Study Committee C4

Power System Technical Performance

10992_2022

The blackout event in Thai power system: stability assessment, investigation, and prevention

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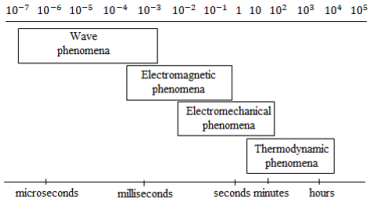
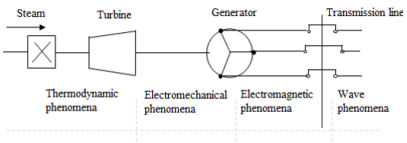
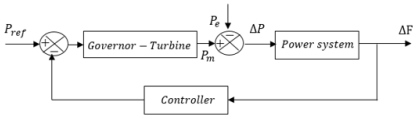
The power system technical performances

- The power system technical performance presenting in this paper, the blackout event in Thai power system is the electromechanical phenomena





The system frequency response (SFR) model



$$\frac{\Delta F(s)}{\Delta P(s)} = -\frac{\omega_n^2 T_R}{\beta} \frac{s + \frac{1}{T_R}}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$$\Delta f(t) = \mathcal{L}^{-1}\left(\frac{\Delta P}{s} \frac{\omega_n^2 T_R}{\beta} \frac{s + \frac{1}{T_R}}{(s + \zeta\omega_n)^2 + (\omega_n\sqrt{1-\zeta^2})^2} \right)$$

$$\lim_{s \to 0} s\Delta F(s) = \frac{1}{\beta}\Delta P$$

$$\zeta = \frac{\frac{2H\omega_n}{\beta}}{\beta}$$

$$\omega_n^2 = \frac{\beta}{2HT_R}$$

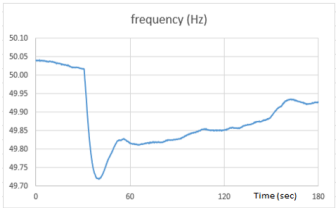
$$2\sum_{i=1}^{n} H_i \frac{df}{dt}\Big|_{t=0} = \Delta P$$

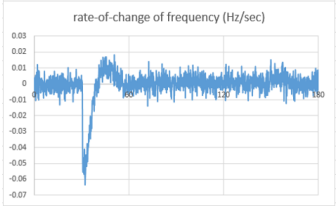
The identification of the SFR model

- Refer to the data of frequency changing in the disturbance event on July 25, 2015, the loss of 670 MW power generation from the Thailand's grid have been used for the identification of the power-frequency transfer function of the SFR model

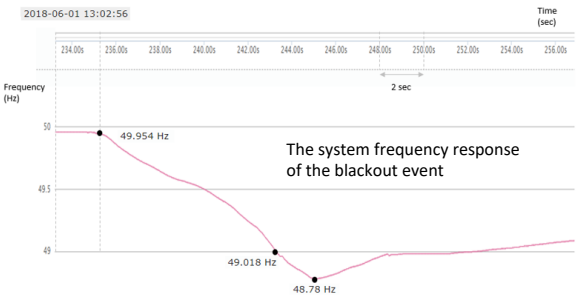
The blackout event in Thai power system

- In June 01, 2018 at 13:06, the both 500-kV transmission line in the northern area tripped
- This resulted in the power plant disconnected while delivering the 1,300 MW to the power grid
- The power system frequency started to decrease continuously from 49.95 Hz to 48.78 Hz
- The 4,000 MW of load was shed by the under frequency relay at 49.0 Hz and 48.8 Hz
- This event leads the one important question for the Thailand's power grid. That is ' why did the loss of generation just 1,300 MW result in blackout? '
- The suspicion has been cleared up by the frequency stability simulation and assessment

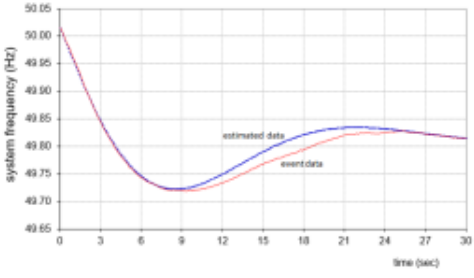




Power system parameters	Estimated data
T_R, Time constant	4.6 sec
β, Stiffness of power system	336 MW/0.1 Hz
H, Power system inertia	11.35 sec (at 23,994 MVA)



The system frequency response of the blackout event



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10992_2022

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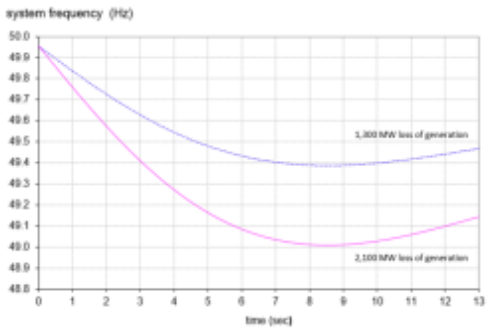
(continued)

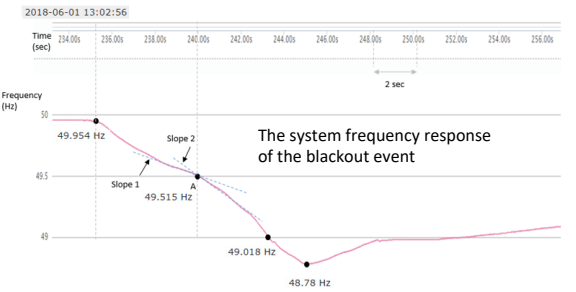
The frequency stability assessment of the blackout event

