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Modelling and Simulation of Generator Protection Scheme against Frequency Variations

Ankit Patel 1, Dr. Vijay Makwana 2
Electrical Department, GCET, V.V. Nagar, Gujarat, India

Abstract —*This paper discusses various stability problems which may occur because of frequency variation. MATLAB SIMULINK modeling tool is used for the simulation of about problems. MATLAB SIMULINK also helps the fresh engineers to simulate the power system in normal and abnormal/faulty conditions*. *In this paper, design and testing of variation of frequency because of variation in load/generator parameters. Over and under frequency schemes have been implemented by using programming in MATLAB/SIMULINK*

Keywords- *power system Stability, Programming logic for protection, Frequency measurement, modeling of frequency relay*

I. INTRODUCTION

To maintain system stability is one of the most difficult challenges of power system. There are three major stability problems namely, Frequency instability, Voltage instability and Angle instability [1]. MATLAB/SIMULINK modeling tool/software is the most preferable option to simulate the system and to simulate the system behaviors under faulty conditions. MATLAB is also most commonly used software for fresh learners and researcher. Digital over /under frequency relay model has been designed using MATLAB/SIMULINK in this paper. Mechanical power is produced by turbine and given to the generator. Finally Generator converts the mechanical power into the electrical power [2]. Frequency instability problem happened when there is a large mismatch between load and generation. The difference between the mechanical and electrical power, causes the variation on the generators speed. Because of that the power system frequency varies in a wide range

There are three general types of frequency relays used in the market are 1) Induction-Cylinder Relay.2) the Digital Relay.3) the Microprocessor Relay. In digital frequency relays zero crossing of voltage is measured and a counter starts and continues counting until the next voltage zero crossing occurs or in some cases the next positive going zero crossing. It will show the period of the waveform and the frequency can be calculated. Depending on the situation the frequency relay trips after a set time as per the relay characteristics. If the system attains normal frequency, the relay will reset [5].

In this paper explained about over and under frequency variations in the system and to protect the system against it with the use of breaker. First of all voltage from the PT measured and obtain frequency at given signal. Program implemented for the over and under frequency limits, to check the result of frequency for the tripping. Case-1 for over frequency limits and case-2 for under frequency limit have been implemented.

II. MEASUREMENT OF FREQUENCY

To protect the power system against blackout during major variation in generation/load, frequency relay is used. The condition of islanding occurs due to loss of supply in case of distributed generation [3]. Power frequency should be maintained should be stable in any condition. The frequency delivered must not vary more than ±1%. Variation in voltage is permitted below 132KV is ±6%, whereas regulation is permitted for voltage higher than 132KV is ±10% [4].

In power system, generation should be equal to summation of demand and losses to keep system stable. The frequency may fluctuate in a very wide range during abnormal or faulty condition. The equation for the initial rate of frequency change is given as follows,

$$\frac{df}{dt} = -\frac{\Delta P}{2H} \qquad (1)$$

Where,

ΔP = the difference of power during a fault in per unit.
H = the inertia constant

III. WORKING OF DIGITAL FREQUENCY RELAY

Frequency Measuring Block (FMB)

The FMB calculates the frequency of a voltage signal from the voltage transformer. The time difference between the two successive zero crossing (S1 and S2) is measured to decide the Frequency magnitude as shown in Fig.1.To calculate the total time of a whole waveform, the difference between S1 and S2 is multiplied by value of 2, in Eqn. (2).

