Comparison of the Effect of Series and Shunt Control Devices on the Limit of Transient Stability

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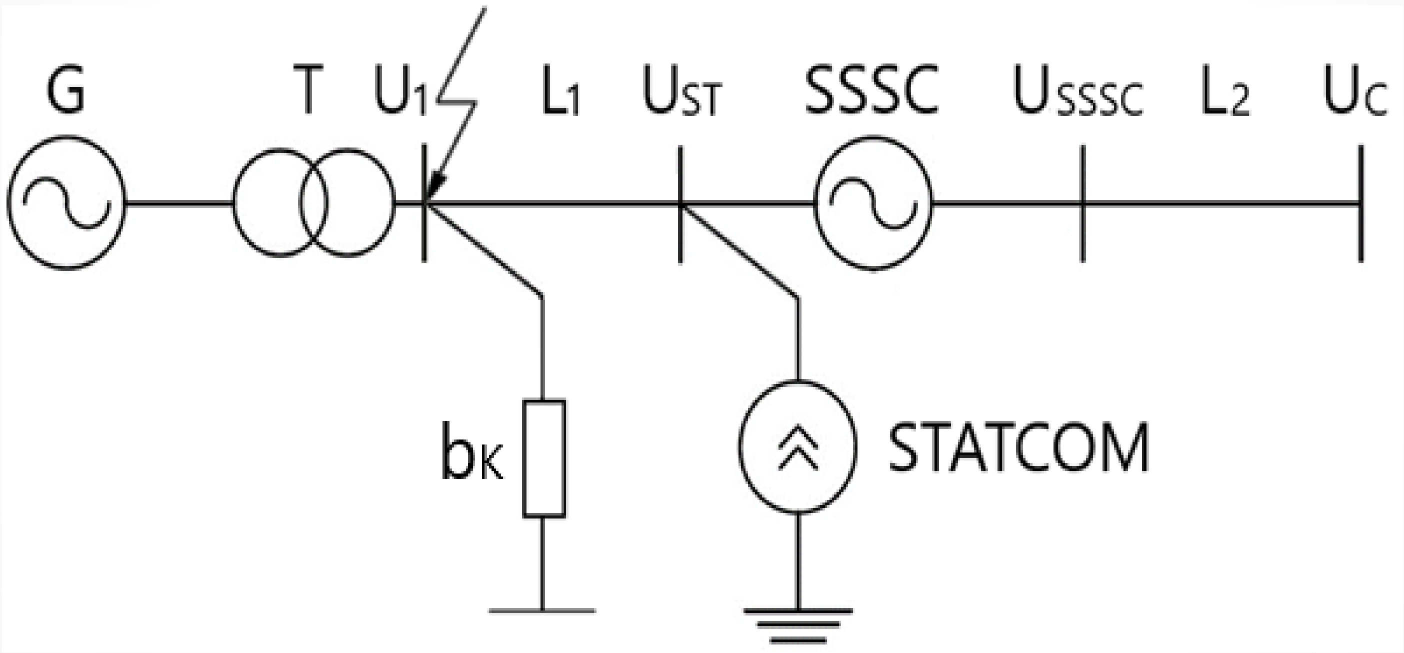
