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THE MODERN TECHNOLOGY IMPLEMENTATION FOR SAFE ENERGY TRANSITION

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Abstract: The role of electrical energy becomes more important with the progress in transitioning towards clean energy and thus increases the importance of electric power networks for society and economy. The need of electrification and of renewable sources is growing. The risk that can appear is that the transition to clean energy may stagnate if the networks are not sufficiently updated for connecting the new supplies of electricity on consumer demand. This paper emphasises the theoretical aspects and the importance of the static power-electronic devices installed in AC transmission (where static synchronous series compensator SSSC device is considered as one of the active power control facilities) as an essential features to avoid technical problems in the power networks, for increasing the transmission capacity and assuring efficiently the stability of the system.

Key words: active power control, series compensator, voltage compensation.

1. INTRODUCTION

The electric network is the main element of energetic systems, sustaining the economic activity through supplying necessary electrical energy to domestic, commercial and industrial customers. As the transition to clean energy advances, the role of electrical energy is increasing, and the energy systems becomes more important. With wider use of electrification and of renewable sources, the development of electric transmission network has a major role in mitigating the risks that may affect transition to clean energy [1], [2].

The electrical network is characterized by:

- grid infrastructure;
- interruptions costs;
- network congestions;
- output diminution;
- contraction of network development deadlines.

It has been noticed that sometimes the networks become an obstacle in transition phase to clean energy and there are risks arising if the development and

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improvements of network are not advancing fast enough. A delayed reform of the electrical network means extending dependence to fossil fuel and determine increase of gases emissions and , in the long run, increased costs to society.

The electric network is major infrastructure element including a lot of components with a high-tech degree of complexity. To understand the present state of network development is not easy due to the difficulties of data availability even with the infrastructure and the technology currently used in their operation and management.

The total length of electrical networks infrastructure has been constantly growing in the last fifty years. The fast growth of use of variable renewable sources and distributed sources creates new challenges and require a large flexibility for electric networks. In the emerging markets and developing economies, significant progress has been made by increasing access to electricity at the same time with the growing demand. The supply chain for the distribution networks has already presented constrains, which generate possible risks for the future of network development.

The flexible AC transmission system (FACTS) provides an important role in the increase of the level of implementation of renewable energy resources, making possible continuous control of active and reactive power in the network [3].

Static Synchronous Series Compensator represents the scheme of series compensation which uses a power converter as synchronous voltage source (SVC) to supply a controllable voltage phased forward in quadrature of current. The SSSC includes a synchronous voltage source (SVS) connected to power network through a transformer. This transformer is connected in series with the transmission line, as the SSSC represents an improvement from compensation based on using series line capacitors. This is an advantageous because when using SSSC the serial compensation becomes independent of the line current.

2. IDENTIFY THE DIFFERENCES AS PATH TO THE FUTURE NETWORKS

In order to be a reliable instrument that enables a safe energetic transition, they networks must fulfil three conditions: to be low maintenance, to be up to date and to answer to the future needs of the energetic system.

The growth of electrical energy demand represents one of the three key factors in driving network expansion in all counties together with the growth of renewable sources and replacement of the obsolete components of the networks [3], [4]. The growth in energy demand is also dependent of some factors such as growing number of people as well as earnings and economy growth. These lead to increasing the use of electrical energy in traditional applications, for example heating and colling devices, communications and industrial applications. In addition, new applications of electricity are evolving rapidly, like for example transportation (electric vehicles), heating (electric heat pumps) and hydrogen production (electrolyze).

Modernization is further made based on a list of criteria analysis which includes technical stage, age, importance, perspective of implementation of telecontrol in conjunction with maintenance work on power transmission networks [5], [1]:

- interconnection with neighbouring power networks;
- zonal system connections or between main power stations;
- release of power from main power plants;
- supplying important consumption areas.

Regarding the implementation of modern technologies in power transmission network, a National Project refers to installation a SSSC device in the 220kV axis Urechesti -Târgu Jiu Nord - Paroşeni – Baru Mare – Hasdat [6], [5].

