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# Regional Coordination of under Frequency Load Shedding using Mat Lab

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**Abstract:**

Rapid growth of electricity demand has contributed to the difficulties in delivering reliable power supply to the consumers. Instability operation of the power system network is considered as one of the significant problems affecting the quality of the delivered power, which are normally caused by the system frequency, angle and voltage fluctuations. The frequency stability is a primary concern as it determines the power system's ability to maintain the steady state operation after experiencing a severe disturbance. In this work, under frequency load shedding is proposed to overcome under frequency problems based on the rate of change of frequency method. The proposed technique is advantageous in term of the selection of the load to be shed at a specific frequency threshold.By using MATLAB/SIMULINK software, the proposed design was tested and simulated on actual 132 kV distribution network, connected to a synchronous generator.

***Keywords:*** *load shedding,under frequency, distribution network, synchronous generator, rate of change of frequency.*

## I. Introduction

As a guide of inequality between source and request frequency deviation can be used. The frequency deviation is needed to ensure the frequency is in permitting scale. The process of transmitting must be operated by the operator or balancing authority to certify the instability, cascading outage and uncontrolled separation will not occur [1]. In practice, when the generation or transmission size is insufficient the transmission authority or balancing authority has the authority to shed load instead risk the uncontrolled failure in the interconnection.

According to another study by J.J. Ford [2] "Load shedding can be categorized into two schemes which is static and adaptive. In the static scheme, as soon as the system frequency drops under certain threshold a certain amount of load is shut down and this scheme is more modest and

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castoff by utilities. Referring to another study by H. Bevrani "In considering the characteristic of the power system [1], nonlinear interacting generators and generator dynamic behavior under large disturbance, the adaptive method is used. The static and adaptive method is based on frequency threshold or frequency gradient. Whenever the frequency drops below the frequency threshold, the under frequency load shedding is triggered. In order to predict the possibility and manage an appropriate emergency plan the frequency gradient is used to provide an important slope.

The imbalance between generation and utilization will strengthens this generator to trip. Therefore, frequency failure will be thoughtful and this reason occurs the under frequency relays of other generators to trip. Thus, a drop outage of generators is started, in the end the entire system come across a wide spread blackout.

Rate of change of frequency (ROCOF) is normally used to determine the magnitude of disturbance in a network [3]. Thistechnique is totally response based. Event-based scheme is used to estimate the magnitude of disturbance. The Outage of significant transmission lines or generators may be an upright characteristic of the magnitude of disturbance. For instance, in a dual zone of control system, outage of tie lines may state the harshness of disturbance for UFLS relays[4]-[7]. By transfer the state of tie line circuit breakers to UFLS relays possibly will help the relays to change their settings conferring to the disturbance. In this method UFLS relays use a conventional setting by default. If a disturbance causes the tie lines to open, this condition is communicated to the UFLS relays in order that the relays automatically change their settings to the alternative approach of operation. On the other paper, analysis about under frequency load shedding in the various condition such as blackout condition, islanding operation, and micro grid has been discussed in many journals [9]-[14].

In this paper, the coordination of under frequency load shedding connected with the various of load is tested. Comparison under frequency load shedding by using conventional and adaptive method also discussed in this work.

## II. METHODOLOGY

An under-frequency load shedding (UFLS) based on adaptive scheme wasproposedin this work to determine the load that needs to be shed effectively. The operation was conducted by considering the system parameter, threshold frequency, total load to be shed and control area. By using frequency response analysis method, the proposed UFLS technique was designed and simulated in MATLAB/SIMULINK software.

### A. Research Framework

In thispaper, it will start by studying literature review about the load shedding and adaptive method. The models of frequency response analysis are represented by measurement of the output spectrum, which characterizes thedynamic system. Then, the range of frequency threshold and the percentage of load. In order to observe the performance of ROCOF, variousof load is simulated in the system.