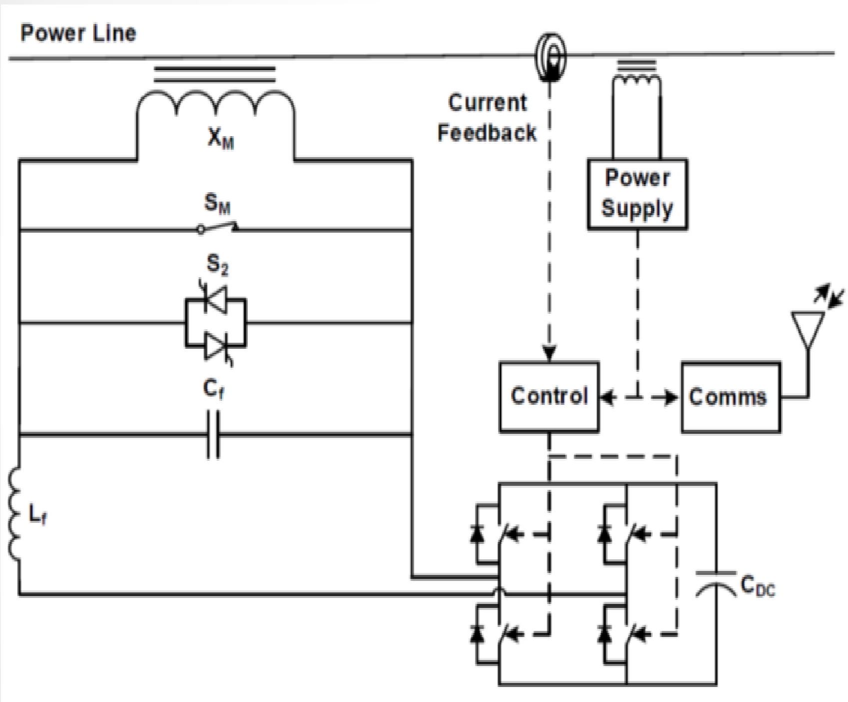
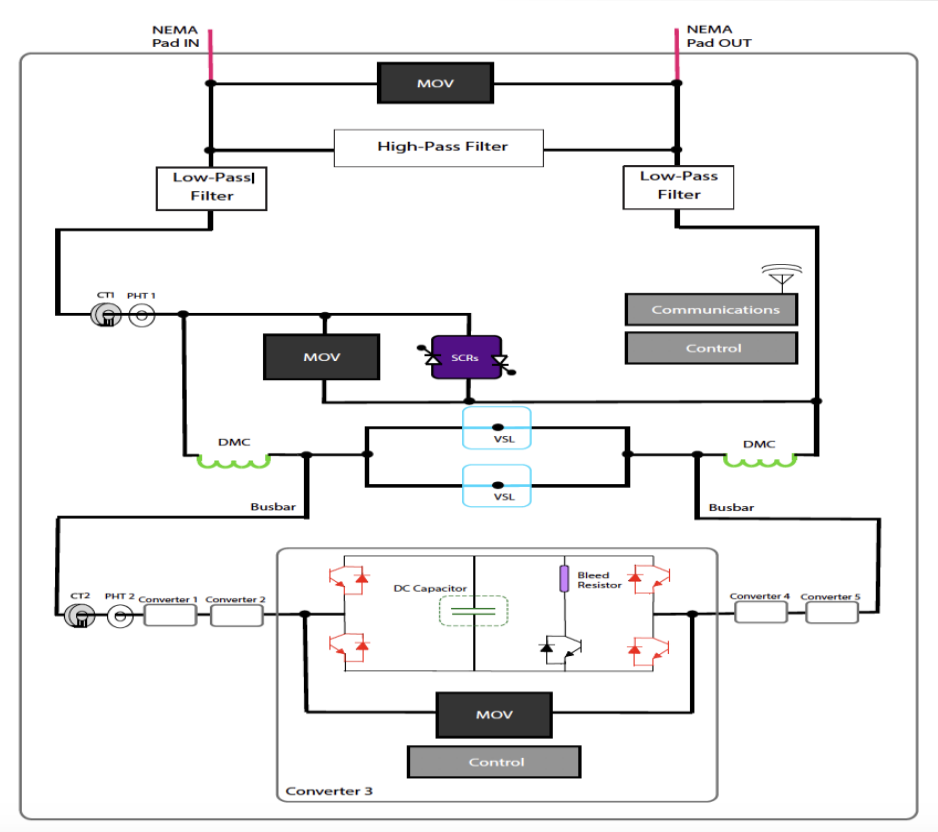
Design scheme of the simple electric power system calculation with compensating devices for transient stability limit