$$S = 2 \times (S2 - S1) \qquad (2)$$

$$Frequency = \frac{1}{Time\ period\,(T)} = \frac{1}{2(S2 - S1)} \qquad (3)$$

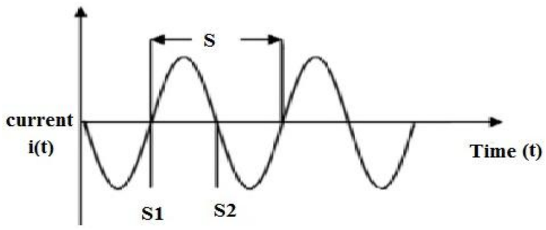

Fig.1: Measuring frequency of a signal

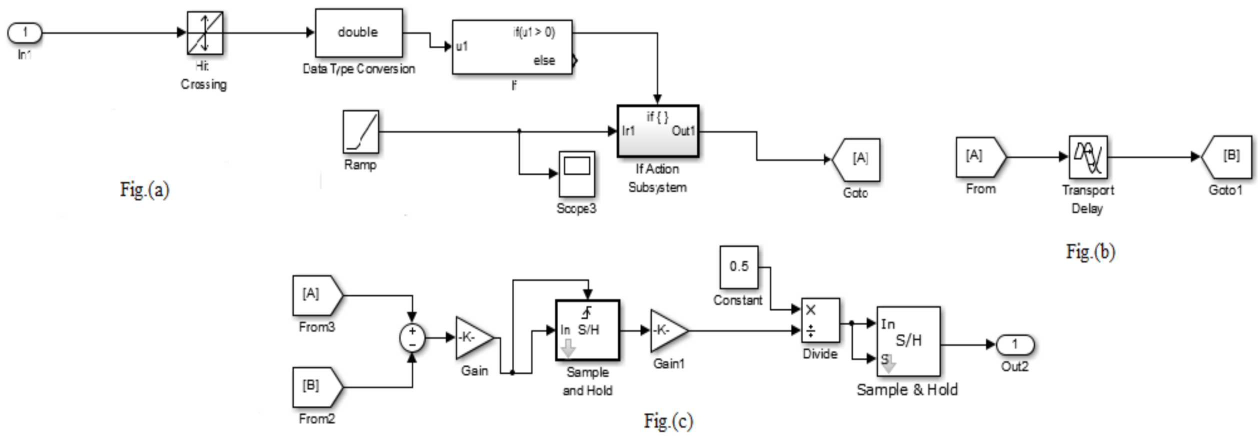

Fig.2: Logic implemented for measuring frequency at a signal

As shown in Figure 2. That to sense the zero crossing 'Hit Crossing' block given in MATLAB/SIMULINK is used. 'Hit crossing' block transfer the input signal at its zero crossings to the '*if*' block. Then after starts sending ramp signal to the output. In variable 'A' the time duration of generated ramp is measured and saved in it. Using the 'Transport Delay' block the variable A is stored in another variable B and the time of the next zero crossing is measured. Now Subtracting B from A as shown in fig.2 at any instant will give half the time period and whose value is held by the 'Sample and Hold' block, till the next zero crossing. By performing the essential computations, it is given by Eqn. (3), we got the instantaneous frequency. The output (calculated frequency) from FMB sends to the programming required tripping action, in case of fault [6].

(A) Implemented program logic for generator control at different frequency variations

```
function y = fcn(u)
%#codegen
p=185e6;
if u>=50 & u<50.5
    p=195e6;
elseif u>=50.5 & u<51
    p=300e6;

elseif u>51.5
    p=0;

end

y = p;
```

(B) Implemented breaker tripping logic using programming

```
function y = fcn(u)
%#codegen
p=0;
if u>=185e6 & u<195e6
    p=1;
elseif u>=185e6 & u<195e6
    p=1;

elseif u>195e6
    p=0;

end

y = p;
```

As shown in above over frequency protection using programming logic respectively. (A) Implemented program logic for generator control at different frequency variations shows logic for increased power of generator at constant load while (B) Implemented breaker tripping logic using programming shows logic for to trip the breaker. We can also implement under frequency protection using this phenomena.

Frequency relay settings		
Nominal frequency For India	Frequency relay	Limit of frequency
50	Under frequency	48.5
	Over frequency	51.5

Table-1

IV. SIMULATIONS AND RESULTS

For relay testing and simulation of this system, a 132kV network is considered. The single line diagram of the network is shown in Fig.3

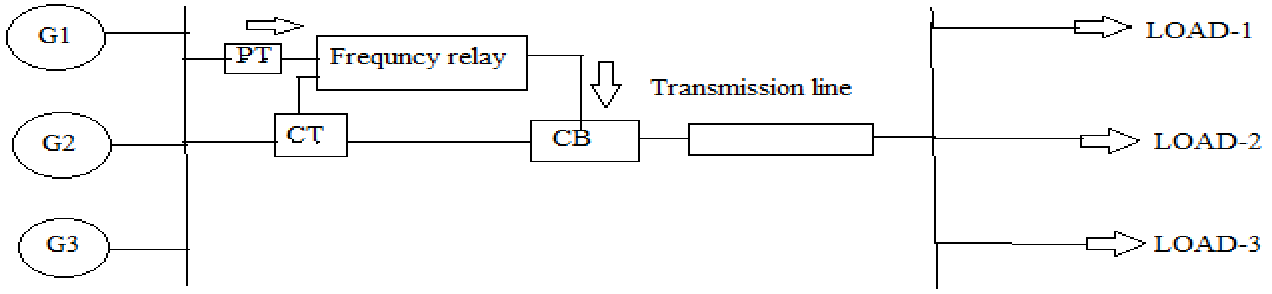

Fig.3 Single Line Diagram of a System

As shown in Fig.3 that the system is tested below various test conditions. In this system three generators are considered using the programming logic and with the system other side load is connected.PT is used to measure the voltage of the system and CT used to measure current in the system. Circuit breaker is used to trip the circuit and isolate the system. Therefore it will protect the system against over and under frequency variations. These tests conditions are given below. Case 1 is for over-frequency and Case 2 is for under frequency.

