The two modes of 48-pulses StatCom

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***Abstract*— this paper presents the detailed analysis of 48-pulses StatCom. To achieve a satisfactory harmonic content, we increase the number of pulses to 48-pulses, in this paper the voltage source inverter (VSI) based on 48-pulses is employed; this is constituted by four three-level converters linked by four phase-shifting transformers. Such device exhibits a low harmonic rate on the AC side, the 48-pulses StatCom can be utilized in high power applications without AC filters. The StatCom is used in voltage regulation mode and it can be used as compensator (Var mode). Simulation results are exhibited to show the appropriateness of the proposition.**

***Index Terms*— FACTS devices, VSI, StatCom, Compensator, Voltage regulation.**

I. Introduction

THE rapid development of the power electronics technology provides opportunities to develop new power equipment to improve the performance of the power system. Flexible alternating current transmission systems (FACTS) technologies have been proposed and implemented based on such technology. FACTS devices can be used for power flow control, loop-flow control, voltage regulation, enhancement of transient stability, and damping of power oscillations. For instance, FACTS devices can be used as series controllers to regulate the line impedance, as shunt controllers to regulate the voltage magnitude, or as series/shunt combination to regulate several signals.

The advancement of power semiconductor devices such as IGBT and the Gate Turn-Off thyristor (GTO) which possess high power handling capability have led the development of controllable reactive power sources utilising electronic switching converter technology [1]. These technologies additionally offer considerable advantages over the existing ones, in terms of space reductions and performance [1]. FACTS are a result of the development in the power electronics area and aim to rapidly control electrical signals [2].

The Voltage Source Converter is the basic building block of FACTS devices such as StatCom and UPFC. Single phase voltage source converters can be inter-connected to form complex schemes. Combined with appropriate controllers, certain harmonics can be eliminated [4].

The Static Synchronous Compensator (StatCom) is a shunt device of the Flexible AC Transmission Systems (FACTS) family it is based on power electronics devices to control voltage to compensate reactive power, and improve transient stability [5][12] Figure 1 shows the basic scheme of a StatCom connected to a bus of the transmission system.

The results of applying a StatCom are similar to those by a rotating synchronous condenser, but without its mechanical inertia and slow time response [3].

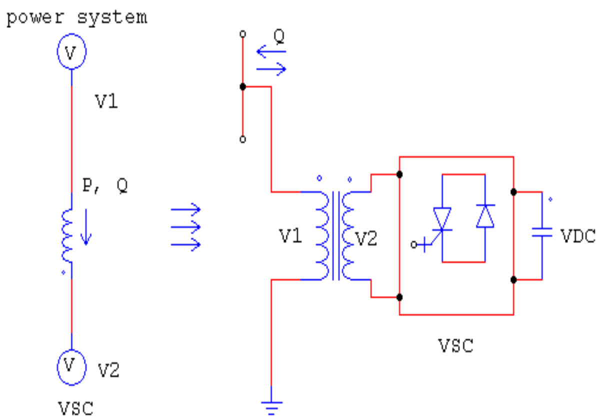

Fig 1. The StatCom's connection

The StatCom basically consists of a step-down transformer with a leakage reactance, a three-phase GTO voltage source converter (VSC), and a DC capacitor [9]. The StatCom regulates the voltage magnitude at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the StatCom generates reactive power (StatCom capacitive); when system voltage is high, it absorbs reactive power (StatCom inductive) [5] [6].

II. VSC's Basic Structure

One of the important requirements in high voltage power applications is that harmonics be kept at some satisfactory level [7]. One way of reducing the level of harmonics presents

in the converter output waveforms is to increase the number of converters [1], [7]. An elementary voltage source converter, based on a phase control scheme, consists of six self-commuted semiconductor switches. Each switch is shunted by a reverse parallel-connected diode; Fig. 2 with a DC voltage source, the converter can generate a balanced set of three-phase voltage waveforms at a given frequency, fig. 3[8].

