Available online at http://jess.esrae.ru/

"Journal of Economics and Social Sciences"

Methods of energy system statical stability improvement

Tomsk Polytechnic University

Yuliya Zeremskaya [a], Evgeny Tsydenov [a], Anton Chimrov [a]

[a] Tomsk Polytechnic University

Abstract

At the present stage of the electric-power industry development the issue of quality and reliability assurance of electric power supply to a customer and the issue of rational maintenance organization are very important. Stability is an important constraint in power system operation and control. In addition to electromagnetic transition process study, it is necessary to calculate and analyze the electromechanical part, specifically the motion of the generators at various system disturbances. This paper describes several ways of improving the statical stability of a single-machine system. Calculating and deriving formulas, simplifications are used as they can't critically deform the general view, however, they must be taken into account

Keywords: power engineering, statical stability, stability improvement, energy stability

1. Introduction

One of the dominant requirements applicable to synchronous machines is to maintain the regime established by the dispatcher. If there is a random change of a system load, the balance of the mechanical moments is disturbed on the generator shafts, and it can lead to the disturbance of synchronous operations of the power plants and to the dropout of generator's synchronism.

Steady-state stability is an ability of the system to maintain synchronous parallel operation of generators during small perturbations and slow changes in operations [1]. Numerically, steady-state stability is assessed based on the factor of margin, which is determined by the formula:

$$K = \frac{P_{MAX} - P_T}{P_T} \cdot 100\%, \tag{1}$$

where $P_{\max}$ - maximum transmitted power, P_T - turbine power (load).

In the normal operating conditions, K should be more than 25% [1].

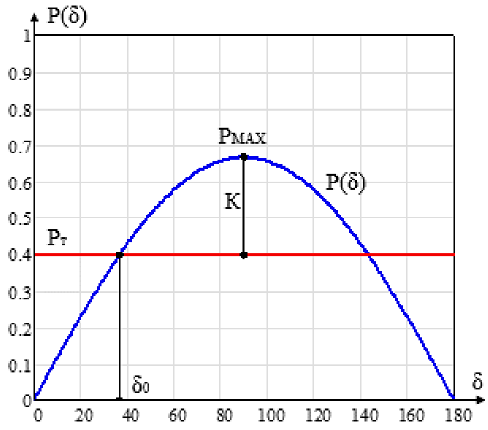
2. Load buses voltage boost

Power-angle diagram of single-machine system is determined by the formula:

$$P(\delta) = \frac{|\vec{E}| \cdot |\vec{U}|}{|\underline{Z}|} \cdot \sin(\delta) = P_{\max} \cdot \sin(\delta), \tag{2}$$

where $\vec{E}$ – generator voltage, $\vec{U}$ – voltage at the load buses, $\underline{Z}$ – system resistance, δ – angle between $\vec{E}$ and $\vec{U}$.

System rest position(δ_0) is defined by the equations P_{T} и $P(\delta)$.



Picture 1 – Power-angle diagram

Analyzing the formula (2) it can be concluded that the system can be more stable by increasing the maximum transmitted power of the generator under constant load.

Maximum power is determined by the formula:

$$P_{\max} = \frac{|\vec{E}| \cdot |\vec{U}|}{|\underline{Z}|} \quad (3)$$

The increasing of electromotive difference of potential to large values is not possible because of exciting current limiting. The voltage of the system can be increased to the next class, but it can lead to general equipment replacement, which is inefficient from the economic point of view. The voltage increase is possible under the current class. If the system voltage is increased by N times, the maximum transmitted power will also be increased by N times.

Factor of margin before voltage increase:

$$K_1 = \frac{P_{MAX1} - P_T}{P_T}. \quad (4)$$

Factor of margin after voltage increase:

$$K_2 = \frac{P_{MAX2} - P_T}{P_T} = \frac{N \cdot P_{MAX1} - P_T}{P_T}. \quad (5)$$

It may be expressed in the following way:

$$\frac{K_2}{K_1} = \frac{N - L}{1 - L} \cdot 100\%, \quad (6)$$

where $N = \frac{P_{MAX2}}{P_{MAX1}}$, $L = \frac{P_T}{P_{MAX1}}$.

If a voltage class is 220 (kV), then the maximum voltage increase can be up to 242 (kV) [2].

So, N = 1,1.

If load power $P_T = 0,48\,(\text{pu})$, and $P_{MAX1} = 0,85\,(\text{pu})$, then:

$$L = \frac{P_T}{P_{MAX1}} = \frac{0,48}{0,85} = 0,565,$$

$$\frac{K_2}{K_1} = \frac{1,1 - 0,565}{1 - 0,565} \cdot 100\% = 123\ (\%).$$

It can be concluded that the steady-state stability's factor of margin will be increased by 23%. Therefore, the stability factor may vary greatly depending on the initial parameters of the system.

3. Installation of series capacitor bank

Another way to increase steady-state stability is the reduction of resistance. The impedance of the system consists of generators, transformers and lines resistances. The real system resistance is active-inductive, so to connect the capacitive load is a possible way to reduce it.

The series capacitor bank (SCB) is examined. If the resistance of SCB – X_{SCB}, then total system resistance is:

$$X_{S2} = X_S - X_{SCB}. \tag{7}$$

The resistance of SCB is:

$$X_{SCB} = \frac{U^2}{3 \cdot Q_{SCB}}. \tag{8}$$

Using mathematical manipulations it can be shown in the following way:

$$\frac{K_2}{K_1} = \frac{X_{S1}}{X_{S1} - X_{SCB}} \cdot \left[1 + \frac{\left|\vec{E}\right| \cdot \left|\Delta\vec{U}\right| + P_T \cdot X_{SCB}}{\left|\vec{E}\right| \cdot \left|\vec{U}\right| - P_T \cdot X_1} \right], \tag{9}$$

where $\Delta\vec{U}$ - voltage increase at the end of the line because of line resistance reduction.

Thus, the necessary resistance (power) of the series capacitor bank may be calculated by setting the desired value of the steady-state stability coefficient.

4. Conclusion

This paper presents methods for increasing voltage and installation of series capacitor bank as a way of increasing steady-state stability. To gain this, the following key methods are used in practice [3]:

- installation of automatic control systems of strong action and frequency and automatic load-frequency control system;
- improvement of emergency automatic protective devices and relay protection;
- installation of asynchronized synchronous generators;
- construction of direct current link;
- installation of reactive power sources.

Thus, it may be concluded that the uninterruptible power supply depends on the ability of the electrical system to withstand any disturbance stability of power system. Fail-safe performance is determined by many factors and one of the most important one is stability against perturbations.

References

1. Berkovich, M.A. et al. Automation of electric energy system [Avtomatika energosistem]. Moscow: Energoatomizdat. 1991.
2. GOST 32144-2013. Electric energy. Electromagnetic compatibility of technical equipment. Quality standard of electric energy in the systems of generally duty electric power supply. [Elektricheskaya ehnergiya. Sovmestimost' tekhnicheskih sredstv ehlektromagnitnaya. Norma kachestva ehlektricheskoj ehnergii v sistemah ehlektrosnabzheniya obshchego naznacheniya]. Moscow: Standartinform. 2014.
3. Shabad, V.K. Electromechanical transients in electric power systems. [Elektromekhanicheskie perekhodnye processy v elektroehnergeticheskih sistemah]. Moscow: Akademiya. 2013.