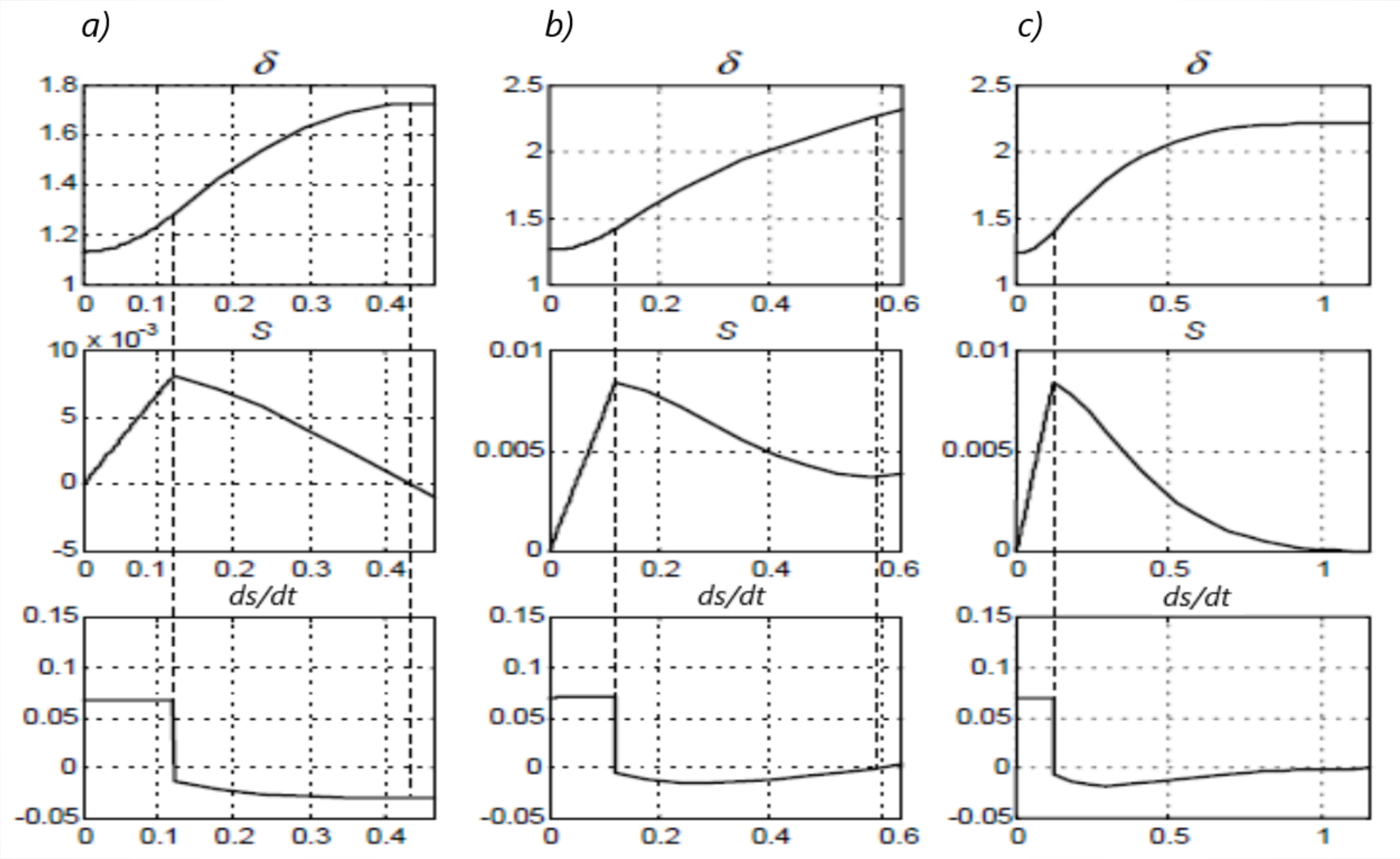


The principle of operation and the scheme of the SSSC

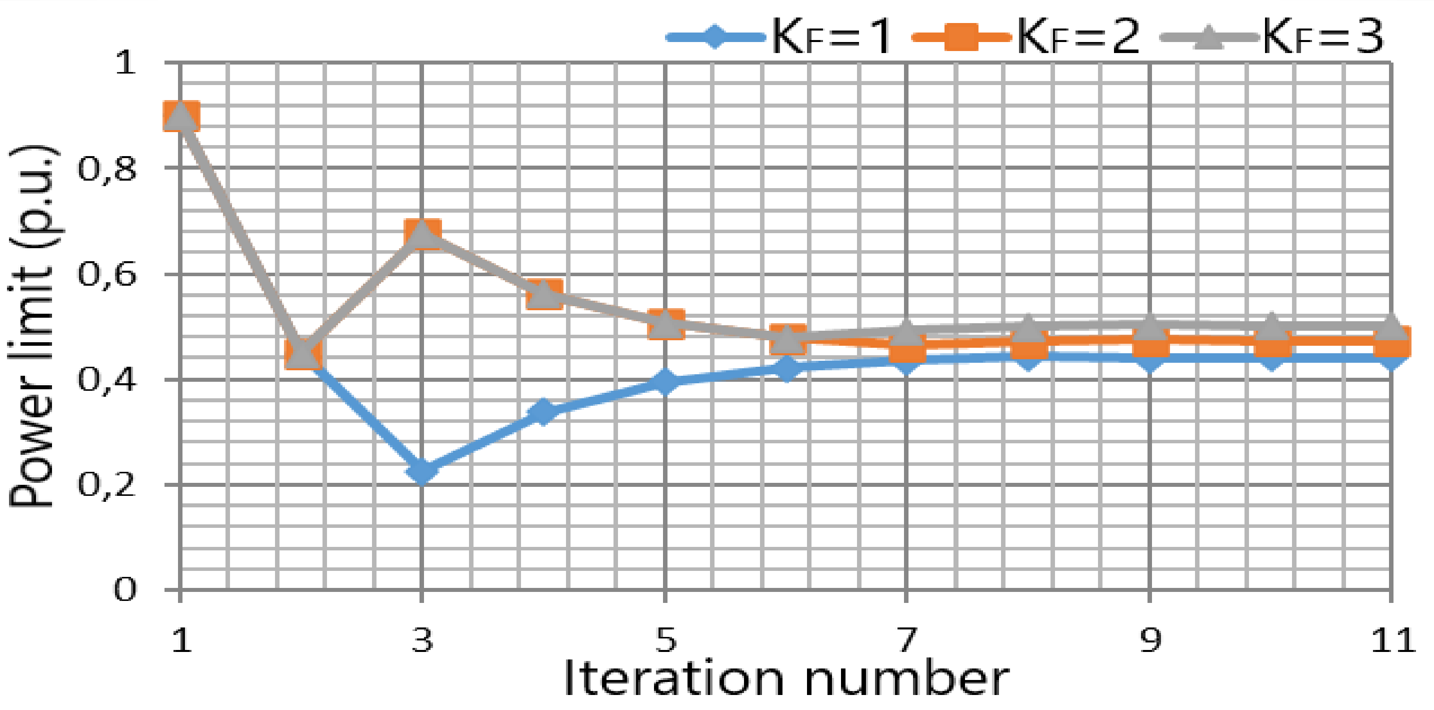




The angle – δ, slip signs – s and its derivative – ds/dt dependences of a stable (a), unstable (b) and transient (c) limit processes



Generator power change during the search for the value of the transient stability limit (turbine generator TVV-800-2)