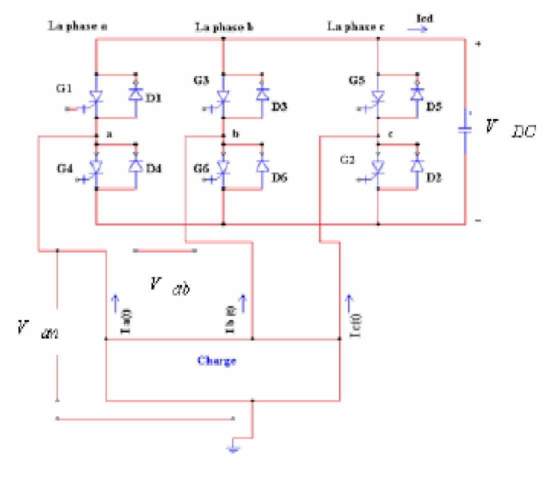

Fig. 2. Six pulses inverter

The line to line output voltage is illustrated by fig. 3

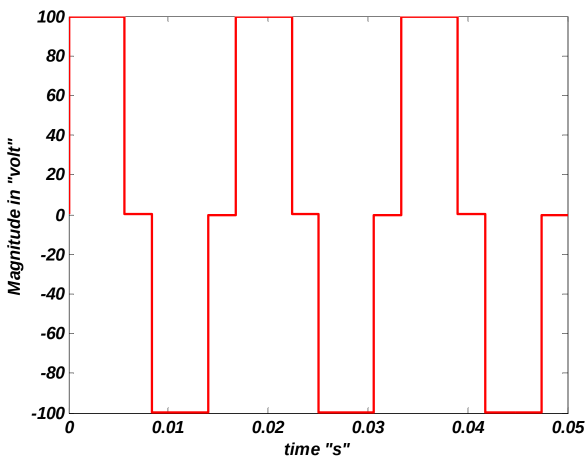

Fig. 3. The line to line output voltage

The simulation of the VSI illustrated by fig. 3, and choosing a band frequency of "0-6000 Hz", we will be able to have the spectrum of the harmonics according to: fig. 4.

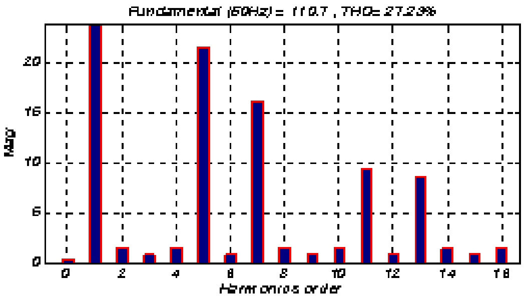

Fig. 4. Harmonics components

The spectrum of the harmonics presented by fig. 4 give the amplitude of the harmonics. We can note « 5th, 7th, 11th, 13th.....» with a total distortion of harmonics « THD » =30.40%.

For This reason the VSI twelve pulses was developed. The VSI twelve pulses is illustrated by fig. 5

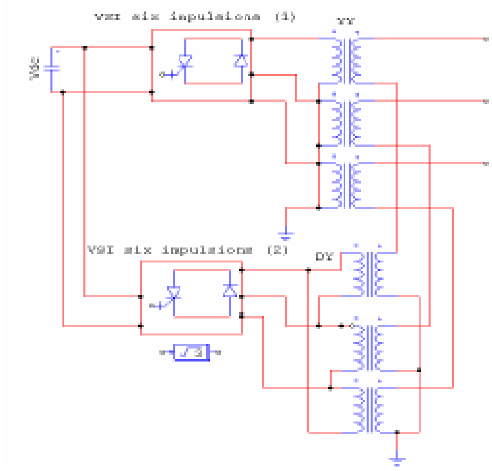

Fig. 5. VSI twelve pulses

The output voltage is illustrated by fig. 6

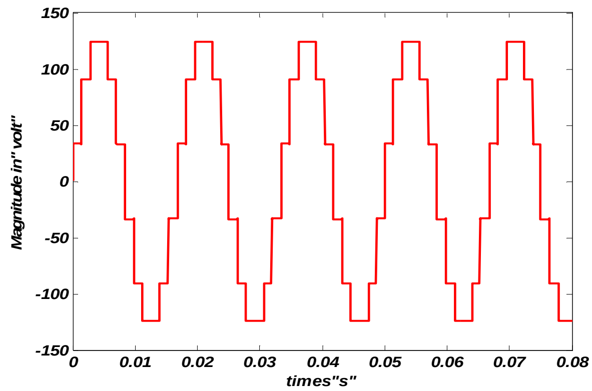

Fig. 6. The twelve pulses Output voltage

The simulation of the VSI illustrated by fig. 6, and choosing a band frequency of "0-6000 Hz", we will be able to have the spectrum of the harmonics according to: fig. 7.