During over frequency condition, synchronous generator power increases and load remains constant. By using the programming logic, we can change the power of synchronous generator or we can also add or remove synchronous generators. The logic for increasing power is implemented here in this paper. Case-1 is over frequency case and its upper frequency limit is 51.5Hz. At the starting period, system run on normal condition after some time delay generator power is increased with programming logic but at that time load is constant. Because of this conditions frequency variations occurs and it crosses the set limit of over frequency. Beyond this limit breaker get tripping signal and the system isolated. To isolate the breaker at upper limit of frequency, programming logic is implemented as shown in Fig.4.

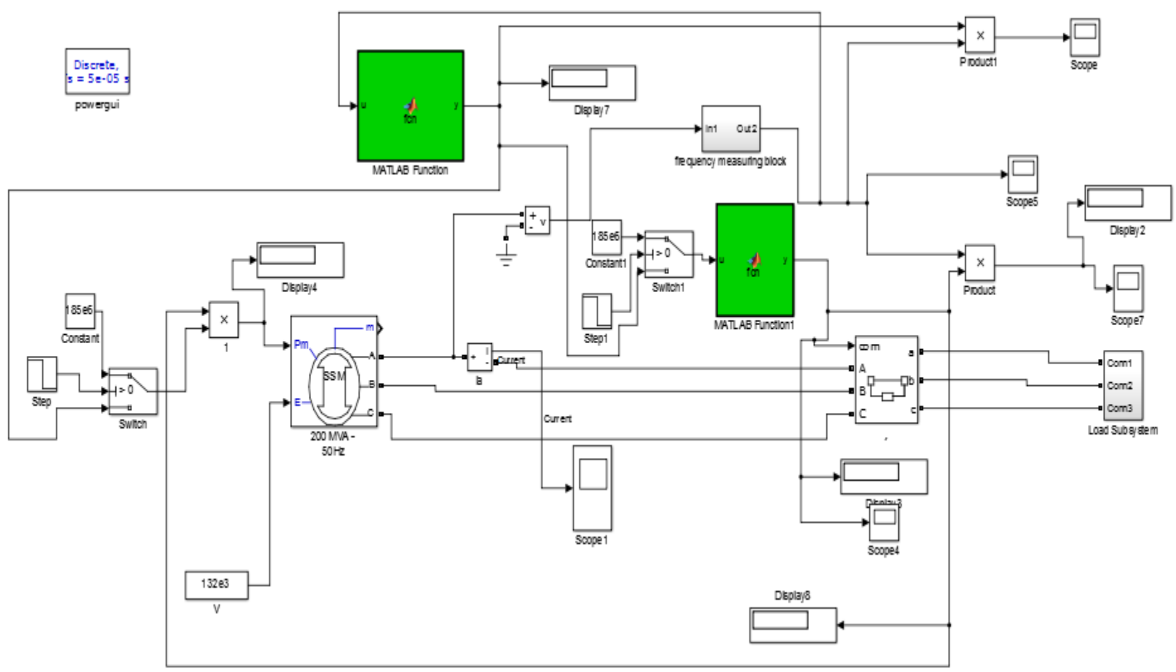

Fig.5:.Simulation of over frequency condition

To simulate the under frequency case, synchronous generator power is kept constant but load is increased. In this case the load is increased gradually into the system after some time delay. Due to increased load, a frequency variation occurs. Initially breaker is kept open, so load is not increased at that time after some time it is closed and load is increased into the system. Because of this increased of load into the system, frequency of the system is decreased. Due to decreased in frequency, the breaker trips when the frequency goes below the limit of 48.5 Hz. This frequency relay block isolates the breaker for this under frequency protection as shown in Fig.6.

