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# Simulation 35 kV 35 MVar STATCOM in EMTDC PSCAD

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**Abstract.** This paper presents the model of STATCOM in EMTDC PSCAD, which can work in different modes: constant system voltage control mode, constant system reactive power control mode and constant power coefficient control mode. All modes is realized and plots are plotted.

## 1. Introduction

STATCOM control strategy is categorized into primary control strategy and secondary control strategy. Primary control strategy offers device reactive power control, constant system reactive power control, power factor control, and constant system voltage control, while secondary control strategy offers low voltage ride through control, conditioned restarting control, pulse locking control, etc.

## 2. STATCOM control strategy

According to system current detected by STATCOM, STATCOM output current and load current can be calculated. The reactive component  $i_q$  can be calculated through PARK transformation of load current. The transformation equation is as below:

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \sin \omega t & \sin(\omega t - \frac{2\pi}{3}) & \sin(\omega t + \frac{2\pi}{3}) \\ -\cos \omega t & -\cos(\omega t - \frac{2\pi}{3}) & -\cos(\omega t + \frac{2\pi}{3}) \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad (1)$$

### 2.1 Constant system reactive power control

This control strategy means STATCOM can compensate all system reactive power dynamically to make system reactive power to be zero, or compensate part of system reactive power dynamically to keep system reactive power to be a constant value.

### 2.2 Constant power factor control

Power factor control makes system power factor reach to the reference value, which usually has supplied by factory. STATCOM completes the task of controlling system power factor by outputting corresponding reactive power detected by using the calculation method of power factor control.

### 2.3 Constant system voltage control

STATCOM generates reactive power fast with the slope in transient process to maintain stability of the power grid.



STATCOM receives the output from closed-loop regulator as the reactive current (or reactive power) reference that the compensator should generate. A PI controller used to ensure voltage regulation in both steady state and transient state.

When the voltage drops and the compensator U-I characteristics decreases, STATCOM can adjust the amplitude and phase of the AC voltage of its convertor to provide the required reactive current only restrained by the rated current of STATCOM. When the voltage reference changes, the U-I characteristics will move upwards or downwards accordingly.

Voltage regulator compares the measured control variable with the reference value, and then put it in the transfer function of the controller. The controller then calculates the reactive current according to STATCOM U-I characteristics and generate (absorb) the same amount of current for compensation through STATCOM closed-loop controller.

The slope of the U-I characteristics curve known as difference adjustment rate is defined as the ratio of voltage amplitude increment to current amplitude increment in the linear control area of the compensator.

$$K_{SL} = \frac{\Delta V}{\Delta I} \Omega \quad (2)$$

Where,

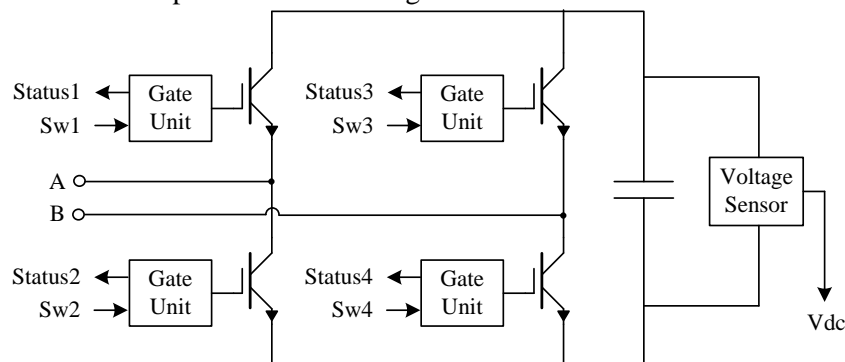
$\Delta V$  is the Voltage amplitude increment (V)

$\Delta I$  is the Current amplitude increment (A)

The slope can also be defined as the ratio of voltage change to voltage rating when STATCOM generates maximum reactive power. The slope is usually kept in between 0% to 10%, and is typical in between 3% to 5%.

