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Abstract

        This article provides the influence of the active, inductive capacitive load on the static stability of synchronous generators and compiled the angular characteristics of the generator power at various loads. When a resistive load is connected, an intermediate power extraction of P_r (δ) occurs. It can be defined as the difference R_g (δ) – P_h (δ) = P_r (δ), depending on the angle δ. The presence of this selection leads to an increase in the ultimate in static stability generator power. However, this reduces the possibility of transmitting power to the receiving system. Therefore, we can talk about the ambiguous (positive or negative) effect of the intermediate active load on the static stability of the generator of a single-machine power system. The reactors are connected tightly or through switches at the end points of power transmission lines with a length of over 300 km to prevent over voltages during switching to compensate for the excess reactive power generated by power lines. Capacitor batteries (CB) are sometimes installed and connected at intermediate points of power lines in order to maintain normal voltage levels when transmitting high power fluxes. It should be noted that the conclusions regarding the effect of shunt reactors and capacitor banks on static stability apply to complex power systems.

Key words: *synchronous generators, static stability, active loading, inductive load, capacitive load.*

Introduction

In case of medium and long distance transmission of electric energy (200 km and more) in intermediate points of lines, as a rule, different elements and parts of the power system are connected. These can be shunt reactors, capacitive transverse compensating devices (capacitor batteries), and controlled reactive power sources, substations with intermediate electrical load or local low-power systems. These connections have an impact on the static stability of power transmission, which is reflected in an increase or decrease in the limits of static stability. Let us evaluate such influence of the most widespread connections, assuming that they are represented by passive elements in the scheme of replacement of single-machine power system.

Influence of active load. Let's assume that the intermediate load H (Fig.1.scheme, a), working with a power factor equal to unity, is presented in the scheme of replacement with active resistance ᴈ (Fig.1.scheme, b). Since this scheme has a T-shaped form with elements $Z_1 = jx_1, Z_2 = jx_2$, $Z_3 = r$, it is possible to use formulas to determine the generalized parameters: Influence of active load. Suppose that the intermediate load H (Fig.1.scheme, a), working with a power factor equal to one, is presented in the scheme of replacement with active resistance d (Fig.1.scheme, b). Since this scheme has a T-shaped form with elements $Z_1 = jx_1, Z_2 = jx_2$, $Z_3 = r$, it is possible to use formulas to determine the generalized parameters for it:
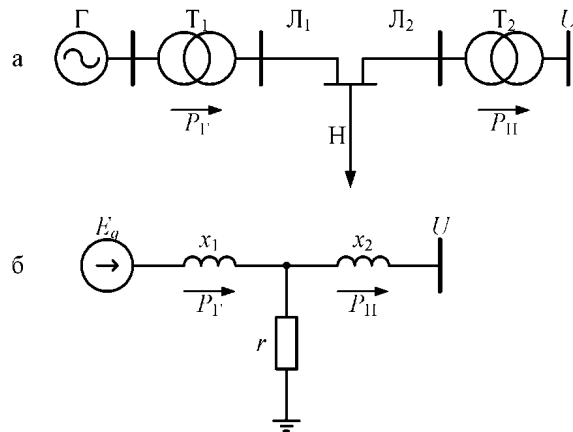
Fig. 1. Scheme. Power systems with active load at the intermediate point of the line (a) and its replacement scheme (b)

$$Z_{11} = jx_1 + \frac{jx_2 \cdot r}{jx_2 + r} = z_{12}e^{j\Psi_{11}};$$

$$Z_{22} = jx_2 + \frac{jx_1 \cdot r}{jx_1 + r} = z_{12}e^{j\Psi_{22}};$$ (1)

$$Z_{12} = Z_{21} = jx_1 + jx_2 + \frac{jx_1 \cdot jx_2}{r} = j(x_1 + x_2) - \frac{x_1 \cdot x_2}{r} = z_{12}e^{j\Psi_{12}}.$$ (2)

As stated above, the arguments of own resistances are:

$\psi_{11} < 90°$, $\psi_{22} > 90°$ Therefore, the corresponding complementary angles are positive: $\alpha_{11} = 90° - \psi_{11} > 0$, $\alpha_{22} = 90° - \psi_{22} > 0$. The argument of ψ_{12} of mutual resistances Z_{12}, Z_{21} in this case is in the range of angles from 90° to 180°, because the real component of these resistances $r_{12} = r_{21} < 0$. Accordingly, the complementary angle $\alpha_{12} = 90° - \psi_{12} < 0$.