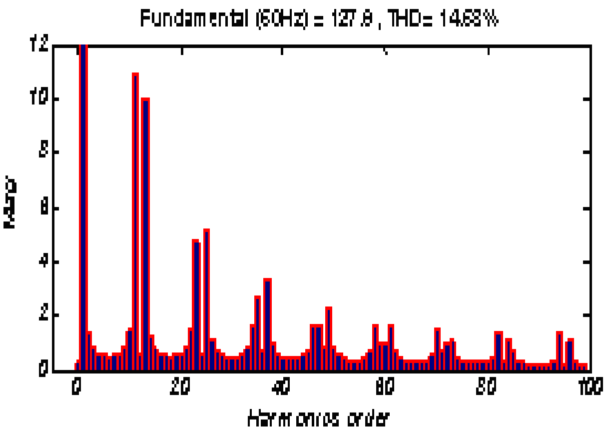

Fig.7. Harmonics components

We can note that the harmonics "5th, 7th, 15th, 17th…" are neutralized. THD is decreased; its value is 14.63 %**.**

To obtain a more satisfactory harmonics, we increase the number of inverter. The VSI twenty four pulses is illustrated by fig. 8

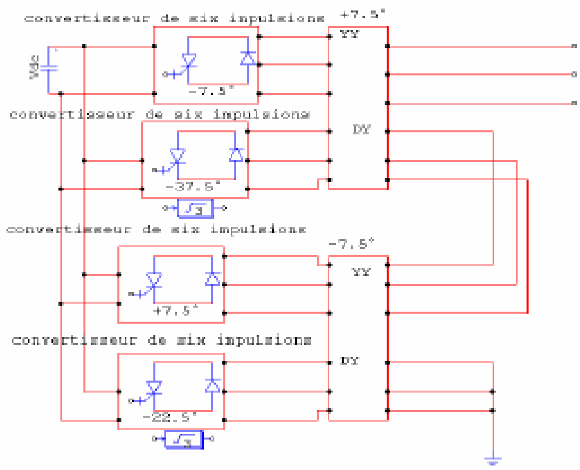

Fig. 8. VSI twenty four pulses

The output voltage is illustrated by fig. 9.

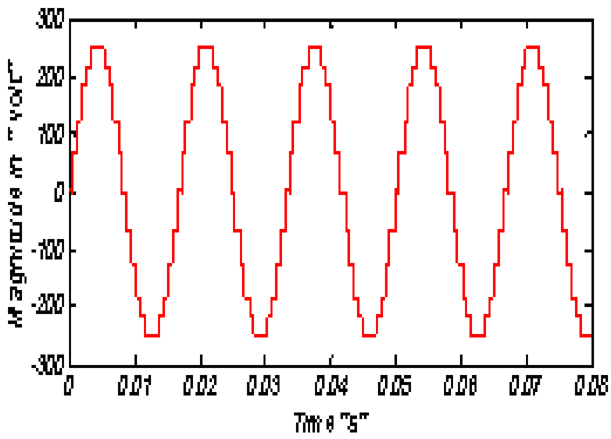

Fig. 9. Twenty four pulses voltage

The simulation of the VSI illustrated by fig. 9, and choosing a band frequency of "0-6000 Hz", we will be able to have the spectrum of the harmonics according to: fig. 10

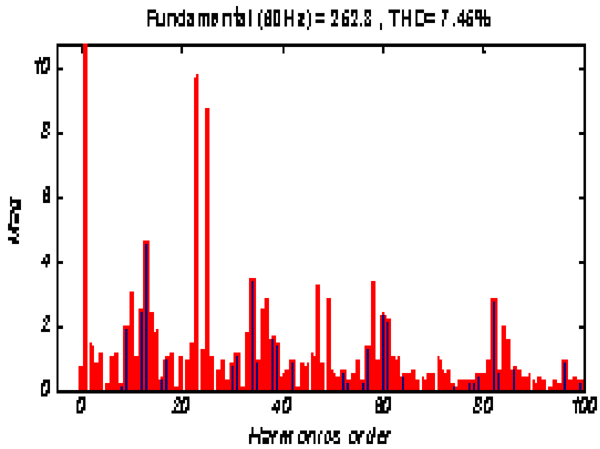

Fig. 10. Harmonics components

Using the results obtained from fig. 10, we can note that it exists only the harmonics "23th, 25th, 47th, 49th…». The THD is decreased; its value is 7.46 %**.**

By combining two 24-pulses VSC, phase-shifted 7.5° from each other, an equivalent 48-pulse converter [8] is constructed. The 48-pulse converter is displayed in Fig. 11; it is formed by four three-level converter linked by four phase shifting transformers. Fig. 13 depicts the quality of the output-voltage obtained from such converter. It can be deduced that the harmonics are reduced by increasing the number of pulses [1] [10]. This kind of converter give rises to a better voltage control on modern power systems [10].