### 3. STATCOM model description

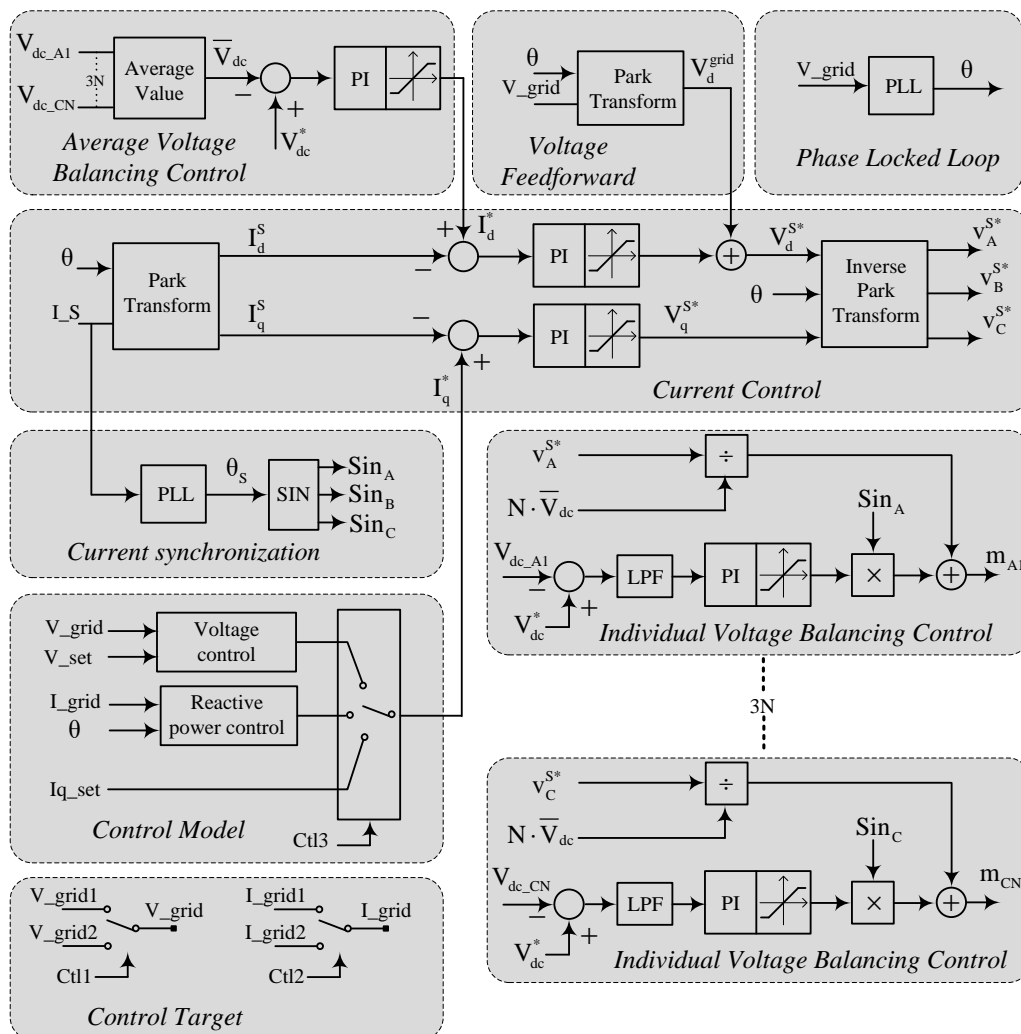
STATCOM model and description is shown in Figures and Tables below.



