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BENEFITS OF USING SVC FACTS DEVICES IN POWER TRANSMISSION SYSTEMS

BENEFICIILE UTILIZĂRII DISPOZITIVELOR FACTS DE TIP SVC IN REȚELELE ELECTRICE DE TRANSPORT

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Abstract: *The use of an SVC-type FACTS device at the 110 kV voltage level in the Nordic 32 test grid helps to regulate the voltage level, control the power flow, and reduce power losses. In the Nordic 32 network, the biggest voltage level variations were identified in the 110 kV nodes where the voltage are almost at the maximum admissible level. The SVC equipment has been dimensioned for the most accurate control of the voltage and an optimization of the power circulation in order to reduce power losses. SVC devices are also used to increase the integration capacity of renewable energy sources.*

Keywords: SVC, FACTS, Nordic 32, voltage control, power losses, renewable energy sources, photovoltaic power plants.

Rezumat: *Utilizarea unui dispozitiv FACTS de tip SVC la tensiunea de 110 kV in rețeaua electrică de test Nordic 32 ajută la reglajul nivelului de tenisune, controlul circulației de putere și reducerea pierderilor de putere. În rețeaua Nordic 32 cele mai mari variații ale nivelului de tensiune au fost identificate în nodurile de 110 kV în care tensiunea se apropia de nivelul maxim admisibil. Echipamentul SVC a fost dimensionat pentru un control cât mai exact al tensiunii și o optimizare a circulației de puteri în vederea reducerii pierderilor de putere. De asemenea dispozitivele SVC sunt utilizate ăi pentru creșterea capacității de integrare a surselor de energie regenerabilă.*

Cuvinte cheie: SVC, FACTS, Nordic 32, controlul tensiunii, pierderile de putere, surse de energie regenerabilă, centrale electrice fotovoltaice.

1. Introduction

Using the Nordic 32 power grid [1] as a test and validation environment, the main benefits that can be obtained by using modern reactive energy compensation devices of the SVC type were analyzed.

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In order to establish the optimal location of the SVC device, the voltage level in all network nodes were calculated and the nodes where it is close to the limit value were identified.

The dimensioning of the FACTS device was carried out with the aim of both a more accurate control of the voltage level in the node, but also the optimization of the power circulation in order to reduce power losses in the analyzed area.

Considering the current dynamics of electrical grids, in which the main trend is represented by the integration of new renewable energy sources, the use of modern reactive energy compensation devices has an essential role in controlling the voltage and maintaining the stability of the grid.

2. Nordic 32 test system

Nordic 32 is a test grid developed by K. Walve and it features a simplified network variant similar to the Swedish and Nordic grid.

The electrical grid consists of four main areas: Equivalent, North, Central and South. The distribution of energy consumption and production is shown in Table 1.

The Nordic 32 network was implemented and simulated using the NEPLAN 10 software.

Table 1. **Distribution of energy consumption and production in Nordic 32 grid zones.**

Zone	P Load [MW]	Q Load [MVAr]		P Gen [MW]	Q Gen [MVAr]
South	1390,0	549,0		1590,0	213,4
Central	6070,0	2131,5		2850,0	1026,6
North	1180,0	395,0		4641,1	765,4
Equivalent	2300,0	600,0		2300,0	270,5

The structure of the Nordic 32 400 kV grid is presented in figure 1.

3. SVC (Stativ Var Compensator)

A static Var compensator (SVC) is, according to IEEE and CIGRE, “a static Var generator whose output is varied to exchange capacitive or inductive current so as to maintain or control specific parameters of the electric power system, typically bus voltages [3].