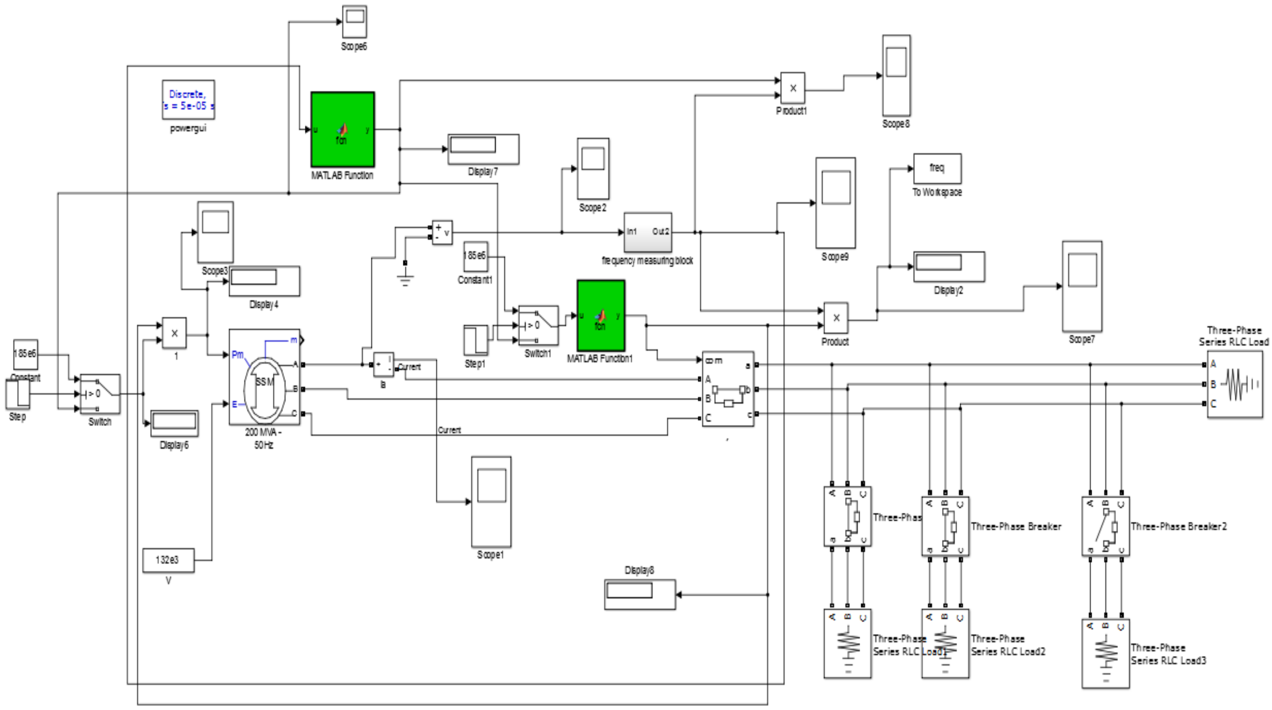

Fig.6: Simulation of under frequency condition

Case 1:

In this case, generation in increased gradually but at the same time the load is kept constant. Due to increasing generation, over frequency effect occurs on the system. Breaker will get 1 signal at normal frequency. When breaker will get 1 signal at that time system behaves as a normal and at over frequency, breaker will get 0 signals and breaker will trip. Due to tipping of breaker, system become isolated and protect against the over frequency. The current and frequency waveform are as shown in Fig.7 and Fig.8 respectively.