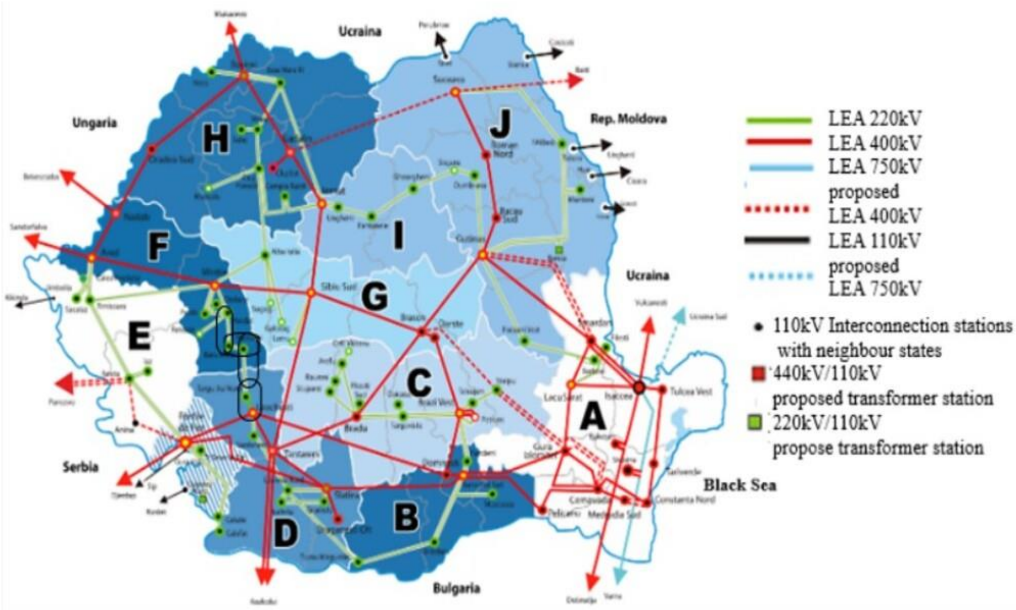

Fig. 1. The available capacity for transmission network connection and possibility of SSSC implementation; Source: www.transelectrica.ro

2.1. Static synchronous series compensator

The SSSC device consists a synchronous voltage source in series transmission line using a transformer between m, n nodes. For supplying the storage capacitor and for power compensation a power source is necessary in the inverter. Taking into account that the longitudinal resistance and the transversal admittance are negligible, the lines reactance is considered (X_{l1}, X_{l2}).

Parameters P_{ref} and Q_{ref} control the amplitude VSSSC of the voltage supplied at the output of VSC that is necessary for exchange of the reactive and active power with the power grid. The P_{ref} will be set to zero value if the VSC is used only for exchange of reactive power [7], [1]. Since VSC is used for series compensation and runs only for established fundamental frequency, the sub-synchronous resonance is avoided because the impedance for different frequencies will be practical zero. This feature of the SSSC sets it apart of series capacitor method whose impedance is depending on frequency and can generate resonances for various reactive impedances from the power network.

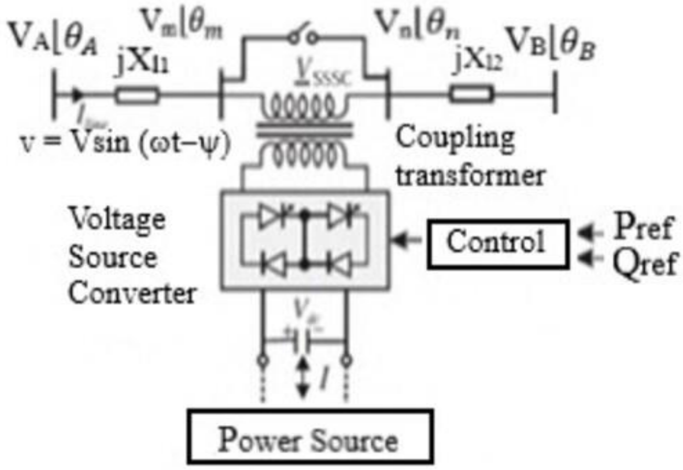

Fig. 2. Components structure of SSSC

2.2. The operation structure

Up to its designated voltage rating, the SSSC can deliver capacitive or inductive compensatory voltage independent of line current because of the independent voltage source characteristic of the VSC. The two operating modes are: voltage compensation and reactance compensation [7], [3].