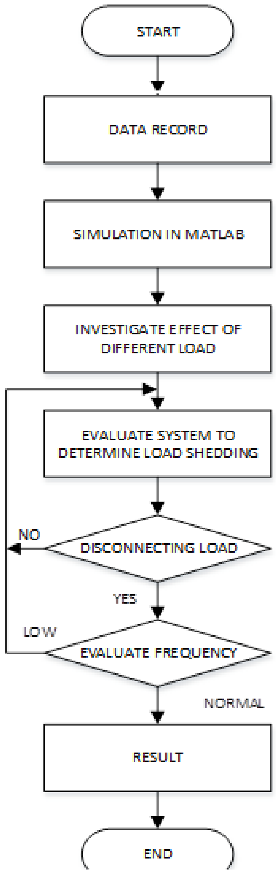


Figure 1: Flowchart of the proposed UFLS technique

The evaluation process is the stage to determine the load shedding when the various loads were applied. The determination of load shedding utilizes the equation of frequency deviation and inverse Laplace.Then, the system will evaluate the frequency that has been considered. If the frequency output is not suitable, the system will return to

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evaluate system load to determine load shedding block. After that, the system collects and gather the data until the system find it stable condition. If the condition has been stable, it moves to the next process.

### B. *Design Analysis*

#### 1) *Network Modelling*

A 132 kV distribution network was modelled in MATLAB/SIMULINK software as shown in Figure 2.

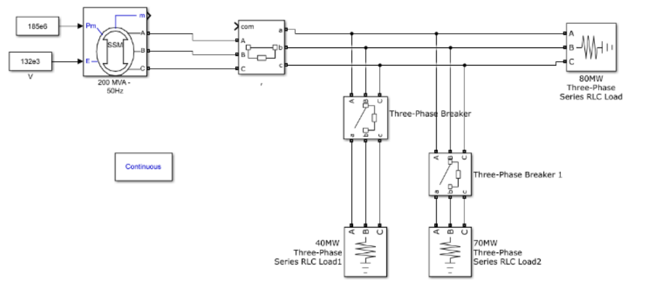


Figure 2: 132kV generator distribution network

The model consists of a 50 Hz, 200 MVA, 132 kV synchronous generatorsconnected to the load.The network has 3 phase series RLC load. At each load there are 3 phase circuit breakers. The total load of this system is 190MW.The rated output power of the generator is 185 MW.The frequency measurement unit, frequency detection and rate of change of frequency (ROCOF) blocks were also included in the simulated model.

#### 2) *Conventional Under Frequency Load Shedding*

Under Frequency Load Shedding is a protection which monitors system frequency. The conventional UFLS is a traditional method used to stable the generation and load when underfrequency befall. This method sheds a fixed amount of load and its location.

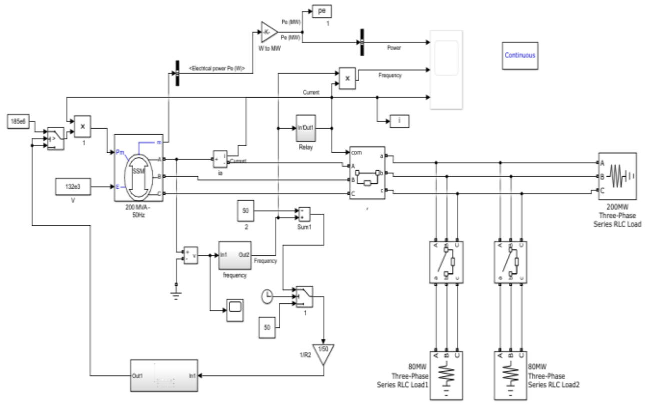

Figure 3: Under Frequency Load Shedding Conventional Method

Figure 3 has 200MVA 132KV generators is feed the load. The system above used to simplify synchronous machine which generates 200MVA 50Hz. The output power of this machine is 185MW. The frequency detection block is tested on this network. The generator feed load by 3-phase voltage sources.The frequency is tested in phase A which measure the voltage and current using multimeter to record the value. The frequency block in the figure above is used to differentiate the frequency at phase A. Then, the output of frequency block will split into two. One goes to sample and hold the element. The other one, go to feedback to the generator. Sample and hold element measure and trip the circuit breaker that meet its condition. This model used 3 phase circuit breakers. Circuit breaker 1 is controlled externally.