**Figure 1.** Simplified STATCOM cell model.

**Table 1.** Description for the simplified STATCOM cell model

Name	Description	Type
<b>Sw1</b>	Switchin signal of Switch 1	Optic
<b>Sw2</b>	Switchin signal of Switch 2	Optic
<b>Sw3</b>	Switchin signal of Switch 3	Optic
<b>Sw4</b>	Switchin signal of Switch 4	Optic
<b>Status1</b>	Overcrrrent1, Overvoltage1 of Switch 1	Digital/Optic
<b>Status2</b>	Overcrrrent2, Overvoltage2 of Switch 2	Digital/Optic
<b>Status3</b>	Overcrrrent3, Overvoltage3 of Switch 3	Digital/Optic
<b>Status4</b>	Overcrrrent4, Overvoltage4 of Switch 4	Digital/Optic
<b>Vdc</b>	Measure of DC Voltage capacitor	Analog



**Figure 2.** Function scheme of STATCOM cell.

Explanation of parameters using for different tasks are shown in Tables below. Parameters in Table 2 are need for calculation of the active power absorbed by the STATCOM in order to compensate total losses.

**Table 2** Parameters for Average Voltage Balancing Control

Inputs		Outputs	
$V_{dc\_A1} \dots V_{dc\_AN}$	Voltage of A Phase DC capacitor	$I_d^*$	Current Reference for STATCOM
$V_{dc\_B1} \dots V_{dc\_BN}$	Voltage of B Phase DC capacitor		
$V_{dc\_C1} \dots V_{dc\_CN}$	Voltage of C Phase DC capacitor		

Parameters in Table 3 allows obtaining Grid voltage direct component in order to compensation Grid Voltage Fluctuation

**Table 3** Parameters for Voltage Feedforward

Inputs		Outputs	
V_grid	Voltage of grid	$V_d^{\text{grid}}$	Grid Voltage Direct Component
$\theta$	Grid Angle		

Parameters in Table 4 is given for Phase Locked Loop (PLL). PLL calculates voltage Angle.

**Table 4** PLL-Phase Locked Loop

Inputs		Outputs	
V_grid	Voltage of grid	$\theta$	Grid Voltage Angle

Parameters in Table 5 calculates the active power absorbed by the SVG in order to compensate total losses.

**Table 5** Current Control

Inputs		Outputs	
I_S	Current of STATCOM	$I_d^*$	Active Power Current Reference for STATCOM
$I_d^*$	Active Power Current Reference		
$I_q^*$	Reactive Power Current Reference		

Parameter in Table 6 obtain a signal that has the same phase of STATCOM Current.

**Table 6** Current Synchronization

Inputs		Outputs	
I_S	Current of STATCOM	$\sin_A, \sin_B, \sin_C$	STATCOM Current Synchronization Signal

Parameters in Table 7 are needed in order to Set the Control Model: Voltage Control, Reactive Power control and Manually Control.

**Table 7** Control model

Inputs		Outputs	
I_grid	Current of Grid	$I_q^*$	Reactive Power Current Reference for STATCOM
V_grid	Voltage of Grid		
V_set	Voltage Set Value		
$\theta$	Angle of Grid Voltage		
Ctrl3	Control Model Set		

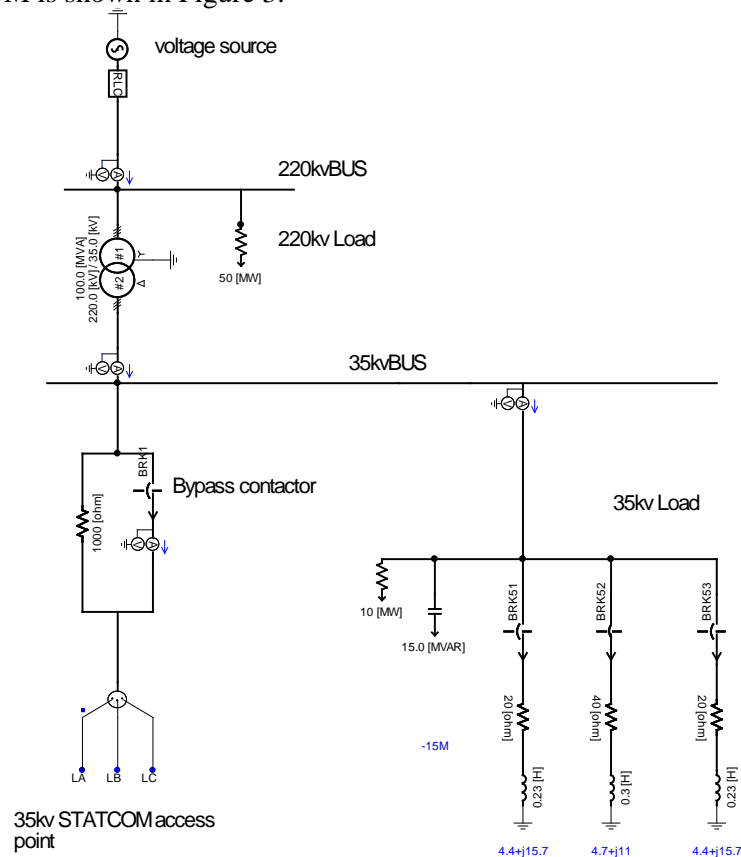
Parameters in Table 8 are used for Compensator Target.