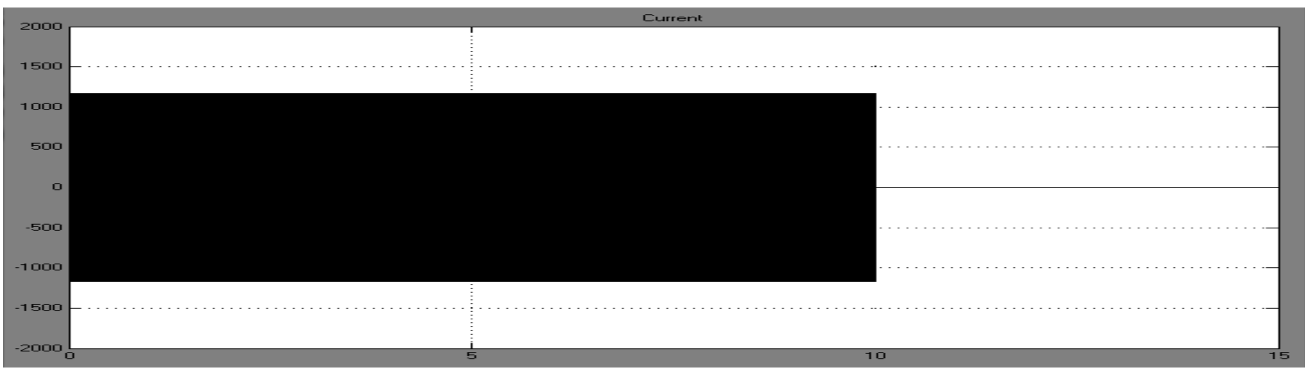

Fig.7: Current Waveform for over frequency

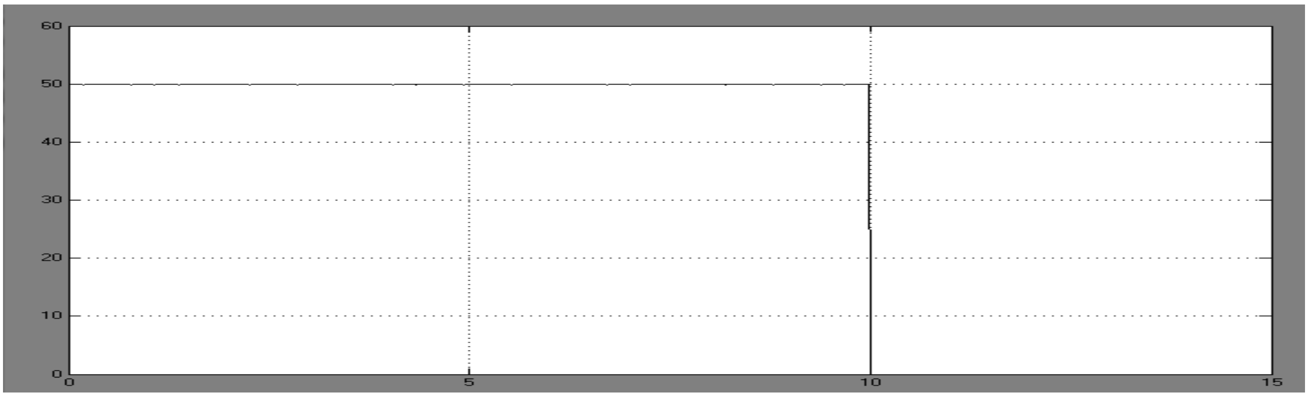

Fig.8: Frequency waveform for over frequency

B Case 2:

In this case, generation is constant but load is inceresed after some time. Due to increased of this load into the system , frequency of the system is deacresed. Under frequency limit is set at 48.5 Hz in this system. Breaker will get 1 signal at normal frequency and at under frequency it will get the 0 signal at the breaker and it will trip. Due to tipping of breaker, system become isolated and protect against the under frequency. The frequency and current waveform are as shown in Fig. 9 and Fig.10 respectively.

Fig.9: Frequency waveform for under frequency

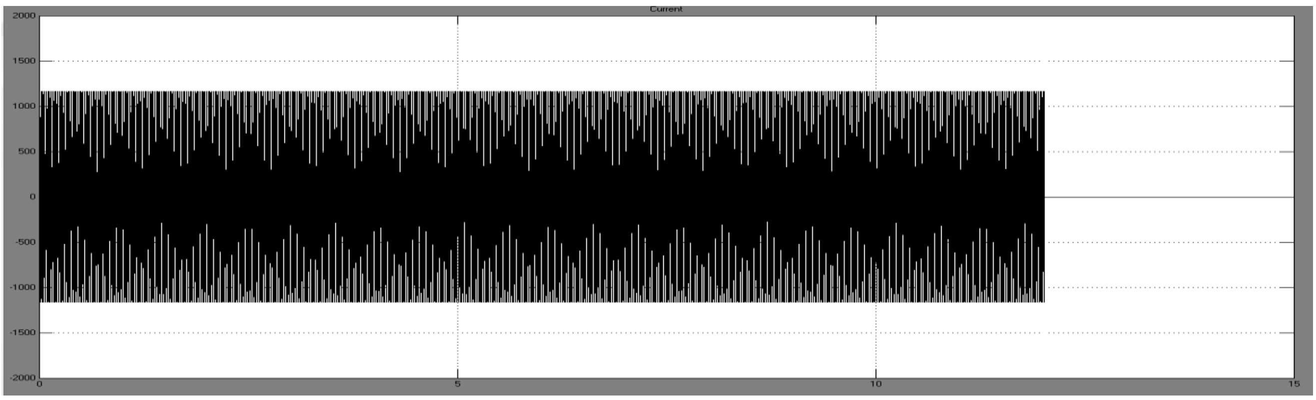

Fig.10: Current waveform for under frequency

VIII CONCLUSION

The paper has presented the modeling of the measurement of a frequency at a signal and implemented programming to control over frequency limit (51.5Hz) and under frequency limit (48.5Hz). By using the programming logic, tripping of breaker at a given over and under frequency limit has simulate in MATLAB/SIMULINK. Due to tripping of breaker, system becomes isolated. It will protect against over and under frequency. It has good advantage in terms of their sensitivity and frequency control wide range. In this paper protection of generator against over frequency limits (51.5Hz) and under frequency limits (48.5Hz) as shown in above results.

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