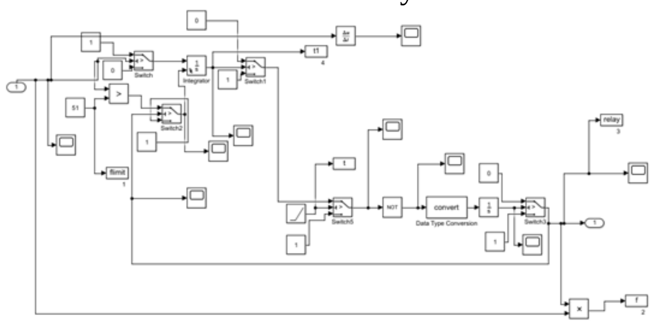

Figure 4: Frequency detection block

Figure 4 shows the diagram of the frequency detection block. The input signal 1 is from phase A line. The input signal 1 is split into two lines. The input 1 is connected to switch. The switch process either true or false by using constant 0 and 1. If the condition is true, the output will go to Integrator block. Moreover, the input 1 also connected with the relational operation.The operation has a constant of 51 which the limit of frequency. Then, the output of relational will go to switch2 and the output of switch2 will go to integrate same as a switch. The output of Integrator will go to switch1. The condition 0 and 1 same as switch. The output of switch1 will go to switch5 by ramp and the output of switch5 will go to not operate and go to data type conversion. The Integrator is used to integrate the data from the data type conversion and the output of it will go to switch3 to output 1.

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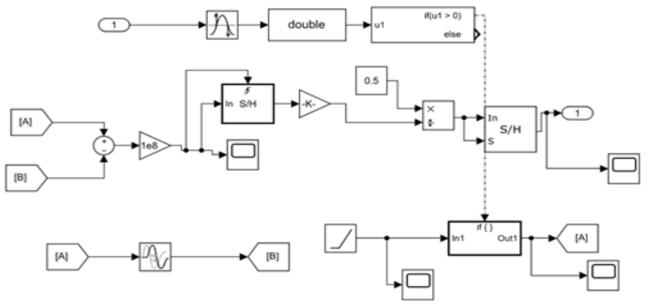


Figure 5: Delay and hold element

Figure 5 shows the delay and hold the element. Delay element is used to prevent the relay from sending a false signal to circuit breaker. The hit Crossing block is used to detect the zero crossing. The block passes the input signal at its zero crossings to the block, which in starts sending ramp signal to the output. The time duration of generating ramp is measured and saved to a variable 'A'. The variable A is stored in another variable B by using the Transport Delay block and the time of the next zero crossing is measured. Subtracting B from A at any instant will give half the time period whose value is held by the Sample and Hold block, till the next zero crossing. After performing the necessary computations, the instantaneous frequency is achieved.

*3) Under Frequency Load Shedding Adaptive technique*

Adaptive method is a technique for load shedding. This technique can adapt the reaction of frequency in system. The system monitors the frequency by use COI FFTD.

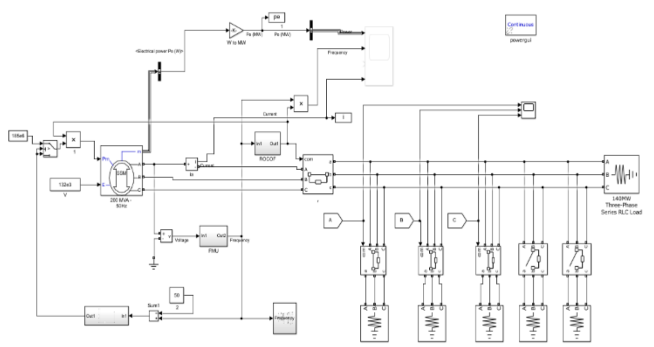

Figure 6: model of under frequency load shedding adaptive

This model consists of generator 200MVA 132KV feeds to the load. This model included frequency measurement unit, frequency detection block and rate of change of frequency (ROCOF). The system above used to simplify synchronous machine which generates 200MVA 50Hz. Thus, the output power of this machine is 185MW. The frequency detection block is tested on this network.

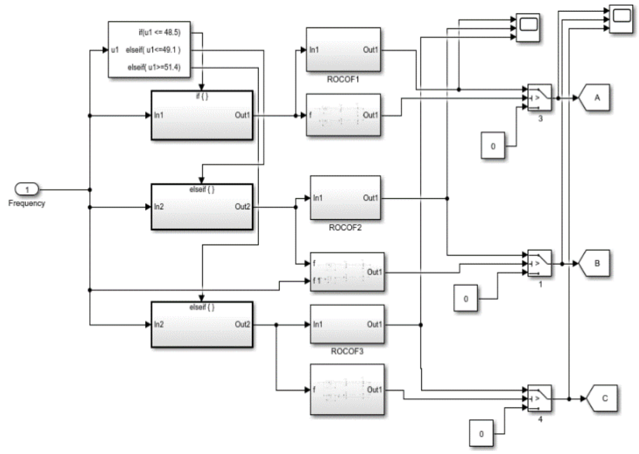


Figure 7: UFLS system to Trip circuit breaker

Figure 7 is the block for frequency measurement unit and rocof. In this condition, the input 1 is from frequency signal. The signal will pass to if condition block. The condition is when frequency below 48.5Hz the if condition will go to if action block. The input of if action block is same as if condition block. The signal pass to if action block to rocof and under or over frequency measurement. Then, the switch will send the signal to trip the breaker. The system is stable after breaker open. Otherwise, the signal will pass to another if action block to determine the signal to trip the breaker or pass to another if action block.

