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Online Identification of the Moment of Inertia of Generator Unit by PMU

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Contents

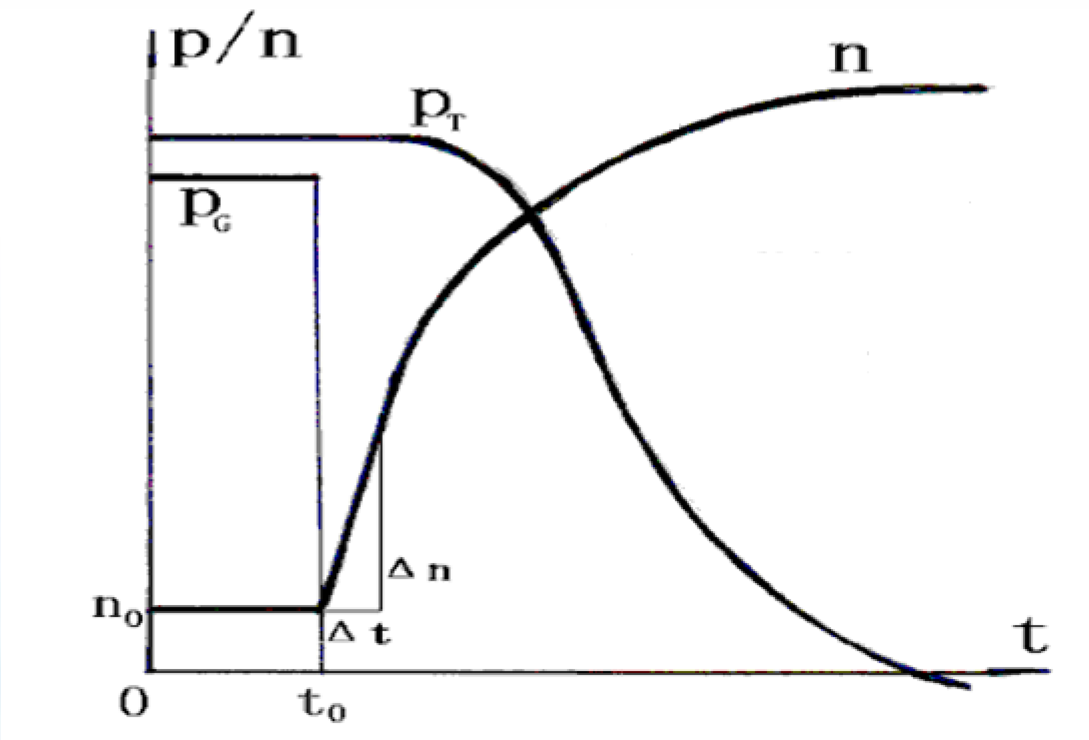
The necessary for identification of MOI

- The moment of inertia is one of the most important parameters that determine the dynamic performance of a generator unit.
- It is a combined moment of inertia of all the rotatory components that includes:
  - rotatory components made by different manufactures and with complicated structures
    - generator
    - Turbine
    - rotatory exciter
  - Water in hydraulic turbine

Field test of MOI

- The combined MOI of generation unit should be tested and verified at the field of power plant.
- Traditionally load rejection tests are used to obtain the combined MOI at the field of plants.
  - load rejection test has great damage to generator unit, and will shorten the life the unit.
  - Create operation risk to power system.
  - Some units cannot have the opportunities to conduct the load rejection tests because of the lack of test conditions.