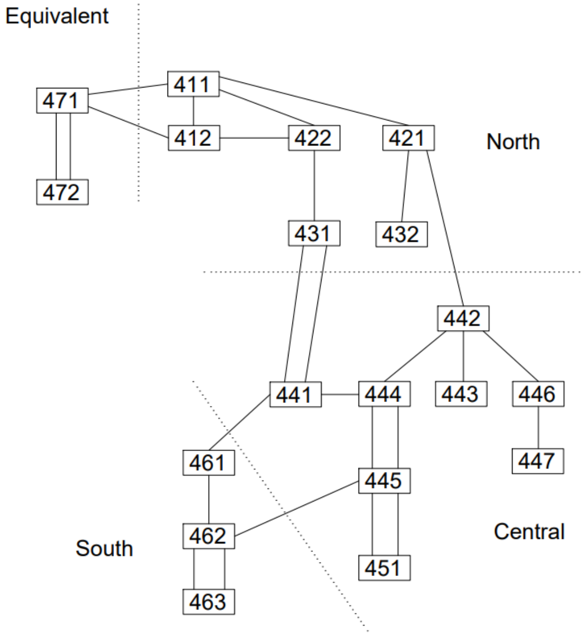

Figure 1. The structure of the 400 kV Nordic 32 grid

The use of static VAr compensators can increase the performance of the power grid in which they are installed. Among the advantages of using SVCs in electric power transmission systems, the most important are: contributes to the reduction of power losses on transmission lines, stabilizes the voltage level in the system and damping of voltage and power oscillations in the grid.

The operation of the SVC is based on the compensation of reactive power variations of consumers using a coil and a capacitor. The continuous regulation of the current is carried out with the help of the coil (LCT), and using the capacitor (CCT), such that the balance of the reactive power absorbed by the load and compensator assembly is corrected.

The capacity of a SVC is calculated using the formula:

$$Q_C = \frac{U_n{}^2 - U_c{}^2}{X_c} \tag{1}$$

Q_c - capacity of the SVC [kVAr];
U_n - nominal voltage in the node [kV];
U_c - the voltage wanted after connecting the SVC [kV];
X_c - SVC reactive impedance [Ω].

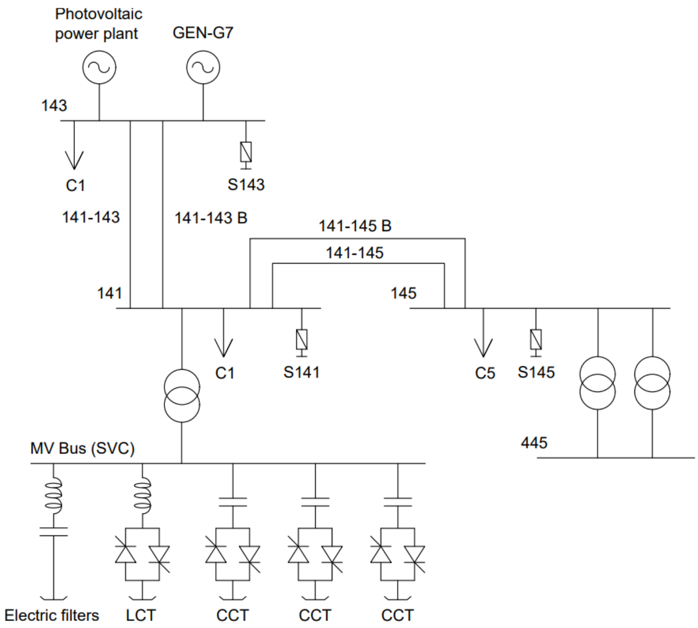

Figure 2. Connection point of the SVC and photovoltaic power plant in Nordic 32 grid

4. Base case scenario

All simulations were run using the NEPLAN 10 program developed by PSI Software AG PSI Group.

In order to establish the optimal location of the SVC installation in the network, the load flow was calculated. In this way, specific nodes were determined where the voltage level has the values closest to the admissible limit value. Following this analysis, it turned out that the node where it is necessary to connect the SVC installation is node 141.

Figure 3 shows the voltage level (expressed in percentages) in every node of the Nordic 32 test system. The maximum admissible voltage value (110%) and the minimum admissible value (90%) are marked in the diagram.