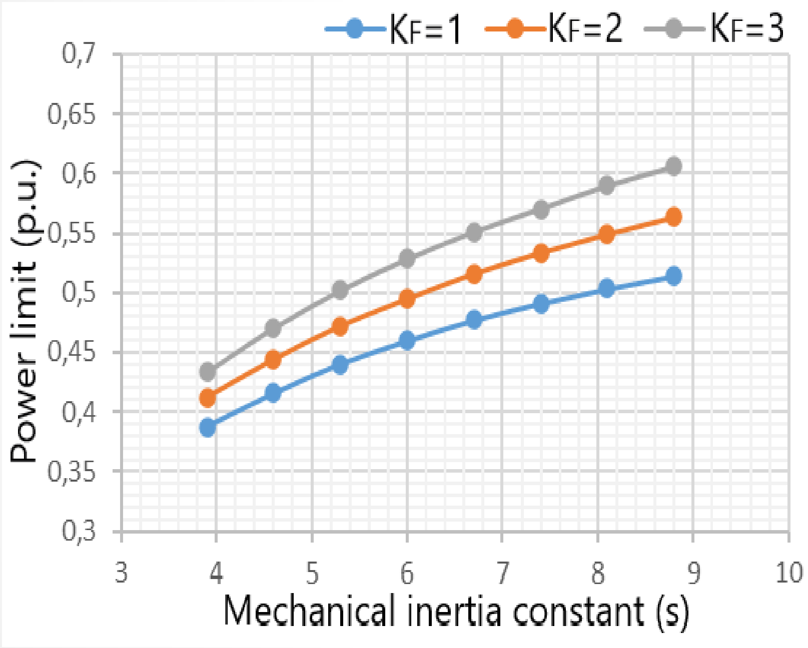


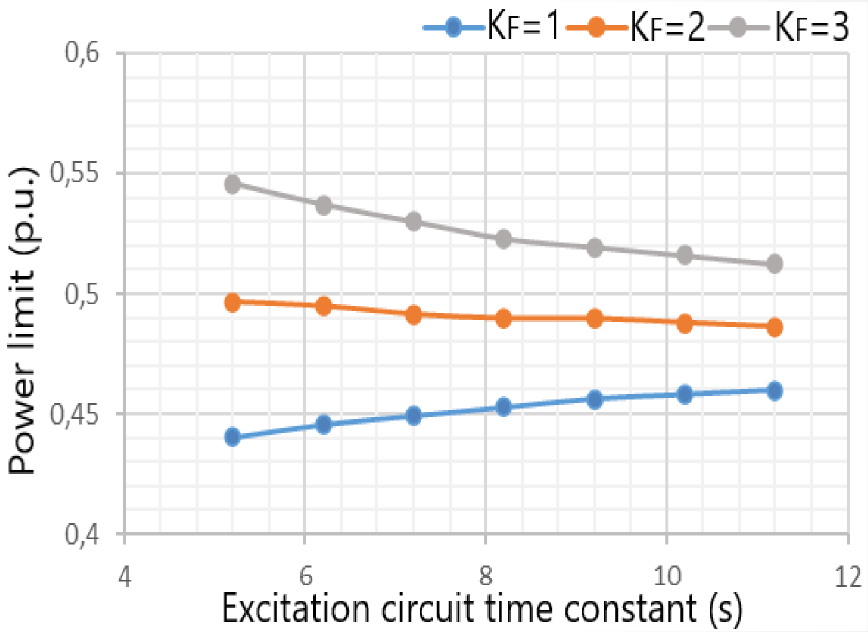
Turbogenerator TVV-800 parameters

$X_d = 2.28$ p.u.; $X'_d = 0.304$ p.u.; $X''_d = 0.216$ p.u.; $T_{d0} = 9.2$ s; $T_i = 5.3$ s.