**Table 8** Control Target

Inputs		Outputs	
I_grid1,2	Current of Grid	I_grid	Current and Voltage for Compensation Target
V_grid1,2	Voltage of Grid	V_grid	
Ctrl1,2	Control Model Set		

#### 4. Simulation model

Model of STATCOM is shown in Figure 3.

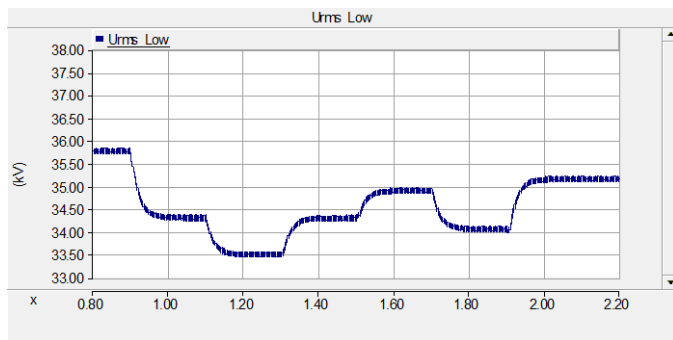


**Figure 3.** Model of one STATCOM cell in PSCAD.

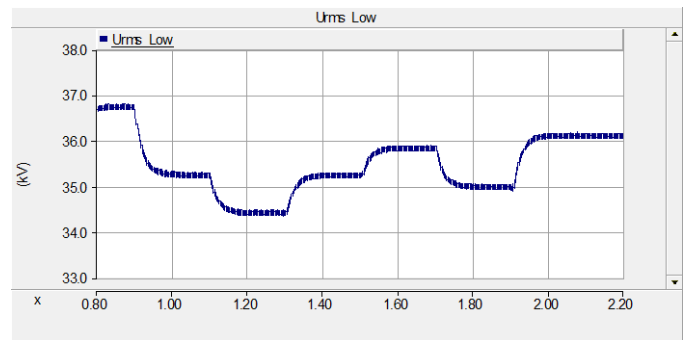
There is 220kV 50MW constant load which, and 35 kV changing load, which connected and disconnected from the system by barkers. STATCOM connected at 35kv STATCOM access point.

#### 5. Simulation results

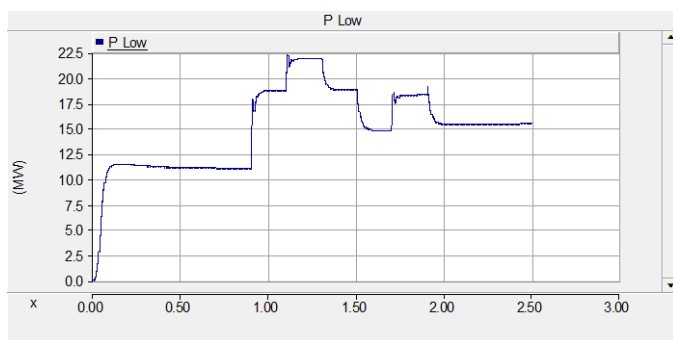
First, the test without STATCOM was provided (Figure 4). The following is the next: a) -RM value of voltage in the grid, b) active power value in the grid? c) reactive power value in the grid and d) reactive power output of STATCOM.