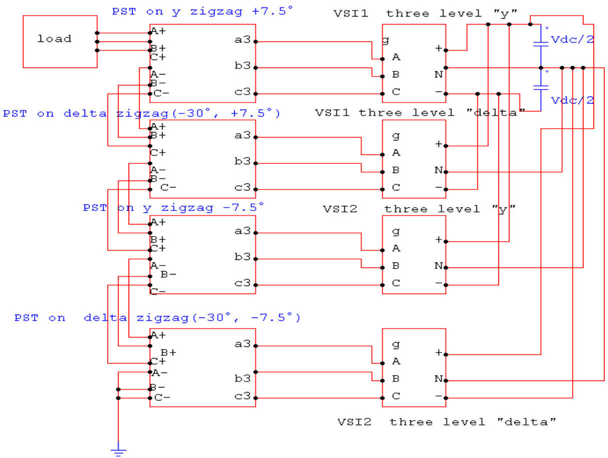

Fig. 11. Three-level 48-pulses VSC

The simulation of the three-level 48- pulses VSC gives the following results.

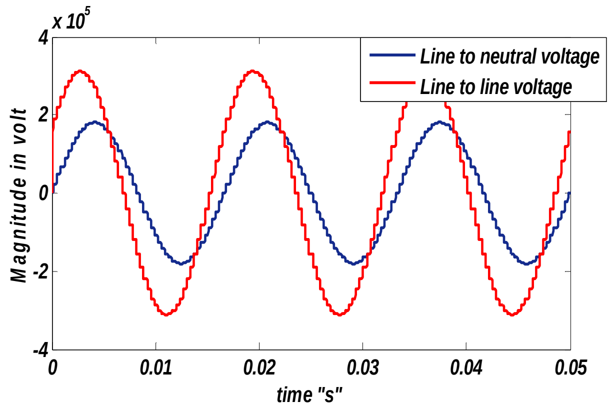

Fig. 12. Three-level 48 pulses VSC output-voltage

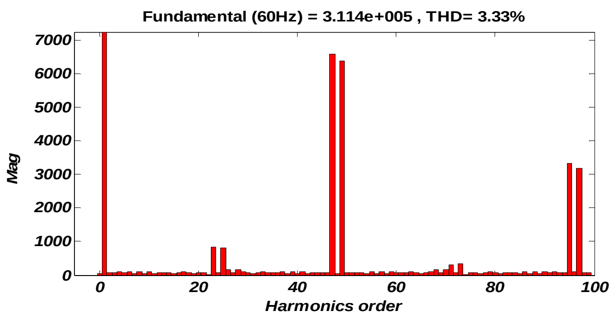

Fig. 13. Harmonic contents

Fig. 12 exhibits that the output-voltage waveform is closely a sine wave. Thus, a filter is not required for eliminating low-harmonics.

III. SIMULATIONS AND RESULTS

A. StatCom in voltage regulation

The power grid in Fig. 14 represents a 500 kV system with a 100 Mvars StatCom embedded with the purpose of regulating the voltage at bus B3. The dynamic responses of several important signals are displayed in Figs. 15-19. The bus voltage B3 is 1.0 p.u when the StatCom is out of service. If the reference voltage Vref is set to 1.0 p.u., the StatCom doesn't exhibit current interchange, Fig. 15-16. The DC voltage is 19.3 kV, Fig. 18. At t = 0.1 s, the voltage source is suddenly decreased to 0.955 p.u. The StatCom reacts by generating reactive power (Q=+70 Mvars), Fig. 17, and the DC voltage increases, Fig. 18.

Then, at t=0.2 s the voltage source is increased to 1.045 p.u, Fig. 16. The StatCom reacts by changing its operating point from capacitive to inductive to keep voltage at 1.021 p.u. At this point the StatCom absorbs 72 Mvars, and the DC voltage has been lowered to 18.2 kV. A figure 19 shows the dynamic response of the reactive current during the capacitive and inductive operation.