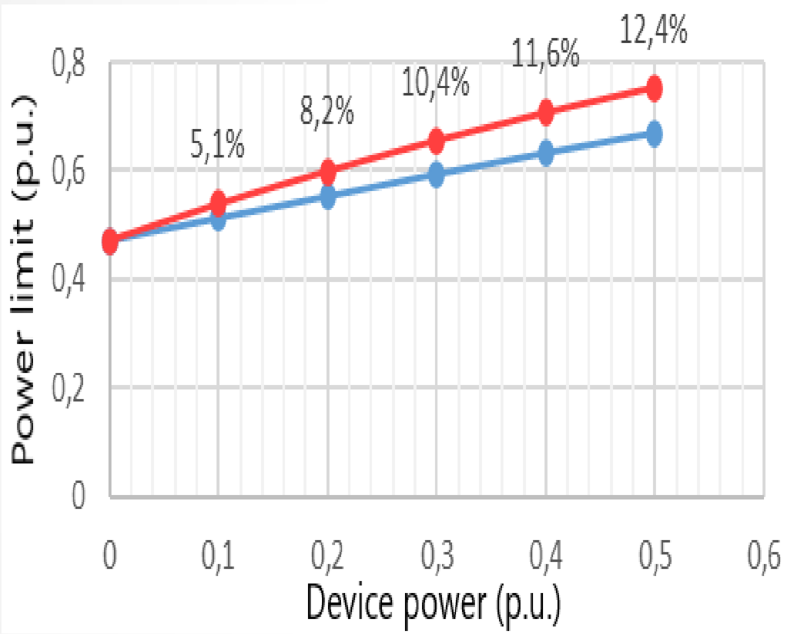
The values of the limits for a two-phase short circuit to ground with a duration of 0.12 s are: $P_{LIMIT} = 0.44$ p.u. with $k_F = 1$, $P_{LIMIT} = 0.472$ p.u. with $k_F = 2$ and $P_{LIMIT} = 0.502$ p.u. with $k_F = 3$, which matches an increase in the limit by 7.2% with a double forcing excitation and by 14% with a threefold.

Examples of stability limit calculation

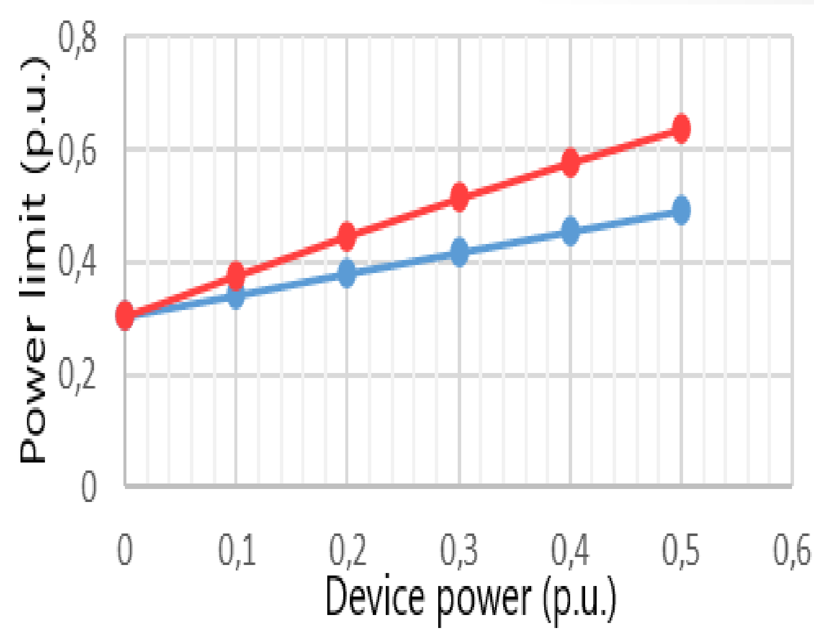




The transient stability limit dependence on the power of SSSC (red curve) and STATCOM (blue curve)

