# Transfer Function Concept Of VSI and its Utilization in Simulation of a SVC and a Parallel Active Filter

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## Abstract

In this paper the operation of a static var compansator and an active filter is simulated by mens of tranfer function (TF) concept of voltage source inverter (VSI). This concept makes it possible to simulate VSIs by generally available simulation packages such as student version of Pspice,Matlab,etc. in a simple manner.Results of simulation show that using the TF concept of VSI solves the problems of convergence,limitation of numbers of nodes an excessive run time of this packages.The PSCAD/EMTDC simulation package is used to verify the obtained results.

## A. INTRODUCTION

The simulation software packages can be used for designing, optimization and analyzing the different kinds of systems. These softwares decrease the cost and time of production especially at the stage of prototype making. There are different simulation programs with different abilities and fields of application such as SABER, ICAP/4, KREAN 4.1, CASPOC, SIMPLORER 3.2, SIMEN, MICROCAP, SIMULINK, ATOSEC 5, EMTP, EMTDC / PSCAD and Pspice [1]. Among these programs the Pspice, probably because of priority in introducing a variable time step during the transient simulation, small size of memory requirement for installation (specially in student version), cheap and considerable facilities in simulation of electrical circuits seems to be more general than others. The main difficulties of Pspice program specially in simulation of power electronic converters which have many switching elements are: long run time, convergence problem, limitation of node number and considerable memory requirement of output file during long transient time simulations.

The transfer function idea solves the above mentioned problems by the simulation of converters as a multiport network avoiding the complexity of micromodels of converter switches [2,3].

This method is used in this paper for simulation of a VSI as a static var compensator and as a parallel active filter too. The EMTDC/PSCAD, that is a professional simulation package, is used for checking the results of transfer function method. A simple and very easy to implement control method is used to on/off control of simulation converter by PSCAD/EMTDC.

## B. SIMULATION of VSI by TRANSFER FUNCTION CONCEPT

The analytical expression of output function to input function of a system is called transfer function (TF). Usually the classical definition of TF is used for linear systems but it is useful to study the operation of highly nonlinear systems such as power electronic converters too. The idea of TF can be used to compute a dependent variable in terms of independent variables. For example in a VSI the dc side current is dependent on three phase output currents and the switching function of VSI. In addition the output voltages of VSI are dependent on dc side voltage and the switching function too. This makes the use of a set of dependent current and voltage sources possible to present a VSI such as shown in fig. 1. This model has two dc ports (3 and 1), three ac ports (7, 8 and 9), three dependent voltage sources $e_a(t)$, $e_b(t)$ and $e_c(t)$ and three dependent current source $i_1(t)$, $i_2(t)$ and $i_3(t)$. The relations between the parameters of voltage and current source are as follows:

$$i_1(t)=i_i(t)*S_{2a}(t) \quad (1)$$
$$i_2(t)=i_i(t)*S_{2b}(t) \quad (2)$$
$$i_3(t)=i_i(t)*S_{2c}(t) \quad (3)$$
$$e_a(t)=V_i(t)*S_{2a}(t) \quad (4)$$
$$e_b(t)=V_i(t)*S_{2b}(t) \quad (5)$$
$$e_c(t)=V_i(t)*S_{2c}(t) \quad (6)$$

$S_{2i}(t)$, $i$=a, b, c, is a two-level switching function. In general case, the switching function of a VSI may be a two level ($S_2(t)$) or a three-level ($S_3(t)$) step function. A two-level step function is shown in fig. 2.

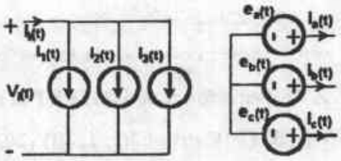


Fig. 1 Macro-Model of VSI

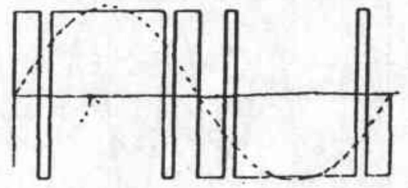

Fig.2 A two level switching function $S_2(t)$.

## C. SIMULATION of VSI as a SVC

It is well known that the SVC is a very suitable system in compensation for reactive power demand of loads [4]. The parallel connection of a VSI with utility via an inductor, simulates the operation of a rotating synchronous generator in var compensation [4]. In fact the SVC absorbs a current from the point of coupling to utility in such a way that the sum of load and SVC current be in phase with the voltage of source. This is shown in fig. 3 by a phasor diagram. In this figure $V_s$ and $I_L$ are the voltage and current of load respectively. $I_{svc}$ is the current that the SVC absorbs and $I_s$ is the ource side current after compensation. This figure shows that the operation of SVC can compensate for the reactive power demand of load. Fig. 4 shows the power circuit of a SVC, a reactive demanded load and a three-phase voltage source.