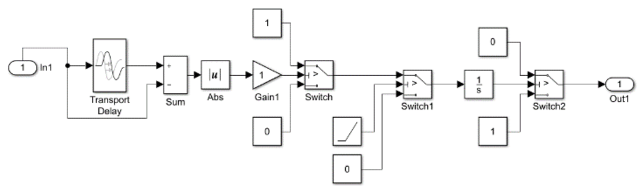


Figure 8: Rate of Change of Frequency (ROCOF) of UFLS

Figure 8 illustrates the ROCOF or df/dt. This function is used for load shedding. The input signal 1 is from frequency measurement unit in the system. The signal pass to Transport Delay block. This block used to delay the signal at $1 \times 10^{-25}$ s with Initial buffer size 1024. The output of Transport delay will go to sum block and pass to absolute block and to gain block. The gain is set to 1. Output of gain will go to Switch control port. The switch will trigger if condition is met. After that, output of Switch will pass to input 1 of Switch1. The control port used ramp with a slope equal to 1. The input port 3 of switch1 is constant 0. Then, the signal pass

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to the integrator to control port of switch2. The input port 1 and port 3 is set to 0 and 1. The output of switch2 is triggered when the condition of 0 and 1 is met. Then it will pass to output 1.

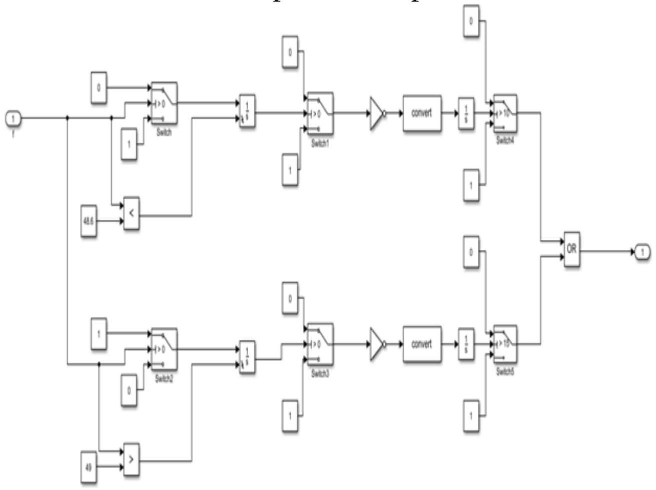

Figure 9: Under/over frequency measurement unit of UFLS

The Figure above shows the measurement under/over of frequency. The input 1 is from the phase A at the system. The input 1 will go to switch or switch 2 to check condition if the frequency under or over. If the condition is less than 48.6 Hz. The output will go to falling integrator. And the output of integrator will go to switch1 control port. The switch1 control port will trigger when output is either 0 or 1. If signal trigger is 0 then it will go to not logical operator. The output of not logical operator will go to input, convertof data type conversion. If true the convert will display 1 if false the convert display 0. Then, it will go to integrate which initial condition is 0. The signal will to switch5 and to OR logic operations. After that, the output will go to output 1. The process for the over frequency is same except for the Integrator which used rising integrator.

*C. Mathematical Modelling*

The frequency response of the various of load on the system can be analyzed by using equation 1:

$$\Delta f(s) = \frac{1}{2Hs = D}[\Delta P_m(s) - \Delta P_L(s)] \quad (1)$$

where$\Delta f$ is frequency deviation
H is the equivalent of inertia
D is the equivalent load damping coefficient

Equation 1 represents formulation of the frequency deviation in the system. Rearranging this equation based on the inverse Laplace transform,equation (2) is obtained as follows.

$$\Delta P_m(t) - \Delta P_L(t) = \Delta P_D(t) = 2H\frac{d\Delta f(t)}{d(t)} + D\Delta f(t) \quad (2)$$

As defined above, the $\Delta P_D(t)$ is proportional to the sum of load variation. When disturbance happensat $t = 0^{+}s$, the total load generation with unbalanced magnitude isformulated as shown below:

$$\Delta P_D = 2H\frac{d\Delta f(t)}{d(t)} \quad (3)$$

Where….