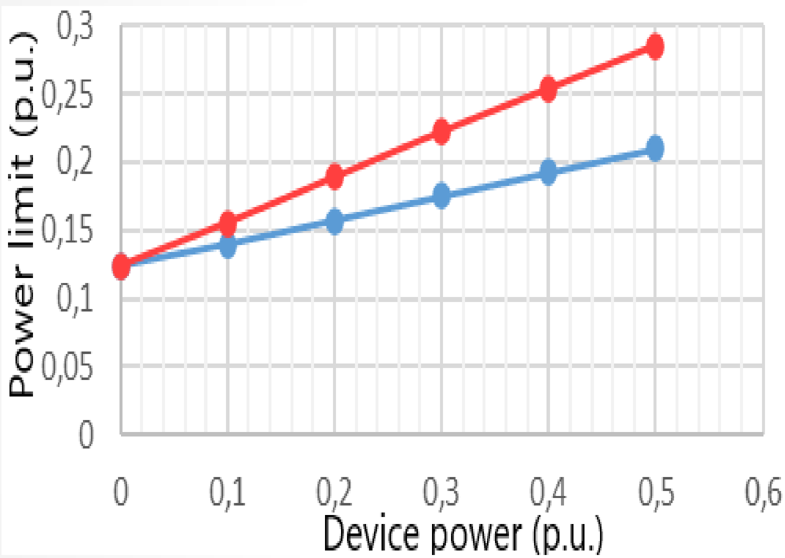


Two-phase short circuit to ground, duration of 0.12 s

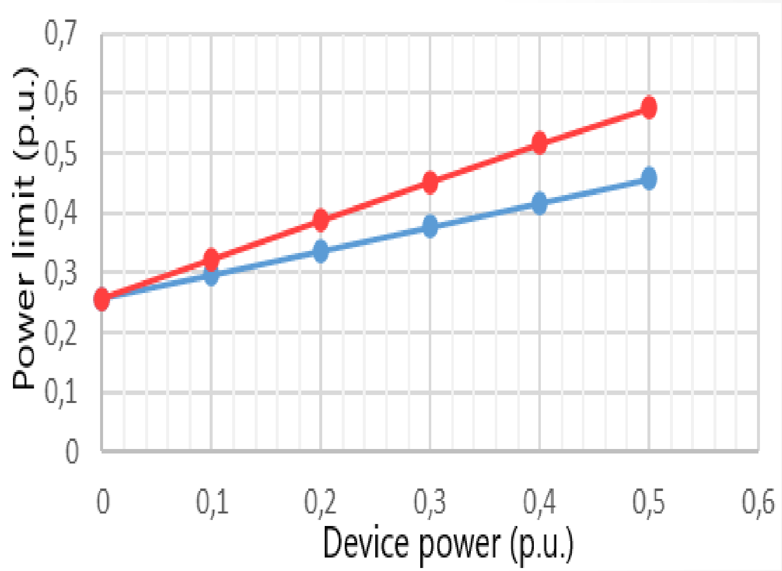


Two-phase short circuit, duration of 0.292 s

The transient stability limit dependence on the power of SSSC (red curve) and STATCOM (blue curve)



Two-phase short circuit to ground, duration of 0.292 s



Two-phase short circuit, duration of 0.292 s, following weakening of the connection with the system by 33%

Conclusion

1. The absolute efficiency of the FACTS devices is quite high, increasing as the severity of the disturbance increases. With the use of STATCOM, the increase in the limit under severe disturbances can be 40 - 65%, with the use of SSSC - up to 130%.

2. In all considered cases, the static synchronous series compensator (SSSC) demonstrates a high relative efficiency, which increases with the devices power increase and the increase in the disturbance severity.

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Thank you for your attention!