5. SVC connected in node 141 scenario

After connecting the SVC to node 141 with Q = 130 MVAr, a series of improvements in the operation of the Nordic 32 network can be observed (in this scenario the SVC is in capacitive power mode). Among them, can be noted the decrease in the load on the lines adjacent to the node where the

FACTS device was connected. Thereby, on the 110 kV lines between nodes 141, 143 and 145, a load drop of up to 4% can be observed. The detailed values for each network element and the difference from the initial value are presented in table 2. S0 is considered to be the base case scenario and S1 is considered the scenario in which the SVC (with 130 MVAr nominal power) device is connected to node 141.

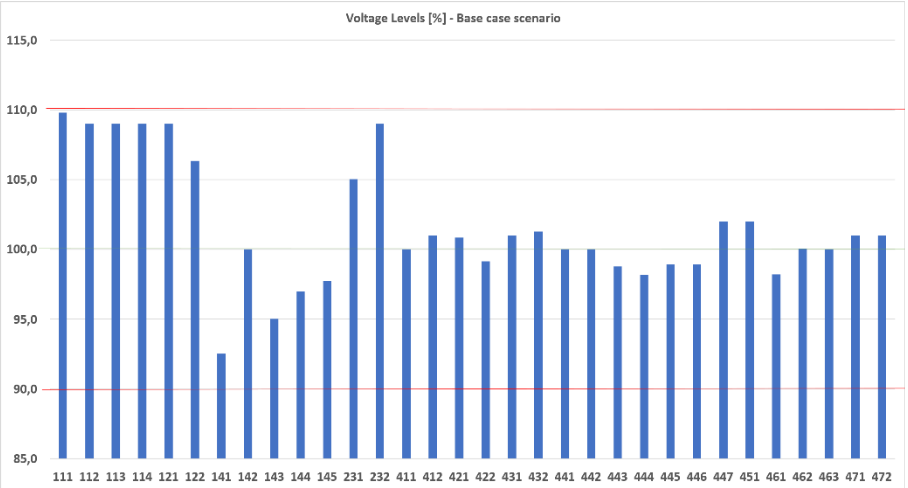

Figure 3. Voltage levels in Nordic 32 grid

Table 2. **Comparison between the loading of the lines in scenario S0 and S1**

Lines loading			
Name	**S0 Loading [%]**	**S1 Loading [%]**	**Delta [%]**
141-143	74,57294	70,71526	3,85768
141-143B	74,57294	70,71526	3,85768
141-145	69,63521	65,62215	4,01306
141-145B	69,63521	65,62215	4,01306

In the area of the 110 kV network where the SVC FACTS device was connected, it can be seen that the voltage level in all the neighboring nodes is close to 100% and that there are no network elements where nominal values are exceeded. The power flow in the analyzed area is presented in figure 4.

Another benefit obtained by using the SVC device in node 141 of the Nordic 32 network is the decrease in power losses through the lines in the immediate vicinity of the FACTS installation. Thus, it can be observed that both the active power losses through the lines and the reactive power losses through the lines decreased after the SVC connection. Figure 5 and Figure 6 show the losses through lines 141-143, 141-143B, 141-145 and 141-145B in both scenarios studied.