Finally, at t=0.3 s the voltage source is set back to its nominal value, and the StatCom operating point comes back to zero Mvars interchange.

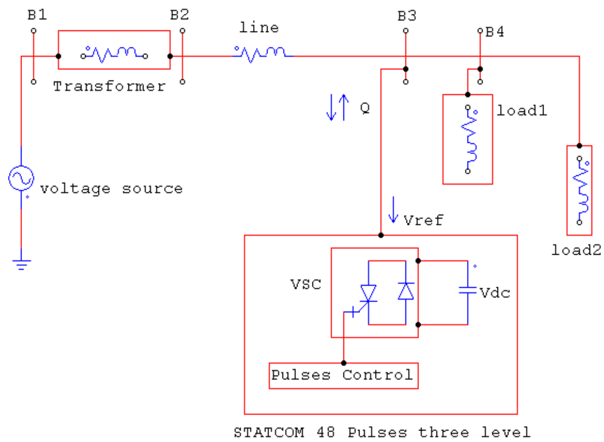

Fig. 14: 48-pulses StatCom connected at bus 3 (B3)

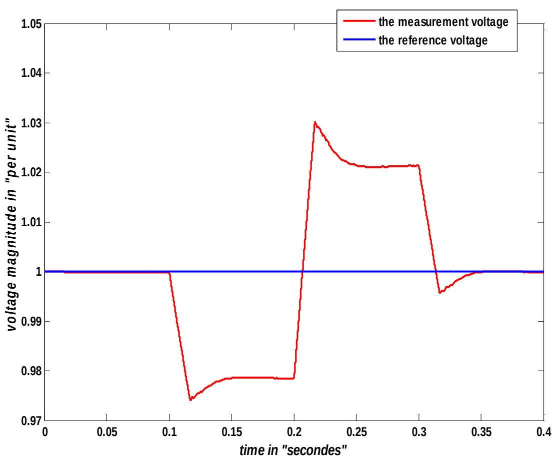

Fig. 15. Voltage measurement

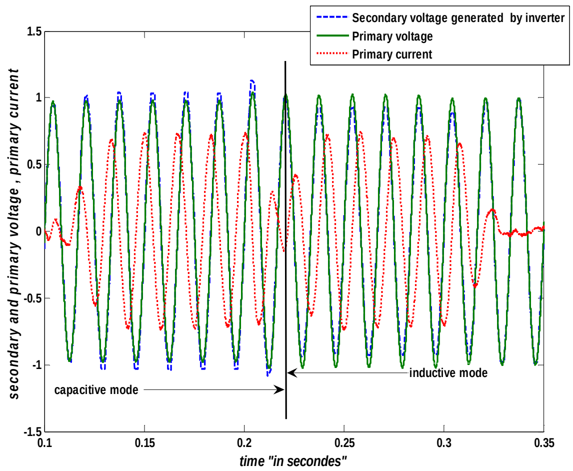

Fig. 16. The dynamic response of StatCom's voltage

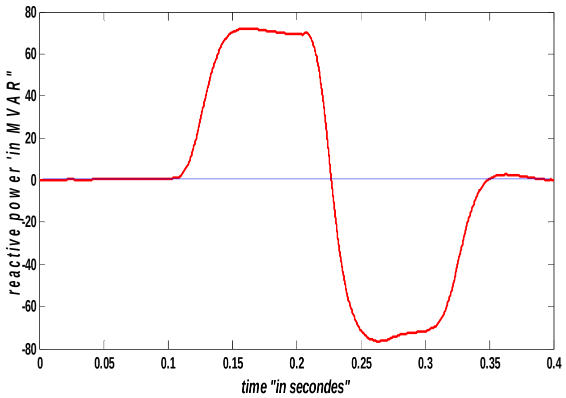

Fig. 17: change of reactive power

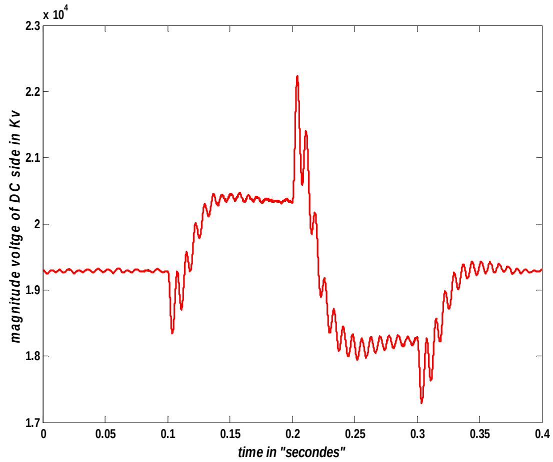

Fig. 18 DC voltage behavior

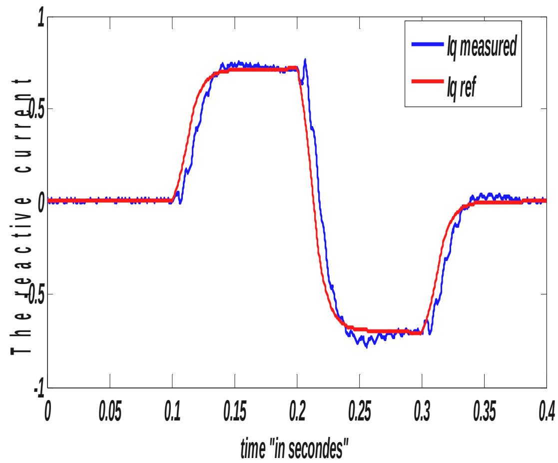

Fig. 19 The reactive current response

B. StatCom in Var mode

A 100 Mvars StatCom shown in fig. 14 is used now as compensator, the dynamic responses of several important signals are displayed in Figs. 20-21.

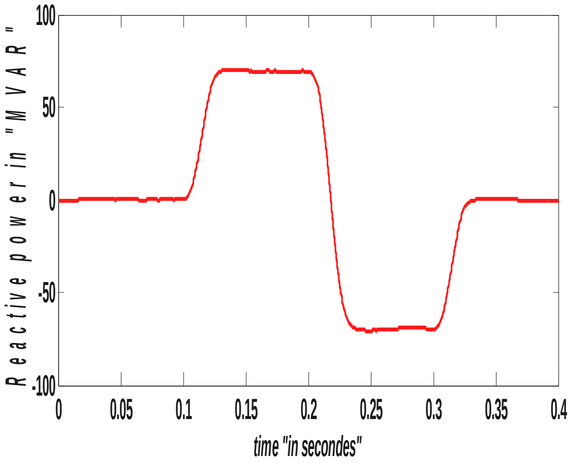

Fig. 20: reactive power in Var mode

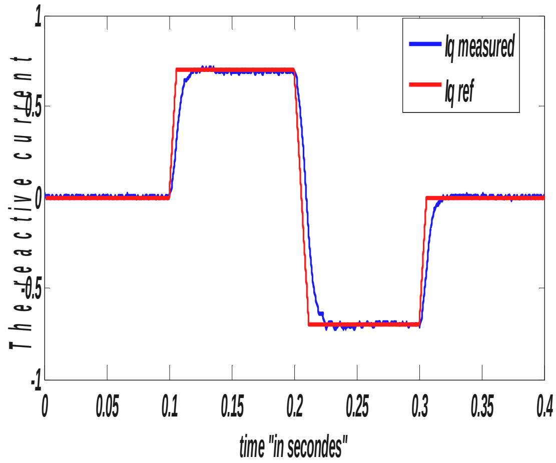

Fig. 21 The reactive current response in Var mode

At t = 0.1 s, the StatCom generate reactive power (Q=+70 Mvars), Fig. 20. During this capacitive mode the reactive current passes from zero operation to 0.7 p.u, fig. 21.

At t = 0.2 s, the StatCom absorb reactive power (Q=-70 Mvars), Fig. 20. During this inductive mode the reactive current change the sign to (-0.7 p. u).

Finally, at t=0.3 s the Mvars interchange is set to zero.

IV. CONCLUSIONS

The StatCom is shunt devices used to help in improve the voltage profile in the transmission system. It functions generating or absorbing reactive power through a voltage source converter. Its simplest configuration is the six-pulse converter. However, multi-pulses configurations are able to generate voltage waveforms with a reduced harmonic content; thus, filters are not required.

The StatCom's dynamic response is fast and able to pass from a capacitive mode of operation to an inductive one, in a few cycles. When the AC voltage decreases, the StatCom reacts by generating reactive power, so the DC voltage increases; this is the capacitive mode. On the other hand, when the AC voltage increases, the StatCom reacts by absorbing reactive power, so the DC voltage decreased; this is the inductive mode [11].

When the StatCom is used as compensator, the move from capacitive to inductive mode, is very fast [12].

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