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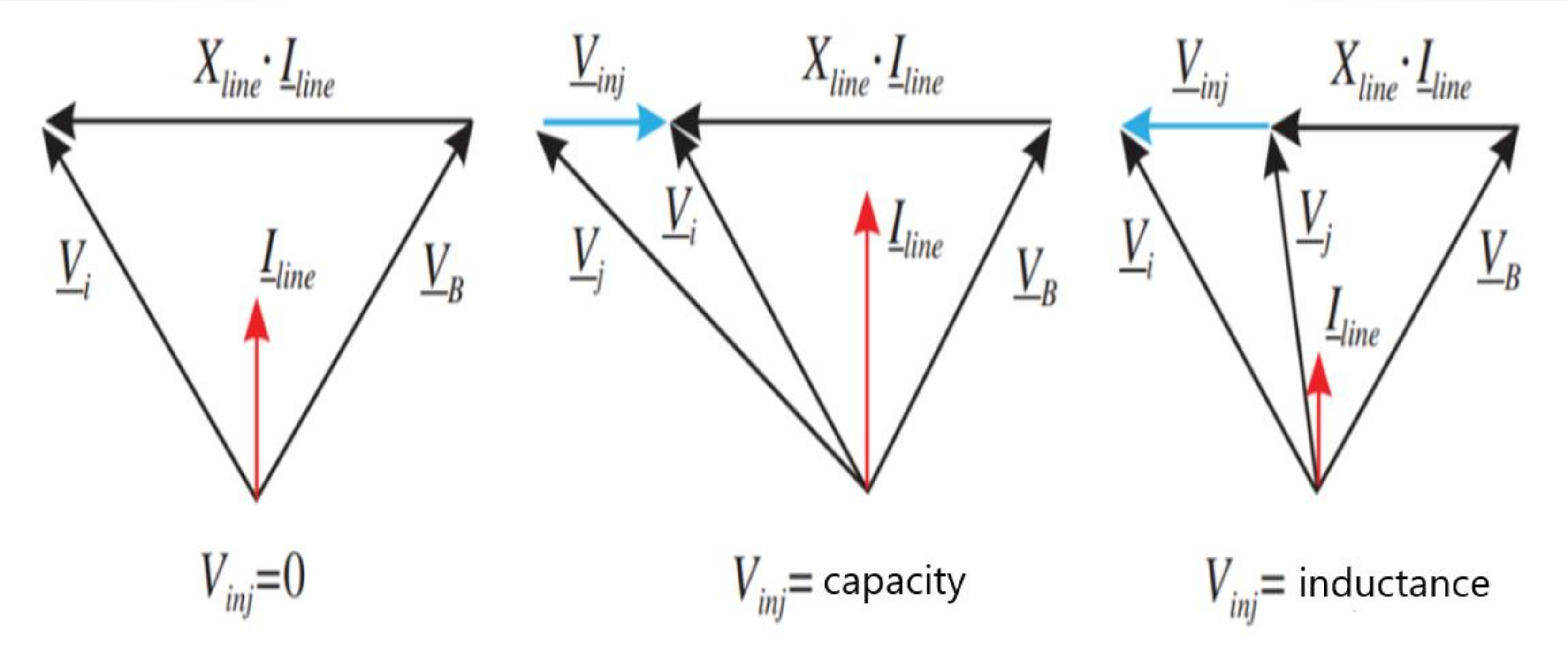
The principle of operation of the SSSC



SSSC Mathematical Model

$$\Delta I_m = \frac{K_{0i}(I_m - I_{set})}{1 + pT_i}$$

$$\Delta E_{qsssc} = \frac{\Delta I_m \cdot S_{sssc} \cdot I_d}{1 + pT_{sssc}} \qquad \Delta E_{dsssc} = \frac{-\Delta I_m \cdot S_{sssc} \cdot I_q}{1 + pT_{sssc}},$$

where I_{set} – the value of the current setting,
K_{0i} – the regulation coefficient for the deviation of the line current (K_{0i} = -10 … -100),
T_{i} – the time constant of the current deviation channel (T_{i} = 0,01 s),
T_{sssc} – the time constant of the SSSC's converters,
I_d, I_q – d,q – the current components.

STATCOM Mathematical Model

The EMF increment of the STATCOM ΔE_{st} is calculated based on the following transfer function:

$$\Delta E_{st} = \frac{K_{st} \cdot (U_{st} - U_{set})}{1 + pT_v},$$

where U_{set} is the preset value of the voltage setpoint,

K_{st} - voltage deviation channel gain,

T_v is the time constant of the voltage deviation channel (T_v = 0.03 s).

d,q - the components of STATCOM currents are calculated in accordance with the relations linking the components of its EMF and the voltage at its terminals:

$$I_{qst} = -b_{st} \cdot (E_{dst} - U_d),$$

$$I_{dst} = b_{st} \cdot \left(E_{qst} - U_q\right),$$

b_{st} is the conductivity of STATCOM taking into account the smoothing reactor and the matching transformer.