The frequency gradient,$d\Delta f/dt$is proportional to the magnitude of total load generation imbalance inthe power system.

$$\Delta f(s) = \frac{-\Delta P_L(s)}{2Hs + D} \quad (4)$$

$$\Delta P_L(s) = \Delta P_L/S \quad (5)$$

Where…..

Rearranging equations (4) and (5), we get:

$$\Delta f(s) = \frac{-\Delta P_L/D}{s[1+\left(\frac{2H}{D}\right)s]} \quad (6)$$

## III. Results and Discussion

All the results will be analyzed and discussed in this chapter, including the fault analysis, rate of change of frequency, and frequency measurement unit. The Matlabsimulink software is used to get all the data needed, which is the software used for designing the protection system. The system used for thisproject is 132kV synchronous generator. All the results obtained and elaboration regarding the finding of this research will be discussed in this chapter

*A. Conventional Method*

To observe the performance of the conventional network, it was tested in the two conditions of load. Thefirst load is 190 MW and second load is 206 MW.

*1) Load 190MW*

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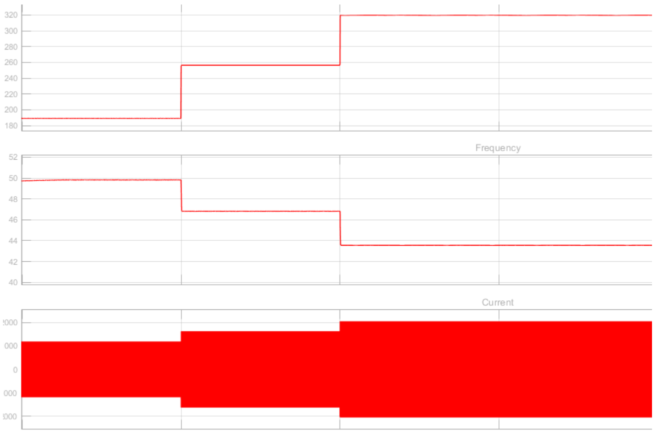

Figure 10: Frequency measurement output signal when the load increase by 80MW

Figure 10 shows the output signal of UFLS. The upper graph shows the power of generator. The red line shows the electrical power from the generator. The power is 185MW. When the load of the system is increased by 80MW the power increase to 256.4MW. The load suddenly increases by 80MW the electrical power increase to 319.7MW. This flow of electric charges constitutes the output electric current supplied by the generator. The generator can supply 200MVA to the system.

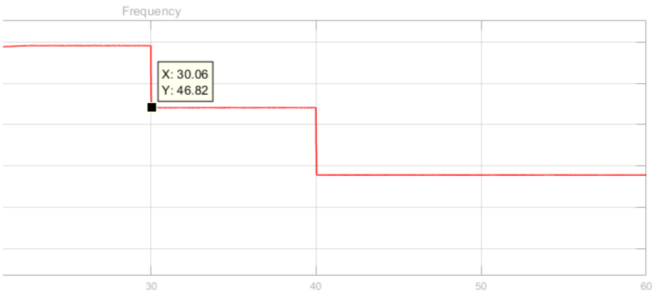

Figure 11: Frequency measurement graph when the load increase by 80MW

The figure above shows the decline frequency when sudden load is increased by 80MW. The total load on the system will be 256MW. The system initially supports 185MW only to the system. When the sudden load increased the frequency decline to 46.82Hz.

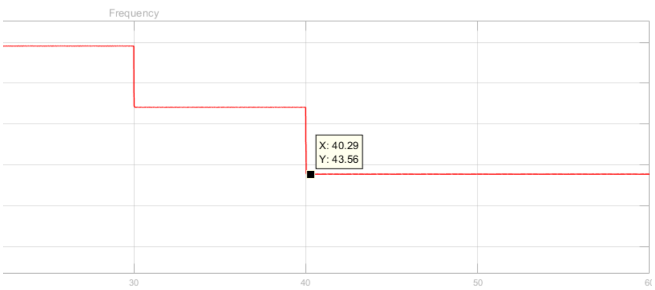

Figure 12: Frequency measurement graph when load increase

Figure 12 shows the frequency signal of the conventional network. When the load increased more by 80MW, it will make the system load is 345MW. Thus, the frequency drops again by 43.56 Hz.