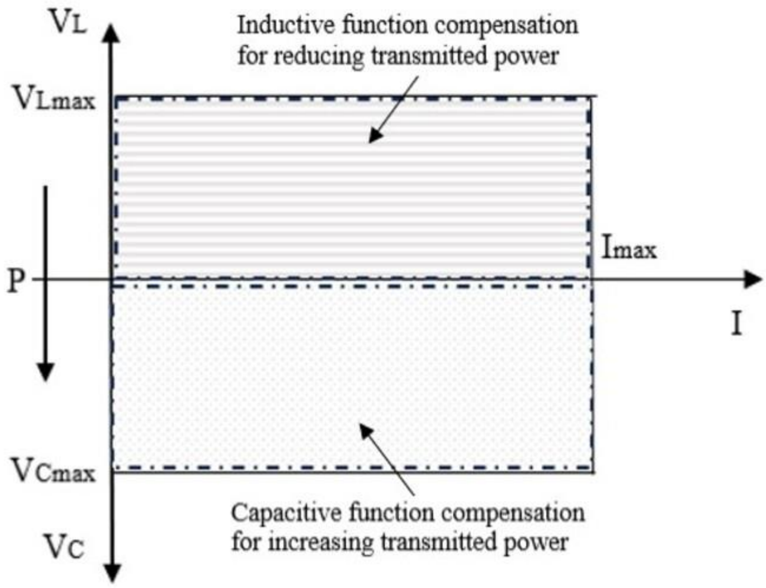

Fig. 3. Design of dependence compensation voltage and line current

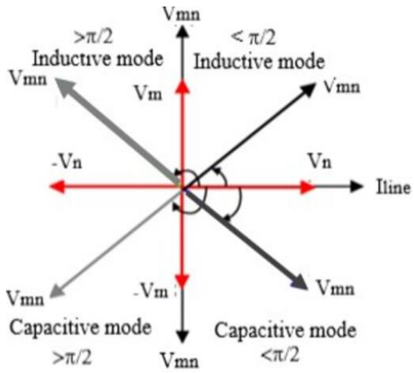

Fig. 4. Types of SSSC operating

If there is no difference of quadrature between the phase of injected voltage (V_{mn}) and the line current I_{Iline}), an exchange of real power between the SSSC and line will appear. Replacing the DC Capacitor from the input with an energy storage solution the real power exchange is assured. The above figure explains that SSSC can operate in all four quadrants to supply active power and to provide reactive power compensation to the ac system [8].

An ideal synchronous generator which can supply a set of three sinusoidal voltages at fundamental frequency can be replaced with Voltage Source Converter (VSC) as a synchronous voltage source. This component can supply or absorb reactive power when is connected to power network same as a synchronous compensator.

The VSC also can exchange active power with power system when is connected to a corresponding energy source or to an energy storage battery. The transmitted power is depending on supplied voltage through controlling the complex argument of the voltage, the SSSC can exchange even active power or reactive power with the power network where is connected [3], [7], [9].

The transformer located on the secondary side can be connected in triangle or star , while the primary windings are connected in series on the transmission lines. The reference values of Pref and Qref are representing the imposed values of power controlled by SSSC device.

Using a three phase VSC for SSSC has the advantage that there is a lower number of semiconductors necessary. There is a disadvantage with respect of the output voltages and their harmonics if the reference voltages are unbalanced.

The currents through semiconductors devices for triangle connection are multiplied 1.73 times when the transformer is in star connection but the compensation voltage through transformer in star connection is divided by 1.73.

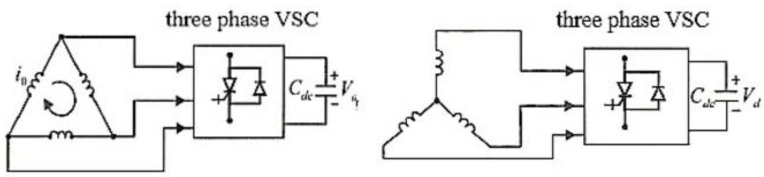

Fig. 5. Triangle and star connection of VSC transformer

3. COMPARATION BETWEEN SERIES CAPACITORS COMPENSATION AND SSSC

In comparation with series capacitor, the SSSC device is more efficient respect to control of power circulation and improved stability [8], [10], [11].