Fig. 2 shows the angular power characteristics of $P_\Gamma(\delta)$, $P_H(\delta)$, constructed by the expressions:

$$P_\Gamma = P_{11} + P_{12M}\sin(\delta - \alpha_{12});$$ (3)

$$P_H = -P_{22} + P_{12M}\sin(\delta + \alpha_{12}).$$ (4)

Here for comparison the characteristic is given

$$P_\Gamma = P_H = P_M \sin\delta$$ (5)

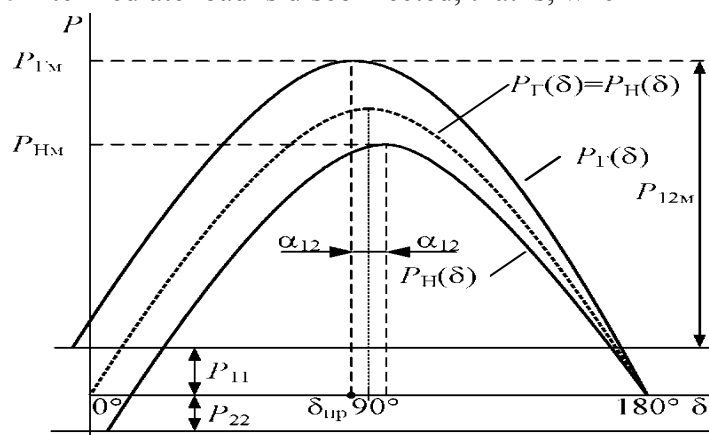For the case when the intermediate load is disconnected, that is, when $r \to \infty$.

Fig.2. Angular power characteristics of $P_\Gamma(\delta)$, $P_H(\delta)$) in the presence of transverse active resistance

As can be seen from Fig. 2, when an active load is connected at an intermediate point of the power line, the maximum $P_{\Gamma M}$ of the angular characteristic of the generator $P_\Gamma(\delta)$ is shifted relative to the angle 900 left to the angle $\alpha_{12} < 0$, and the maximum P_{HM} of the characteristic $P_H(\delta)$ is shifted to the right by the same angle. At consecutive inclusion of active resistance the

opposite picture was observed.

At connection of active load intermediate selection of P_r (δ) power takes place. It can be defined as the difference of $P_Γ$ (δ) - P_H (δ) = P_r (δ), depending on the angle of δ. The presence of this selection leads to the increase of the maximum static stability of the generator power. However, this reduces the possibility of transmitting power to the receiving system. Therefore it is possible to speak about ambiguous (positive or negative) influence of intermediate active loading on static stability of generator of single-machine power system.

Influence of shunting reactor. Shunt reactors (SR) are used in high-voltage power networks to compensate for excess reactive power generated by power lines. Reactors are connected tightly or via switches at the end points of power lines over 300 km long to prevent overvoltage during switching operations. In some cases, the reactors are connected to the higher voltage buses of the station and network substations.

In the accepted idealization of the schemes of replacement of elements, the generalized parameters, as well as the initial ones for their resistance calculation, do not contain material parts:

$$Z_1 = jx_1; \ Z_2 = jx_2; \ Z_3 = jx_L; \tag{6}$$
$$Z_{11} = jx_{11}; \ Z2_2 = jx_{22}; \ Z_{12} = jx_{12}; \tag{7}$$

Therefore, the complementary angles $α_{11}$, $α_{22}$ and $α_{12}$ are equal to zero, and the dependencies of $P_Γ(δ)$, $P_H(δ)$ coincide and are expressed by the same formula

$$P_Γ(δ) = P_H(δ) = P_M \sin δ . \tag{8}$$

Consider the cases where the SR is turned off and when it is in operation.