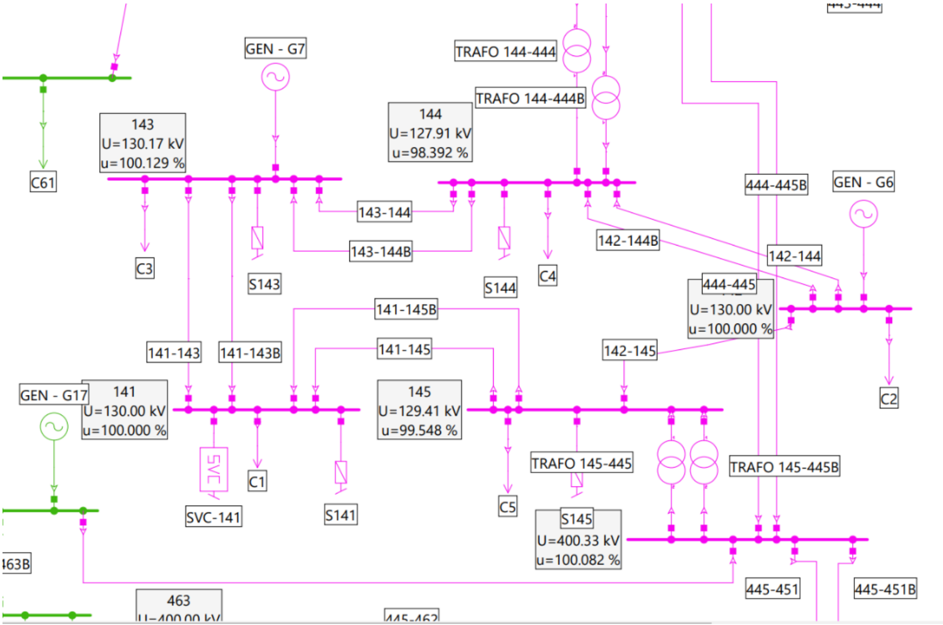

Figure 4. Power flow in 110 kV section of Nordic 32 grid

Figure 5. Active power losses in 110 kV lines

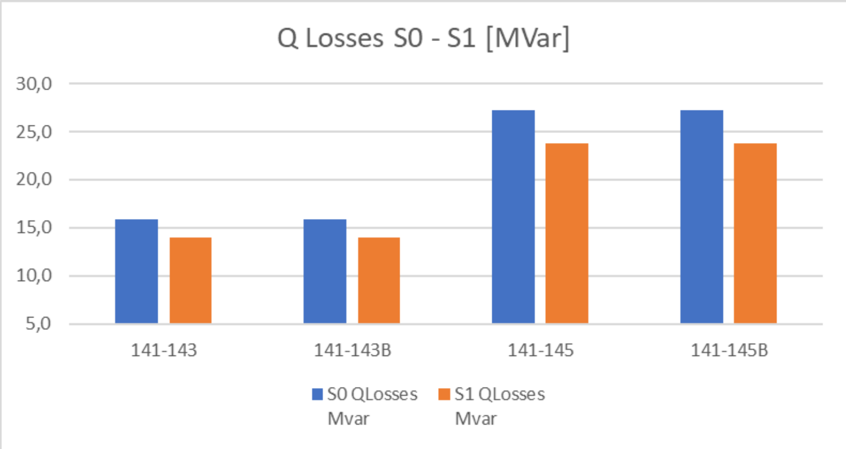

Figure 6. Reactive power losses in 110 kV lines

After connecting the SVC in scenario 1, there is an improvement in the voltage level in the network compared to the situation presented in figure 3. Thus we can see in figure 7 that in the connection area of the FACTS device there are no major deviations in the voltage level and the voltage in the node 141 is at the 100% level.

