropriate source. The system is restored back to the safe limit because of disconnection of such source. Working of the over frequency relay is similar to under frequency relay. Only one

difference between the function of over frequency relay and under frequency relay is that the over frequency relay operates when the system frequency goes above its set limit.

VII. CONCLUSION

This paper has presented detection of frequency, over/under frequency protection using digital frequency relay and load shedding for restore the frequency within a limit. By using the under frequency based load shedding relay, trip signal has been applied to a breaker if system frequency crosses a under frequency limit (48.5). Due to tripping of the breaker, load shedding has started (to isolate some load from the system) and frequency has returned back in the safe limit. This digital frequency relay has also been implemented in islanded mode. Frequency relay has also detected the islanding condition effectively. In this paper, under frequency protection with load shedding has been shown in the result section.

VII. REFERENCES

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