*2) Load 206 MW*

The graph of electrical power shows 206.4MW. When the power loss, the frequency rise to another level to stabilize it. The load is shed due to under frequency range. The range under/over frequency is 48.5Hz and 51.5Hz. This power decline when the frequency drops at 48.5Hz graph of frequency. The system will shed the load to restore the frequency 49.5Hz. When the load suddenly decreased the frequency will increase. The system will restore the frequency 51.5Hz, which below the limit.

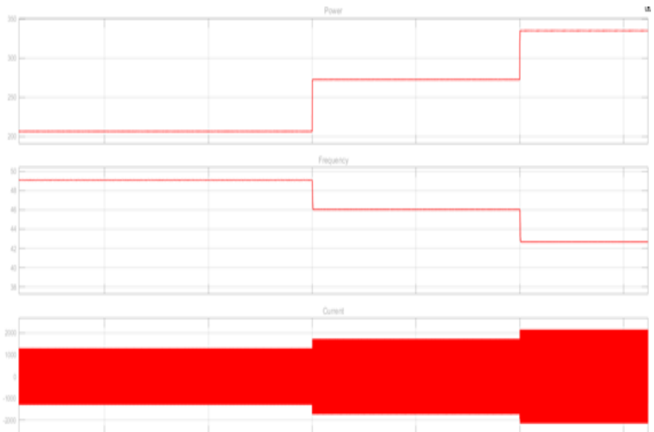
Figure 13: power, frequency and current in UFLS conventional system

## B. Adaptive Method

In order to observe the performance of the adaptive method, the load connected to the network was improve to 207 MW and 245 MW.

*1) Load 207 MW*

By applying the total load 207 MW and used adaptive method, the following output signal was obtained.

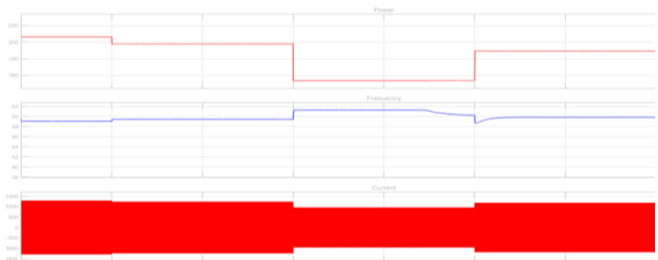
Figure 14: power, frequency and current of adaptive UFLS

Based on figure 14, the graph of electrical power shows 206.4MW. When the power loss, the frequency rise to another level to stabilize it. The load is shed due to under frequency range. The range under/over frequency is 48.5Hz and 51.5Hz. This power decline when the frequency drops at 48.5Hz graph of frequency. The system will shed the load to restore the frequency 49.5Hz. When the load suddenly decreased the frequency will increase. The system will restore the frequency 51.5Hz, which below the limit.

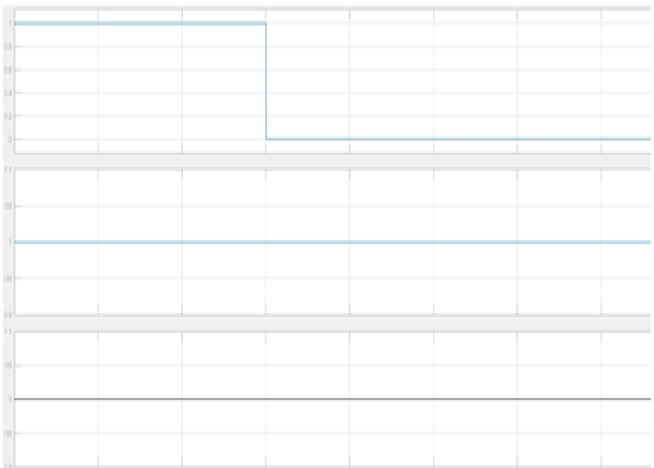

Figure 15: Trip signal of circuit breaker

Upper graph shows, the signal is tripped due to overload. So, the circuit breaker will trip to stabilize the signal. The middle and bottom of the graph show the signal is at 1 which means the breaker is staying closed. This is because the frequency is stabilized and does not need to trip the other breaker.