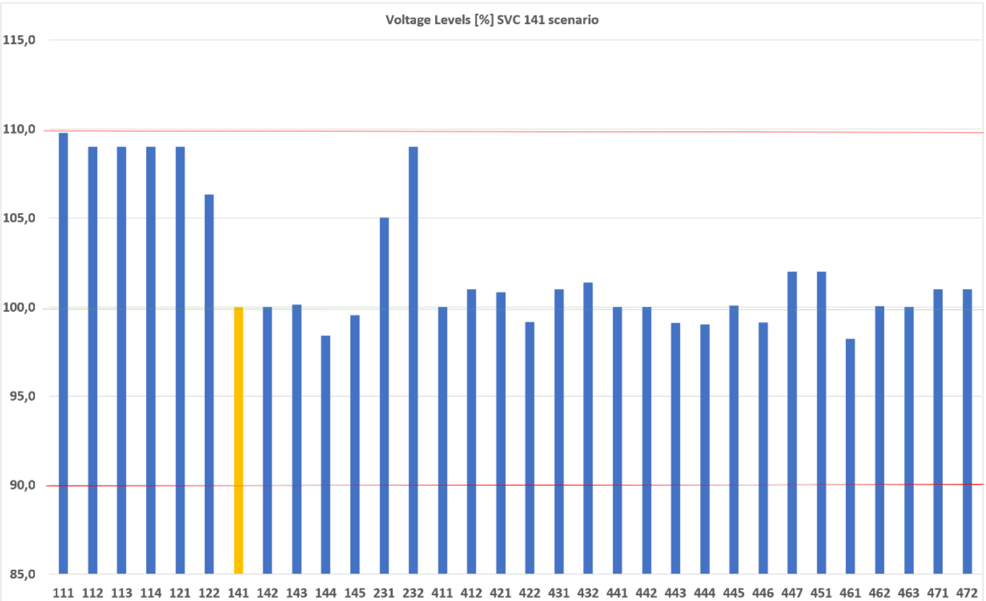

Figure 7. Voltage levels in Nordic 32 grid – scenario S1

6. Grid connection of a photovoltaic power plant in node 143

In order to analyze the benefits brought by the SVC type installations on increasing the integration capacity of renewable sources, the following scenario was studied. A photovoltaic power plant with an active power of 90 MW was connected in node 143 of the network, in order to allow the connection of this source to the network, an operational limitation was made on the classic power plant connected in node 143 with 90 MW. In this case the reactive power value of the SVC is 120 MVAr. In order to analyze all possible operating options, three scenarios were created:

- Scenario 2: The case in which the production is at peak from renewable sources and the SVC installation is not connected;
- Scenario 3: The case where it is a production gap from renewable sources and the SVC is connected;
- Scenario 4: The case in which the production is at peak from renewable sources and the SVC is connected.

After analyzing the three scenarios above, it was concluded that SVC has a very important role in voltage regulation in situations where we have renewable sources of electricity in the network. The main results obtained in the three scenarios are presented in figure 8.

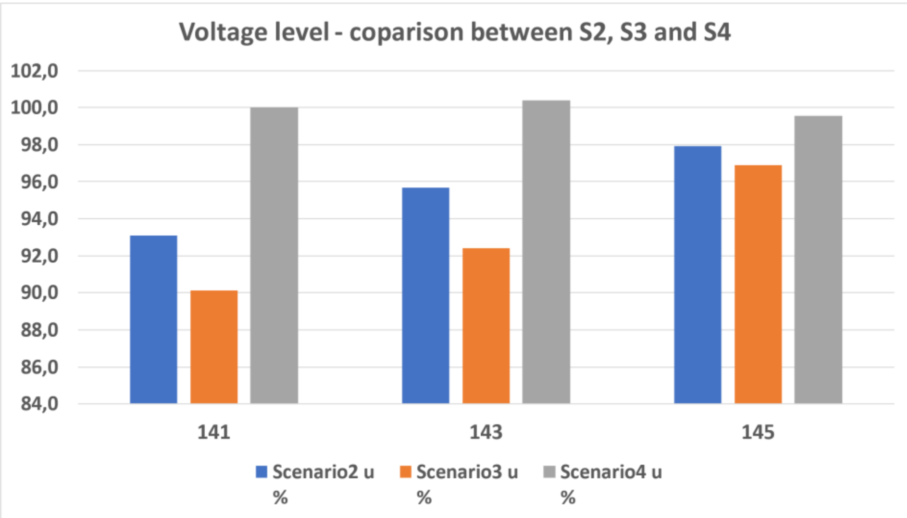

Figure 8. Voltage level comparison between scenarios S2, S3 and S4

7. Conclusions

Following the analysis carried out on the Nordic 32 test network, it can be concluded that the use of SVC-type equipment brings real benefits in the operation and optimization of network parameters.

By connecting a FACTS device in node 141 of the network, a series of benefits were obtained, among which the most important are: regulation of the voltage in node 141 and in the adjacent nodes, reduction of the losses of active power and reactive power in the immediately neighboring lines of the connection point of the SVC equipment and the increase of the power lines transmission capacity that make the connection between node 141 and the rest of the network.

From the perspective of connecting renewable energy sources in the grid, it was observed that if the SVC device is connected, scenario 4, the voltage level in the network is improved.

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