The requirements for field test of MOI



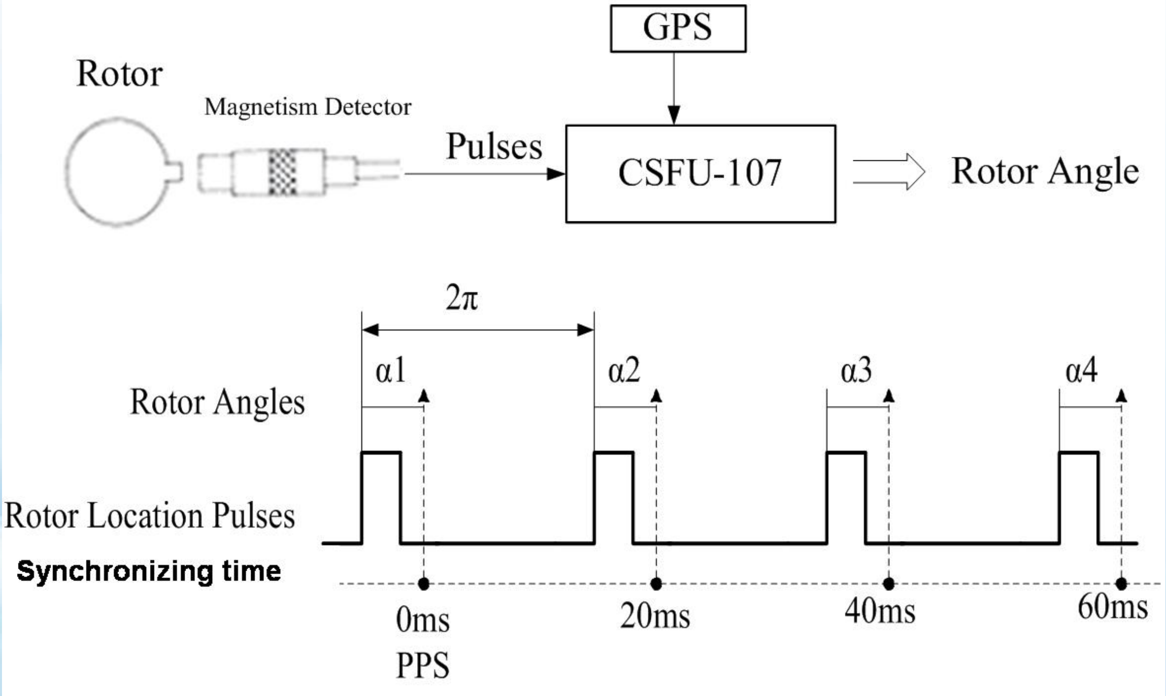
n: rotor speed
P_T: mechanical power of rotor
P_G: output power of gen. unit
t_0: the time of load shedding

$$M = \frac{P_G}{\left(\frac{\pi}{30}\right)^2 n_0 \frac{\Delta n}{\Delta t} \eta_G}$$

- **The highest speed during the test should not exceed 105% rated speed**
- **The precision for speed should be higher than 0.1 turn/minute**
- **The initial linear section of speed rising curve only have tens of milliseconds**
- **The response time should be less than 20ms**

The feasibility of MOI identification by PMU

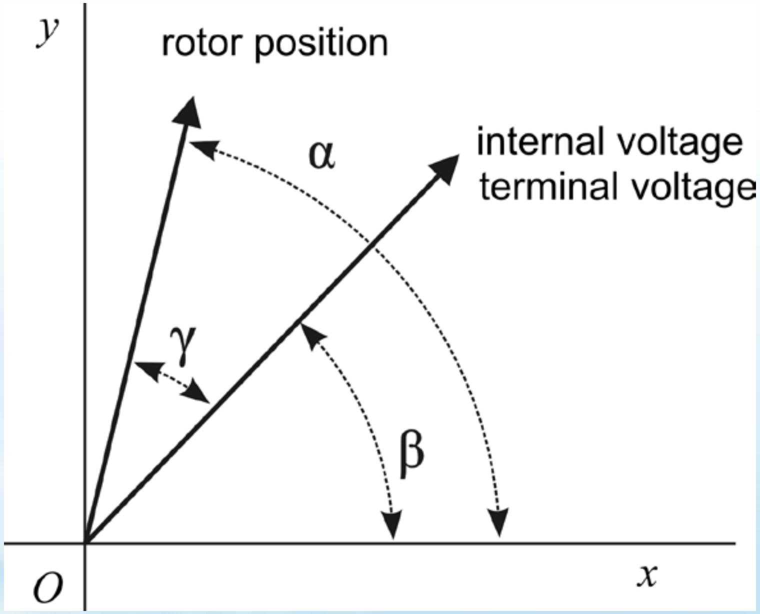
- There are two types of PMUs in China
  - Phasor measurement
  - Rotor angle measurement

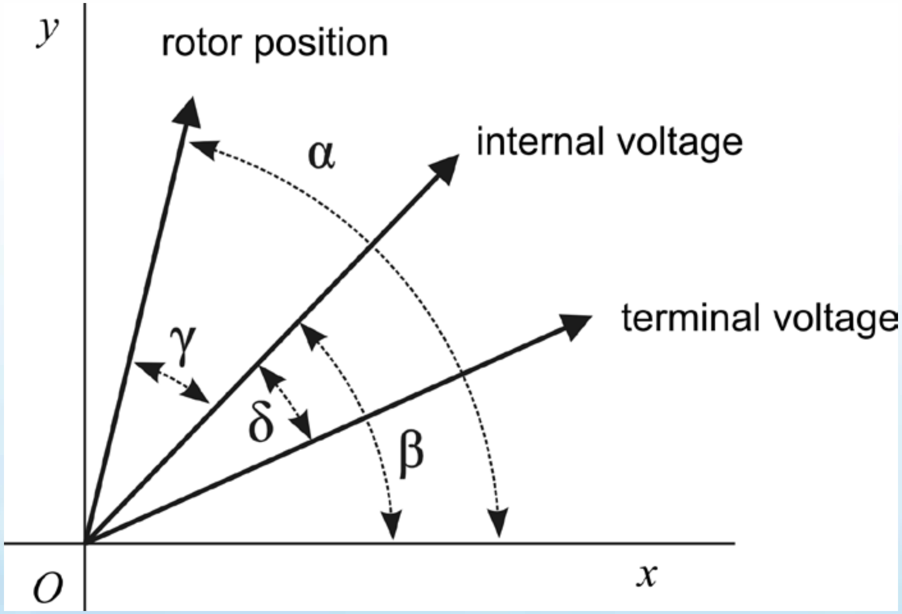


A periodic pulse signal may be produced by a slot added at some arbitrary location on the rotor, and a sensor on the stator.