- The system frequency response simulation f(t) for the case of the loss of 1,300 MW power generation, the maximum frequency deviation is just 49.4 Hz while the maximum frequency deviation of the blackout event is 48.78 Hz
- This confirms that the actual generation outage of the blackout event was not the 1,300 MW, exceeding the 1,300 MW
- The system frequency response simulation f(t) for the case of the loss of 2,100 MW of generation, the maximum frequency deviation is 49.0 Hz, closing in the operating of the frequency relay of the event
- The suspicion for the blackout event is cleared up



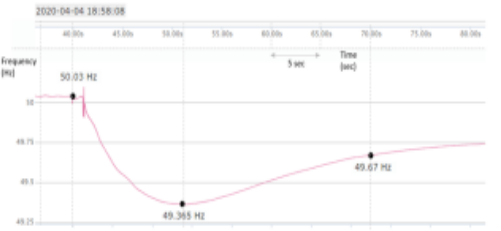
The investigation of the blackout event

- After the power plant disconnected while delivering the 1,300 MW due to the two 500-kV transmission lines in the northern area tripped,
- While the frequency reached the point A at 49.5 Hz, the rate of change of frequency (Hz/sec) changed from the slope 1 to the slope 2
- The system frequency was declining with the high slope Hz/sec due to the 2,500 MW of the 37-small power plants tripped
- The aspect of the loss of 2,500 MW power generation was the widespread cascade tripping and then leading to the blackout
- This resulted in the system frequency collapsed, and the 4,000 MW of load was lost, shed by the frequency protection relay at 49.0 Hz, and 48.8 Hz
- Without the widespread cascade tripping of the small power plants at 49.5 Hz (point A), the trend of the system frequency response is not downward
- This accords with the frequency stability simulation for the case of the loss of 1,300 MW power generation



The following up

- The following up after the frequency protection relay setting of the power plants have been corrected
- The system frequency response of the event on April 4, 2020 with the loss of 1,493 MW power generation, the initial frequency operating 50.03 Hz, and the frequency nadir 49.365 Hz
- The widespread cascade tripping of power plants did not appear while the frequency was declining



The prevention of the blackout event (Frequency instability)

- Knowing the critical point leading to the blackout, the measure for the blackout prevention and mitigation have been operated
- To avoid the widespread cascade tripping of the small power plants while frequency declining
- the technical standards for the connection of the small power plants to the power grid have been revised
- the frequency relay setting of the small power plants have been revised using the 48.0 Hz

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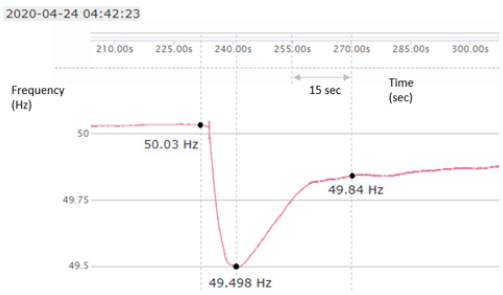
(continued)

The following up (continued)

- The system frequency response of the event on April 24, 2020 with the loss of 1,478 MW power generation,
- the initial frequency operating 50.03 Hz, and the frequency nadir 49.498 Hz.
- The widespread cascade tripping of power plants did not occur while the frequency was declining
- These are the following up after the frequency protection relay setting of the power plants have been corrected
- The frequency stability of Thai power system are verified

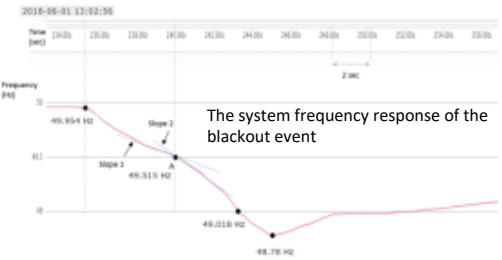


The measure to reduce the risk of blackouts

- Besides the frequency instability prevention, the Electricity Generating Authority of Thailand (EGAT) has assessed and followed up the other technical performances when the event occurred such as
- the short-circuit level,
- the stability limit of the tie-lines,
- the surge overvoltage,
- the power system oscillation,
- the voltage stability,
- etc.

The lesson learned from the blackout event

- The actual weakness of the power system was revealed
- The critical event leading to the blackout was the widespread cascade tripping of the small power plants while the frequency reached the 49.5 Hz
- This is the lesson learned from the blackout event



The system frequency response of the blackout event

Conclusion

- The tripping of the both 500-kV transmission line at 13:06, June, 01, 2018 resulted in the power plant delivering the 1,300 MW disconnected
- ‘ Why did the loss of generation just 1,300 MW result in blackout? ’
- The suspicion is cleared up by the frequency stability simulation and assessment using the system frequency response, SFR model
- The simulation result indicates that the generation outage of the event is not 1,300 MW, exceeding 1,300 MW
- The widespread cascade tripping of the small power plants about 2,500 MW occurring while the frequency reached 49.5 Hz is the critical point leading to the blackout
- To avoid the widespread cascade tripping of the power plants while frequency declining, the frequency relay setting of the power plants have been revised using 48.0 Hz
- On April, 4, 2020 Thai power system disturbed with the event, the loss of 1,493 MW of generation, the frequency nadir of the event was 49.365 Hz
- On April 24, 2020 the Thai power system disturbed with the event, the loss of 1,478 MW of generation, the frequency nadir of the event was 49.498 Hz
- The widespread cascade tripping of the power plants while frequency declining of the events did not appear
- These are the follows up to confirm the frequency stability of Thai power system after the measure for the blackout prevention have been applied