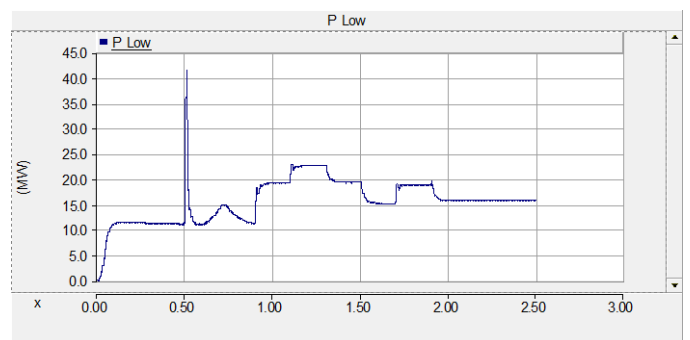
(a)



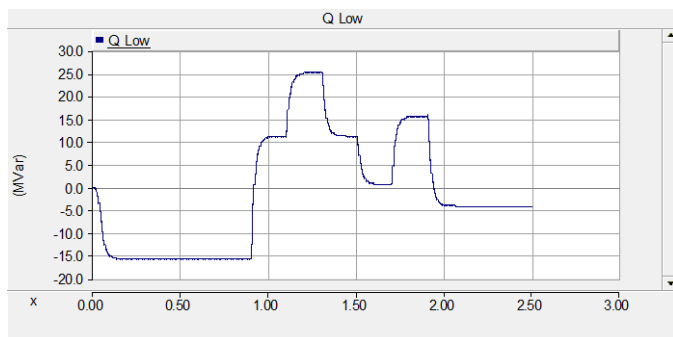
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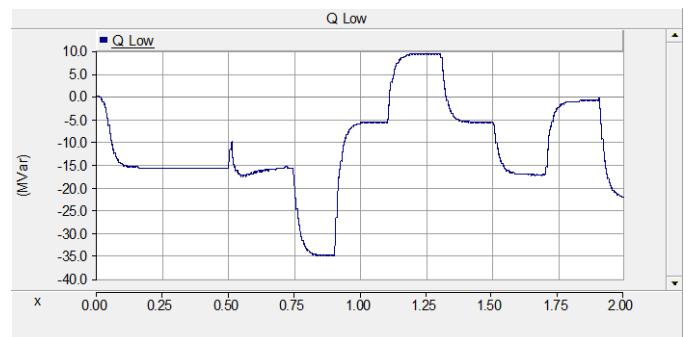
(b)



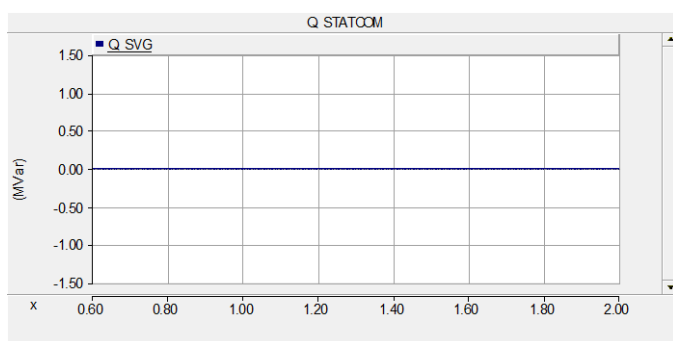
(b)



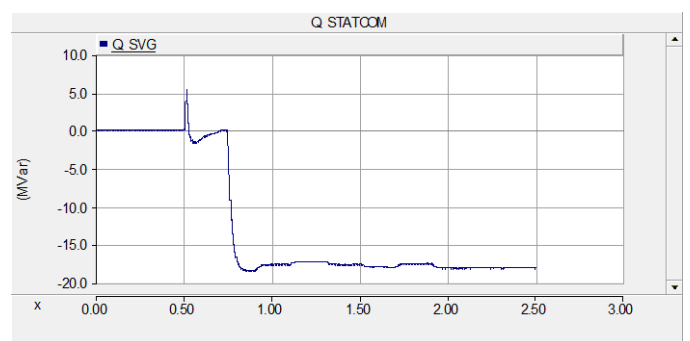
(c)



