Analysis and Improvement Strategy on Power System Inertia in Taiwan

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I. Research Background

To accelerate the development of renewable energy (RE), the government has set a goal of 26.938 GW RE installed capacity to be achieved by 2025. Along with increasing RE penetration ratio, the inertia of power system is declining and inclined to endanger the stability of power system frequency-situations such as increasing ROCOF, decreasing reserve capacity, and dramatic frequency changes. In this study, we analyze the impact of RE to the inertia of power system, and seek for solution against low system inertia.

II. Research Content and Results

This study analyzes the scenarios of integrating a large number of RE resources into the power system based on various RE ratio (ranging from 30% to 70%) and the likely situations of contingency.

We utilize PSS/E software to simulate the power system in 2026, and the scenarios are as follows:

- RE model: Assuming all RE are PVs and doesn`t take inertia response of wind turbines into consideration.
- Distribution of RE: 5% RE distributed in the northern power system, 35% in the middle, and 60% in the southern.
- Priority of generator replacement: Gas generators which are old and located in the south have priority. Nevertheless, IPPs are not on the list.
- Location of RE: For simulation feasibility, REs located in the south are connected to the replaced generator BUS, RE in the north and the middle on the 345kV BUS of the southern system.
- To match different RE ratios, some generators are not replaced, but load shedding.
- Load setting: For dynamic simulation, active power is set at constant current mode, and reactive power set at constant impedance mode.
- The situation of contingency is set at post 1 second of steady state for all scenarios .

Table I and Figs. 1 show the result of simulation which 40.53% RE ratio in light load, Table II and Figs. 2 show the result of simulation which 21.55% RE ratio during peak load hours.

Table I

Result of simulation which 40.53% renewable energy ratio during light load

CASE	Total generation (MW)	Generation loss (%)	Frequency nadir(Hz)	Frequency variation(Hz)	Time of frequency nadir(s)	System inertia(GW*S)
1	21558.7	0.696	59.841	0.159	13.58	119.42
2	21558.7	1.392	59.667	0.333	13.88	118.01
3	21558.7	1.966	59.521	0.479	14.42	118.39
4	21558.7	2.430	59.410	0.590	14.43	114.84
5	21558.7	2.893	59.279	0.721	14.85	111.29
6	21558.7	3.357	59.138	0.862	14.65	107.50
7	21558.7	3.932	59.010	0.990	14.78	115.94
8	21558.7	5.897	58.481	1.519	14.86	113.49

Table II

Result of simulation which 21.55% renewable energy ratio during peak load

CASE	Total generation (MW)	Generation loss (%)	Frequency nadir(Hz)	Frequency variation(Hz)	Time of frequency nadir(s)	System inertia(GW*S)
1	40547.1	0.370	59.919	0.081	14.62	194.08
2	40547.1	1.045	59.766	0.234	13.41	193.05
3	40547.1	1.621	59.638	0.362	14.39	191.47
4	40547.1	2.090	59.483	0.517	14.64	190.6
5	40547.1	2.666	59.381	0.619	14.79	189.02
6	40547.1	3.136	59.262	0.738	14.67	188.15
7	40547.1	3.711	59.121	0.879	15.07	186.58
8	40547.1	4.181	58.993	1.007	15.33	185.19

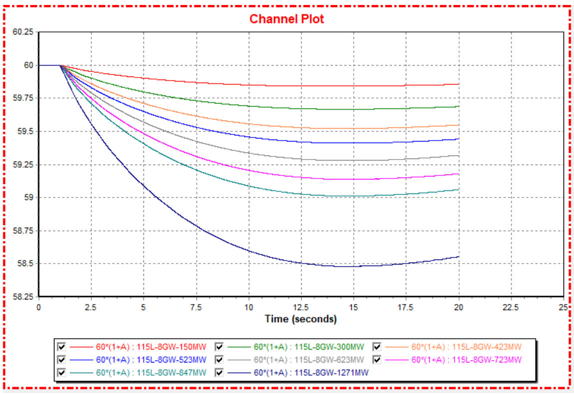

Fig. 1 Result of simulation which 40.53% renewable energy ratio during light load

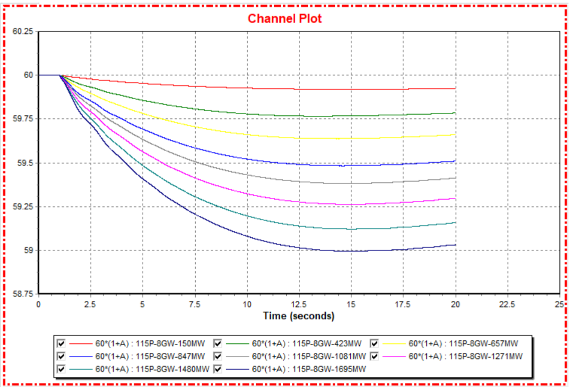

Fig. 2 Result of simulation which 21.55% renewable energy ratio during peak load

Fig. 3 show the relationship between generation loss, frequency variation, and system inertia. The size of circle represents the quantity of system inertia. Light load in 2026, generation loss and frequency variation are highly correlated. For example, in the case of 6% generation loss, the higher RE penetration ratio (16GW), there will be more frequency variation (2.5Hz). In addition, under same RE penetration ratio, when there are more generation loss, there will be more frequency variation. Furthermore, when generation unchanged, the more system inertia (blue circle is bigger than green circle), the less frequency variation. We cab get similar results during peak load, shown in Fig. 4.

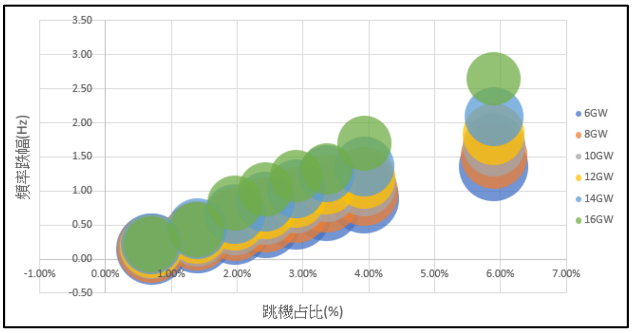

Fig. 3 Relationship between generation loss, frequency variation, and system inertia (light load in 2026).

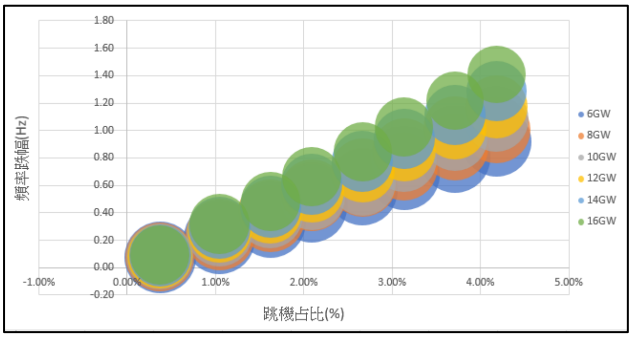

Fig. 4 Relationship between generation loss, frequency variation, and system inertia (peak load in 2026).

C. Conclusion

WhenRE penetration ratio increases, it is necessary to decrease the output of online generators to maintain generation/load balance. Thus, the equivalent inertia of power systems will gradually decrease.

Our comments are as follows:

- No matter the penetration of RE, generation loss and frequency variation are highly correlated in both light and peak load.
- No matter what the RE penetration ratio is, the relation between system inertia and frequency variation are highly linear.
- The less system inertia, the more frequency variation when a contingency event happens.
- According to the simulation scenarios of different RE power generation and contingencies, the relation between ROCOF and frequency variation are linear.