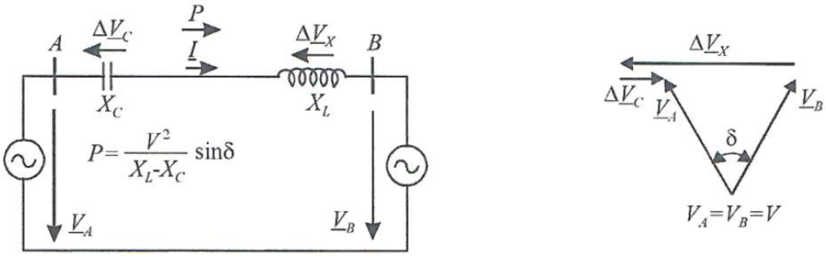

Fig. 6. Basic compensation using series capacitors

Where: $\Delta \underline{V}_C$ – represents the phasor of the compensation voltage produced when the current passes the capacitor and the compensation voltage is proportional with the $\underline{I}$ line, but the opposite polarity as inductive drop voltage;

$X_L = X_{l1} + X_{l2}$ – represents the line inductive reactance;

X_C – represents the capacitor reactance, producing the same compensation effect as synchronous voltage source;

Series capacitor compensation assures an indirectly reduction of equivalent line impedance and increases the line transmitted active power [11], [13], [15].

$$P = \frac{V_A \cdot V_B}{X_L - X_C} \cdot \sin\delta \tag{1}$$

Assuming $V_A = V_B = V$, the above relation becomes:

$$P = \frac{V^2}{X_L - X_C} \cdot \sin\delta \tag{2}$$

The same transmitted power on network line can be established with series compensation using a voltage synchronous source (the below figure) which supplies the same voltage with the voltage supplied at the terminals of the series capacitor. Due to use of the controllable series voltage source at fundamental frequency instead of the series capacitor, it can be obtained a voltage amplitude proportional with the line current phased with $\pm\pi/2$ and keep this voltage constant even when the current I is varying, or can be controlled independent of the current amplitude. Usually, for capacitor compensation, the voltage is phased behind the current in quadrature, but through a simple control, the voltage it can be phased forward the current, emulating an inductive compensation, having the same effect with an increase of line inductive reactance. [12], [16], [17], [18].

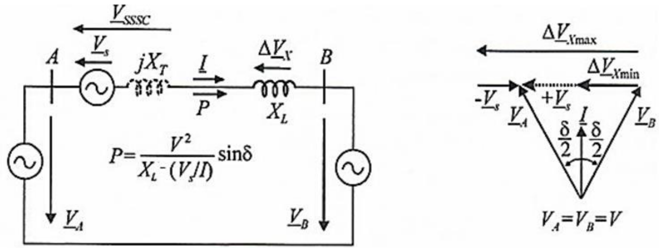

Fig. 7. Scheme of transmission line compensation using the SSSC series device

The common relation for compensation voltage can be expressed as:

$$\underline{V}_S = \pm j V_S(\gamma)\frac{\underline{I}}{I} \tag{3}$$

Where, γ – is a parameter;
$V_S(\gamma)$ – the compensation voltage amplitude injected in series with the line.

4. CONCLUSIONS

The implementation of modern components replacing of obsolete electrical equipment is driven by the faster technological evolution which ensures the operation to high level of today's technology. by replacing the worn-out elements and adding additional features and benefits of new technologies. The SSSC devices are primary active power control facilities designed to increase the transmission capacity for important parts of the power system.

The additional operational features and the flexibility in application that the SSSC effectively provides, are benefits for equipment balance and power flow management. A national developing plan proposal exists for installation of SSSC devices in Romania electrical networks, taking into account the technological issues that appear in Jiu Valley site, particularly with the rise in utilization of intermittent renewable energy sources and market expansion with desired integration at European level.

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