(c)



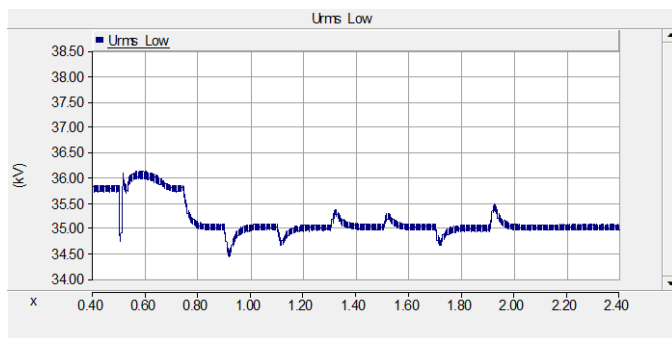
(d)



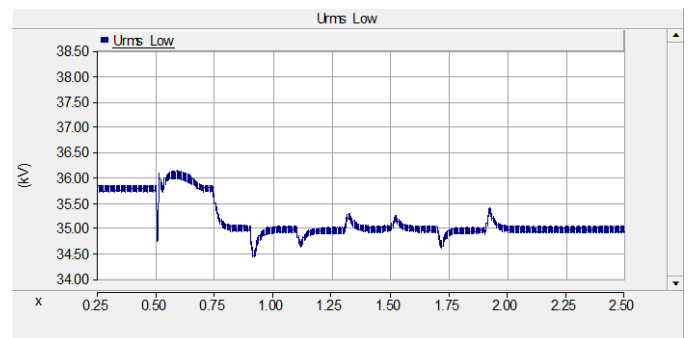
(d)

**Figure 4.** Modeling in case when STATCOM is disabled .

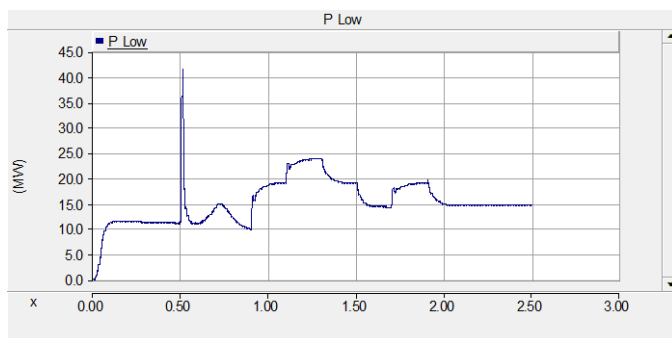
**Figure 5.** Modeling in case when STATCOM works in constant reactive power control mode .



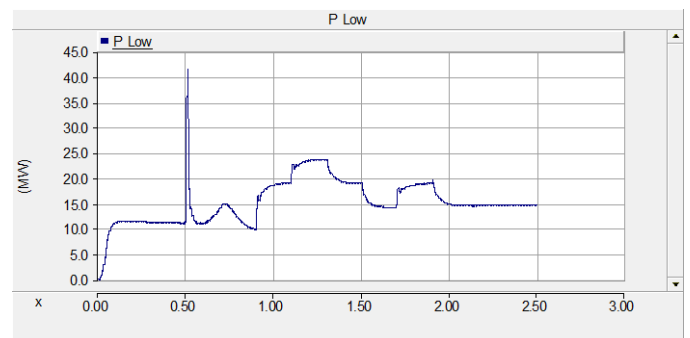
(a)