*2) Load 245 MW*

Figure 16 shows the graph of power and frequency. When the load increased the power is increased, thus the frequency decline below the limit. At initial load, the frequency is at 46Hz which too far from the limit. Thus, the relay will shed a load 1. Once the load was shed. The power decrease from 245MW to 230MW and the frequency rise from 46Hz to 47.9Hz. In frequency limit, it is still under the permissible value of frequency. Therefore, the relay was shed another load to return the frequency at safe state. When the load 2 is shed, the power decrease from 230MW to 204MW. Hence, the frequency is increased from 47.9Hz to 49.1Hz due to load 2 is shed. The frequency is a stable state and within range limit.

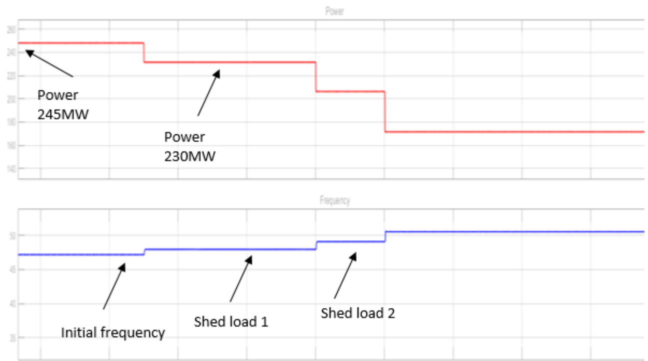


Figure 16: power and frequency signal

Figure 17 represents the trip signal of the circuit breaker. The upper graph shows the signal of circuit breaker 2. When the frequency dropped below the limit. The ROCOF send a signal to trip a breaker. When the breaker 2 trip the frequency rises as shown in figure 4.2.7. Moreover, the frequency still below the limit. Then, the ROCOF measure and send a signal to trip the breaker 1. Which the signal is at bottom of the figure above. The system is stable thus no trip signal sent to breaker.

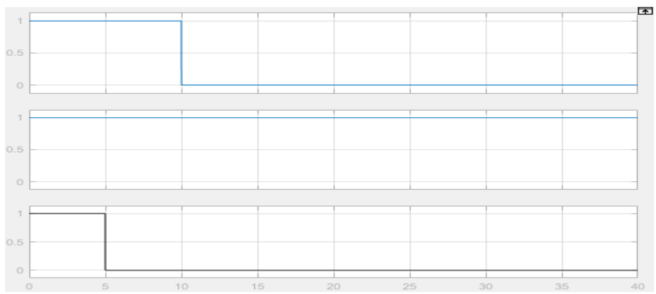

Figure 17: trip signal of circuit breaker

## *C. Comparison between Conventional and Adaptive Method*

In this work, the network also tested by using the same load value. By using conventional and adaptive method, the comparison result is shown in Table 1 as follows.

Table 1: Comparison of current and frequency with different load values

| Type of Data | Conventional | Adaptive |
|---|---|---|
| | Load 200 MW | |
| Current (Ampere) | 1045 | 1159 |
| Frequency (Hz) | 50 | 50 |
| | Load 280 MW | |
| Current (Ampere) | 1583 | 1166 |
| Frequency (Hz) | 46.82 | 49.83 |
| | Load 360 MW | |
| Current (Ampere) | 2000 | 954 |
| Frequency (Hz) | 43.56 | 51.68 |

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Table 1 shows the variations in the load (200 MW, 280 MW and 360 MW), voltage and frequency of the simulated system. Themeasurement of current and frequency when the different load values applied shows the impact to the values of current and frequency itself. For the conventional method, when the load increase, the values of current also increase. However, the frequency of the system is reduced. But in the adaptive method, this applies the opposite. Where the higher the load, the current will decrease and the frequency will rise slightly.

## IV. Conclusion

To restore the system frequency within a given limit, the detection of frequency, under frequency protection using frequency relay and load shedding was implemented in the proposed UFLS adaptive technique. By using the under frequency-based load shedding relay, the trip signal was applied to a breaker as soon as the system frequency crosses the under-frequency limit of 48.5 Hz. Due to the tripping of the circuit breaker, the load shedding started to cut some load from the system while the frequency stabilized backwithin the safe operating limit. Frequency relay has also effectively detected the islanding condition in the simulated system. The proposed UFLSscheme can be a useful guide for future distribution network planning and operation, where power can be delivered to the consumers in a reliable manner.

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