Connection of the SR at the intermediate point of electrical connection of a single-machine power system. In the first case, the mutual resistance Z12' and the corresponding power limit RM' are defined as:

$$Z12' = jx12' = jx1 + jx2 \tag{9}$$

$$P_M' = E\frac{U}{X_{12'}} \tag{10}$$

(Fig.3.scheme, a) introduces additional inductive resistance into the replacement scheme (Fig.3.scheme, b) which is reflected in the generalized parameters Z_{11}, Z_{22} and Z_{12}.
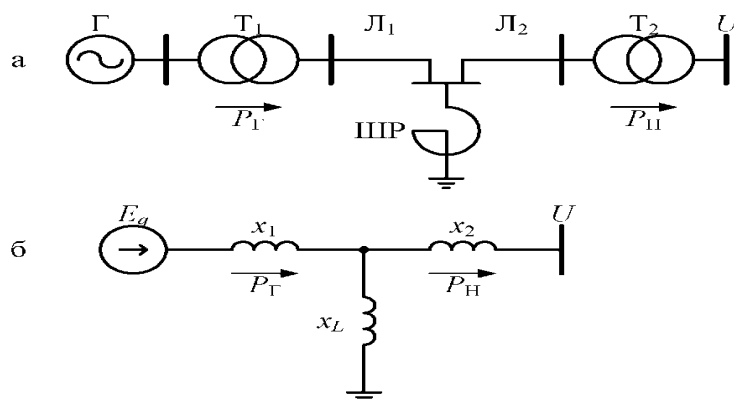

Fig.3. Scheme of power system with SR in the intermediate point of Power Transmission Line (PTL) (a) and its replacement scheme (b)

In the second case, the analogous parameters Z_{12}, P_M are influenced by the inductance of the reactor x_L, which is expressed as:

$$Z_{12} = Z_{21} = jx_1 + jx_2 + \frac{jx_1 \cdot jx_2}{jX_L} = j(x_{12}' + \Delta x_L) \tag{11}$$

$$P_M' = E_q \frac{U}{X_{12}} = E_q \frac{U}{(X_{12}' + \Delta X_L)}. \tag{12}$$

Where $\Delta X_L = \frac{x_1 x_2}{x_L} > 0$. it is obvious that $x_{12} > x_{12}'$ $P_M < 'P_M'$

(Fig. 4.) It is obvious that $x_{12} > x_{12}'$ and $P_M < P_M'$ (Fig. 4). It follows from this that the shunt reactor connected at the intermediate point of the power line has a negative impact on the static stability of the single-machine power system.
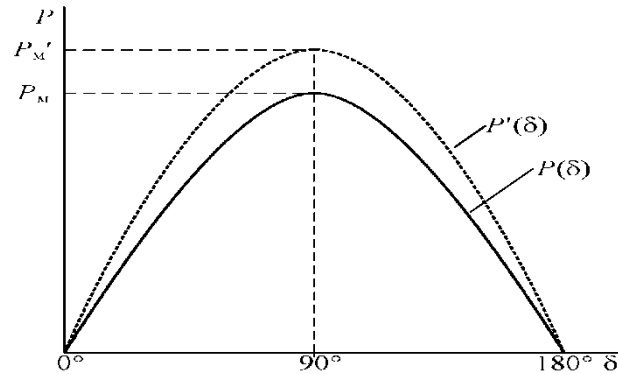