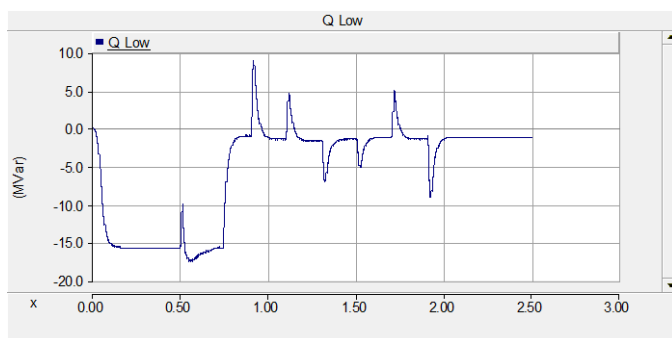
(a)



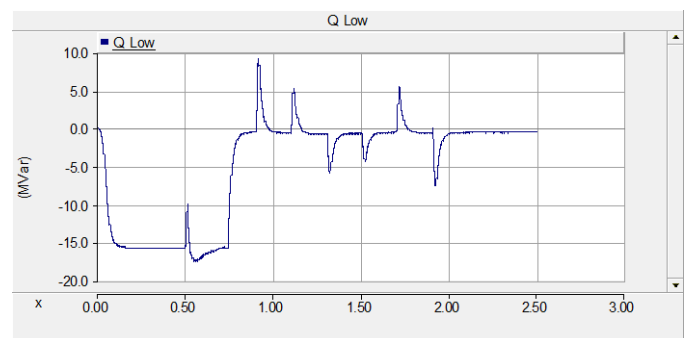
(b)



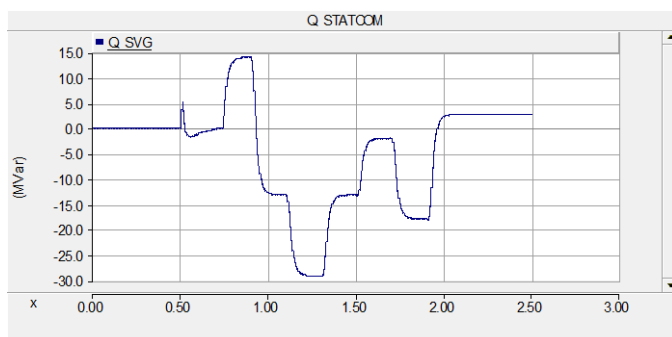
(b)



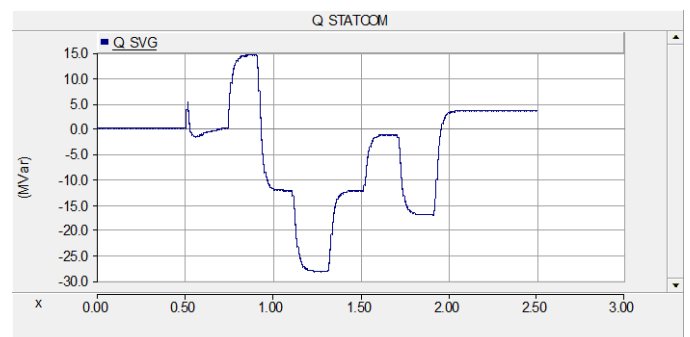
(c)



(c)



(d)



(d)

**Figure 6.** Modeling in case when STATOM works in constnt system voltage control mode

**Figure 7.** Modeling in case when STATCOM works im constant system power factor control mode



## 6. Conclusions

In this work, part of STATCOM was designed using IGBT, and control part was realized via Visual Studio. Park transformation was used to obtain dq-reference frame, and control strategy was described. Examples are provided for one STATCOM cell, but depending on the device configuration, it can be upon 20-25 cells connected in each phase, and phases should have Y-connection. As can be seen on fig. 4 when STATCOM disabled there is voltage fluctuation due to active and reactive power changing. When STATCOM works in constant reactive power control STATCOM continuously generates 15 MVar reactive power. Simulation result on fig.6 and fig.7 quite close to each other due to on the fig. 7 STATCOM works at constant power factor control mode. With compensation of reactive power, voltage fluctuation also decreases. Fig. 6 presents constant voltage control mode, at this mode STATCOM generates reactive power to stabilize the voltage. In this case voltage fluctuation was due to changing the reactive power, but STATCOM provides voltage stabilization due to active power fluctuation.

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