By comparing the rotor position signal with the standard time signal, the rotor position angle can be calculated in PMU.

The feasibility of MOI identification by PMU





Phasor diagram under no-load conditions Phasor diagram with load on generator

The generator power angle δ is then given by the difference between the internal voltage angle β and the terminal voltage of the generator

The feasibility of MOI identification by PMU

- Over speed protection control will not be activated by normal disturbances, and mechanical torque can be treated as a constant for several seconds.
- PMU can record the dynamic performance of generator units in great detail, even though it cannot reflect the transient process properly.
- For generator unit with large capacity, the corresponding time resolution for describing the change of its rotation speed is much greater than 100ms.
- Hence, the MOI parameter is suitable to be identified by PMU.

The movement equation of generator shaft

$$M \times \frac{d\omega(t)}{dt} + D \times \omega(t) = \frac{N_p \times P_T(t)}{\omega(t)} - \frac{N_p \times P_G(t)}{\omega(t)}$$

- Electromagnetic torque of generator can be calculated by active power P_G measured by PMU, then the solution of complicated electromagnetic equations of generator can be omitted
- Variables to be solved
  - the moment of inertia *M*
  - damp ratio *D*
  - Mechanical torque P_T can be treated as a constant in 1s~2s, while the initial value can be assessed from the corresponding electromagnetic active power P_G measured by PMU

Genetic algorithm based optimization to get MOI

$$\min \quad E(M, D, P_T) = \sum_{t=1}^{K} \left(\omega(t) - \omega_r(t) \right)^2$$

- The optimization objective is to minimize the error between the simulated angular speed ω and the measured angular speed ω_r by PMU during a frequency disturbance
- The simulated ω is obtained by

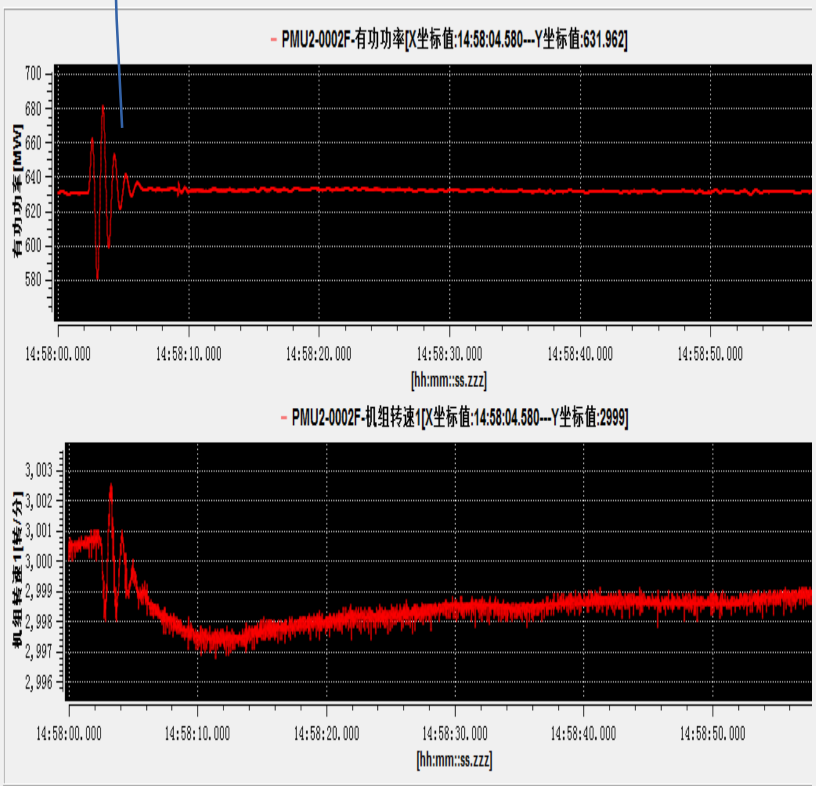
$$\omega(t_n) = \frac{P_T - P_G(t_{n-1}) - D \times \omega^2(t_{n-1})}{M \times \omega(t_{n-1})} \Delta t + \omega(t_{n-1})$$