Fig.4. Influence of the SR on the angular characteristic of the generator power

Influence of the capacitor battery. Condenser batteries (CB) are sometimes installed and connected at intermediate points of power lines in order to maintain normal voltage levels during transmission of large power flows. Let's estimate the influence of CB on the static stability of the single-machine power system under the same design conditions as in previous cases (Fig. 5, a, b).
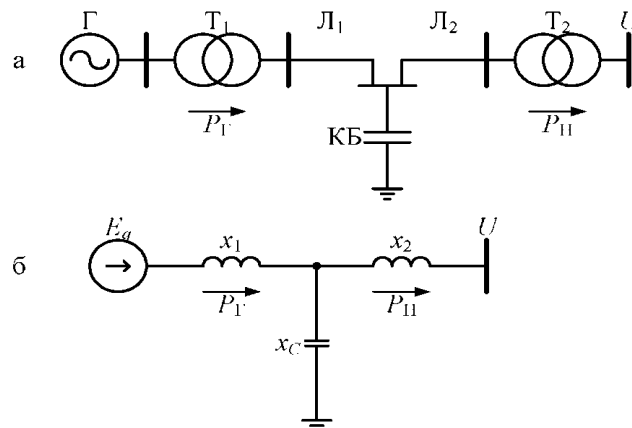

Fig.5. Scheme Power system with CB at the intermediate point of PTL (a) and its replacement scheme (b)

If a capacitor battery is connected to the power system replacement scheme (Fig.5.scheme, b), an element with negative reactivity appears

$$Z_3 = -j\, x_c, \qquad (13)$$

the influence of which on the mutual resistance of Z_{12} and the power limit is determined by the expressions:

$$Z_{12} = Z_{21} = jx_1 + jx_2 - \frac{jx_1 \cdot jx_2}{jx_c} = j\,(x_{12}' - \Delta x_c)\,; \qquad (14)$$

$$P_M = E_q \frac{U}{X_{12}} = E_q \frac{U}{(X_{12}' - \Delta X_c)}, \qquad (15)$$

Where:
$$\Delta X_c = \frac{X_1 X_2}{X_c} > 0$$

From these relations it is can be seen that $x_{12} < x_{12}{}'$ and $P_M > P_M{}'$ (Fig.6), that is, the capacitor battery connected in an intermediate point of a power line, positively influences static stability of a single-machine power system.
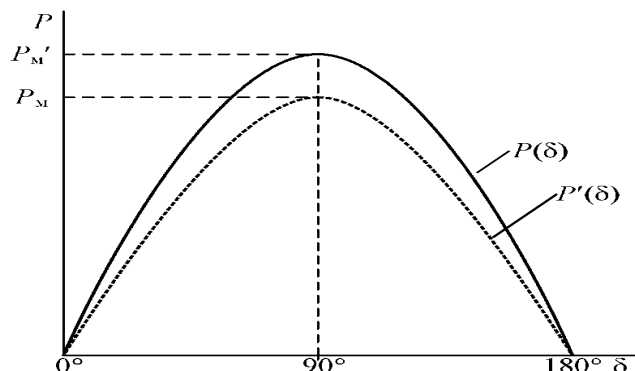

Fig.6. Influence of CB on the angular characteristic of generator power

It should be noted that the conclusions regarding the effect of shunt reactors and capacitor batteries on static stability apply to complex power systems.

References

[1] Venikov V.A. Teoriya podobiya i modelirovaniya (primenitelno k zadacham elektroenergetiki). Izd. 2-e. dop. i pererab. – M.: Vыsshaya shkola, 1976. – 479 s.

[2] Pirmatov N.B, Bekishev A.E, Kurbanov N.A. Modelirovaniya samaraskachivaniya sinxronnogo generatora v srede Simulink Matlab. Tendensii i Perspektivy Razvitiya nauki i obrazovaniya v usloviyax globalizatsii. –Pereyaslav-Xmelnitskiy, 2018. №42. C.585-589.

[3] Fayziev M.M., Kurbanov N.A., Imomnazarov A.B., Bobonazarov B.S., Bekishev A.E. Modelirovanie neyavnopolyusnnogo sinxronnogo generatora v Matlab. – Moskva. Vestnik nauki i obrazovaniya 2017. №5(29). Tom1. C. 10-14.

[4] Venikov V.A., Anisimova N.D., A.I.Dolginorv A.I., Fedorov D.A. Samovozbujdenie i samoraskachivanie v elektricheskix sistemax: posobie. Izdatelstvo «Vysshaya shkola» Moskva, 1964. -256 c.

[5] Elektricheskie sistemy. Matematicheskie zadachi energetiki. Izd. 2-e, dop. i pererab./V.A. Venikov, E.N. Zuev, I.V. Litkens i dr. /Pod red. V.A. Venikova – M.: Vыsshaya shkola, 1981. – 288 s.

[6] Xrushev Yu.V., Zapodovnikov K.I., Yushkov A.Yu. Elektromexanicheskie perexodnye protsessy v elektroenergeticheskix sistemax: uchebnoe posobie Zapodovnikov, Tomskiy politexnicheskiy universitet. – Tomsk: Izd-vo Tomskogo politexnicheskogo universiteta, 2012. – 160 s.

[7] Vaynshteyn R.A., Samoraskachivanie generatorov. Metodicheskie ukazaniya dlya laboratornoy raboty. Izdatelstvo tomskogo politexnicheskogo universiteta 2010, 13 s.

[8] Berdnik E.G., Filippova N.G. Razvitie metodov i algoritmov analiza staticheskoy ustoychivosti slojnyx elektroenergeticheskix sistem // Upravlenie rejimami elektroenergeticheskix sistem: tez. dokl. Ivanovo: IGEU, 1995. S. 7.

[9] Rukovodyaщie ukazaniya po opredeleniyu ustoychivosti energosistem. M: SPO «Soyuztexenergo», 1999.

[10] Mamikonyans L.G., Gorbunova L.M., Gorbunova L.M., Gurevich YU.E., Libova L.E., Timchenko V.F. Metodicheskie ukazaniya po opredeleniyu ustoychivosti energosistem. Chast 2. VNIIE, MEI, Energosetproekt, NIIPT, IED 2005.

[11] Goryachev V.YA., Elinov D.A., Kudashev A.V. Analiz ustoychivosti energeticheskoy sistemy putem imitatsionnogo modelirovaniya v srede matlab. Vestnik Baltiyskogo Federalnogo Universiteta Im. I. Kanta 2012. №2. S. 45-48.

[12] Moskvin, I.A. Kolebatelnaya staticheskaya ustoychivost elektroenergeticheskoy sistemy s mejsistemnoy svyazyu, soderjashey reguliruemoe ustroystvo prodolnoy kompensatsii. Vestnik IGEU. 2013. Vyp. 5. S. 1–5.

[13] Zabello, E. Primenenie prikladnyx programm v raschetax rejimov i ustoychivosti raboty sobstvennyx generiruyushix istochnikov pri ix parallelnoy rabote s energosistemoy. Energetika i TEK. Nauka dlya praktiki. 2011. № 9/10. S. 20–22.

[14] Enin, V.N. Modelirovanie perexodnyx protsessov i analiz dinamicheskoy ustoychivosti sinxronnyx generatorov pri vozdeystvii bolshix vozmusheniy. Nauka i obrazovanie. 2012. №10. S. 495–503.

[15] Volokitina V.V., Nikitin V.V., Opalev YU.G., TebenkovT.G., Imitatsionnaya matematicheskaya model sinxronnoy magnitoelektricheskoy mashiny v generatornom rejime v srede Matlab Simulink. Elektrosnabjenie i elektrooborudovanie. 2011. №4. S. 21–25.

[16] Vagin G.YA., Solnsev E.B., Mamonov A.M., PetrovA.A. Matematicheskaya model elektroagregata mini-TES na baze yavnopolyusnogo sinxronnogo generatora. Izvestiya Tomskogo politexnicheskogo universiteta. Injiniring georesursov. 2015. T. 326, №8. S. 92–101.

[17] Kuleshova E.O. Modelirovanie odnomashinnoy energosistemы s pomoshyu peredatochnyx funksiy v Matlab/Simulink. Sovremennye problemy nauki i obrazovaniya.

2013. № 2. S. 1–6.