where P_G is the output active power of the unit measured by PMU

The curve of a frequency disturbance used in an optimization

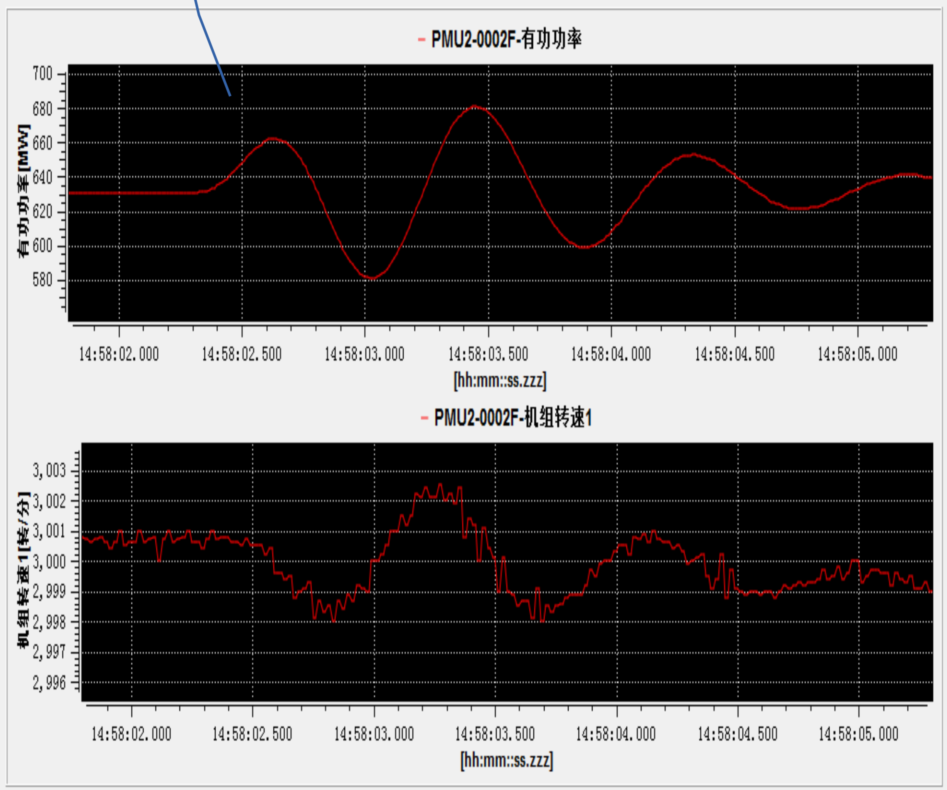
The curve for the full process of a frequency disturbance event

The curve of the first 3 seconds of the event is used for optimization



数据监视区

	名称	最大值	最大值时间	最小值	最小值时间	最大最小差值	平均值
1	PMU2-0002F-有功功率	680.886	14:58:03.450	580.932	14:58:03.020	99.954	631.800
2	PMU2-0002F-机组转速1	3002.500	14:58:03.270	2996.800	14:58:11.400	5.700	2998.479



数据监视区

	名称	最大值	最大值时间	最小值	最小值时间	最大最小差值	平均值
1	PMU2-0002F-有功功率	680.886	14:58:03.450	580.932	14:58:03.020	99.954	632.617
2	PMU2-0002F-机组转速1	3002.500	14:58:03.270	2998.000	14:58:02.830	4.500	2999.951

The optimization result of the above example

MOI *M*(kg*m2)	Damping ratio *D*	Mechanical Power Pm（W）
107155	557	686593169

Identified value of MOI (kg*m2)	Designed value of MOI （kg*m2）	Error of the two values of MOI	Identified value of inertia time constant （sec.）	Designed value of inertia time constant （sec.）	Error of the two values of inertia time constant
107155	107838	-0.63%	4.61	4.65	-0.86%

Identification results for units with different capacity

Names of generator units	Rated MW	Rated MVA	MOI （Kg*m2）	inertia constant （second）
Jurong Plant/27kV.#2	1000	1145	98551	4.243
Xuzhou Plant/27kV.#1	1000	1112	101083	4.481
Xuzhou Plant/27kV.#2	1000	1112	95615	4.238
Kanshan Plant/20kV.#2	600	728	54935	3.720
Yangzhou Plant/20kV.#1	630	741	72030	4.792
Ninghua Plant/20kV.#4	300	388	35651	4.530
Ninghua Plant/20kV.#5	300	388	34059	4.327

Conclusion

- The proposed identification method for the moment of inertia of generator unit have been implemented in the WAMS of the power grid of Jiangsu Province of China
- By using the PMU data during frequency disturbance events, the moment of inertia of generators with PMU can be identified properly
- It can help the operator to check whether the moment of inertia of the generators they are using for dynamic security analysis(DSA) is reasonable

Thank You !