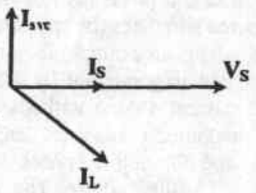


Fig. 3 Description of SVC operation by phasor diagram

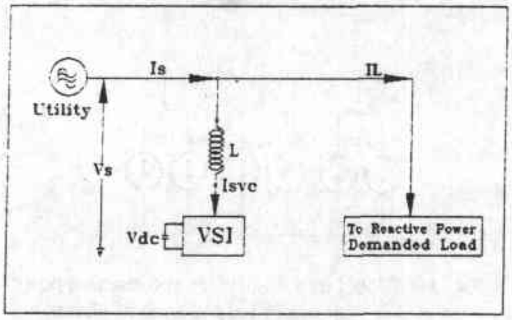


Fig. 4. Simulated power system

This system is Simulated by Pspice with TF concept of VSI. A hysteresis PWM is used to control the switching function and the output current waveshape of VSI. The reference current waveshape that the VSI absorbs from the utility in each of phases are determined in a subcircuit library file by the name of 3HYS. In fact the waveshape of reference current must be determined analytically in this library file. Of course, the magnitude and frequency of fundamental harmonic and the range of hysteresis band may be modified by main program [3].

The subcircuit of 3HYS itself calls some subcircuits such as hysteresis PWM, hysteresis comparator, comparator, current sensor and three-phase sinusoidal voltage sources. The library file of these subcircuits are just as in [3] and the combination of them as a SVC shows the ability of TF idea in simulation of power electronic converters..

Fig.s 5 and 6 show the SVC current $I_{inv}$ the load current $I_L$, utility phase voltage $V_s$, and utility side current $I_s$ that are obtained by Pspice simulation only in phase "a" for simplicity.

These results are checked by PSCAD/EMTDC simulation package. The simulation of system operation by PSCAD/EMTDC is done in switch and converter circuit level [3]. This results in controlling each of switches of converter individually. This requires a control circuit which can compute the reference current in each phase, compares it with actual current of that phase in a hysteresis control mode of operation and generates the on/off signal of each of converter switches. In this paper,the instantaneous reactive power theory is used to compute the desired reference current waveshapes [7]. A new and simple circuit for on/off control of VSI's GTO switches is introduced. This circuit is shown in fig. 7. In this circuit it is not necessary to control the switch by writing a complicate Fortran program and it is enough to use a change-over switch with "integer" numbers 1 and 2 as inputs and the "G" that connects to the gate of GTO as output. The integer number "1" makes the GTO on and integer number "2" makes it off. The command for changing the case of change-over switch comes from the control circuit. If the "ctrl" port connects to integer number "1" then the switch connects "A" port to "G" port, else it connects "B" port to "G" port. The simulated circuit by PSCAD/EMTDC is shown in fig. 8. In this figure only the controller circuit for the switches of phase "R " is shown for simplicity.

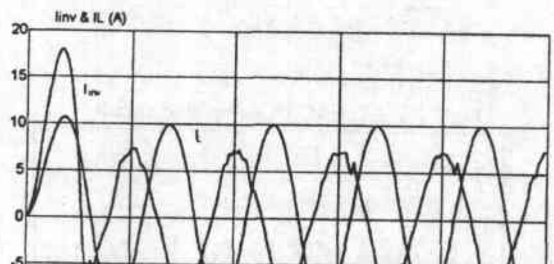


Fig5. Pspice simulated Il and Iinv vs. time(sec)

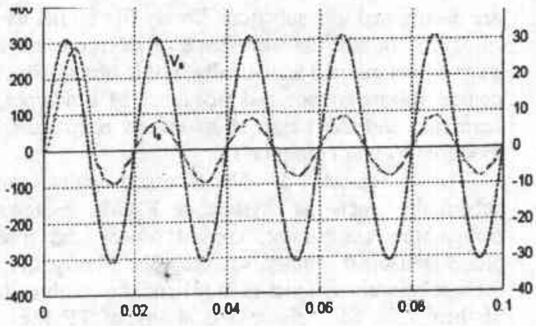


Fig 6. Pspice simulated Is and Vs vs time(sec)

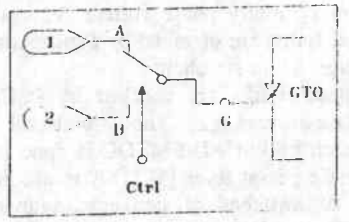


Fig. 7 Presented circuit for on/off control of GTO switches in PSCAD/EMTDC package

The results of PSCAD/EMTDC simulation are shown in figures 9 and 10. These results confirm the results that are obtained by TF concept of VSI.

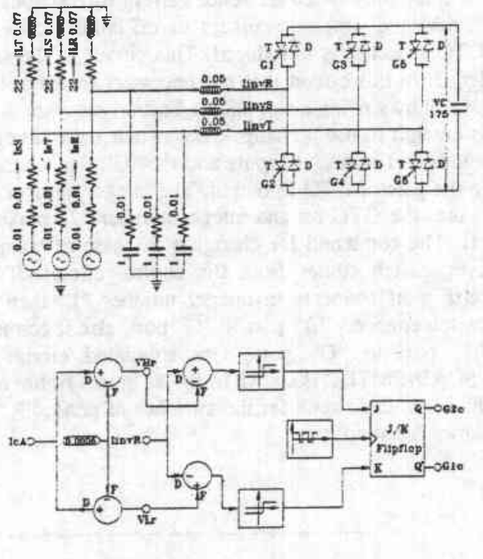

Fig8. PSCAD/EMTDC simulated circuit

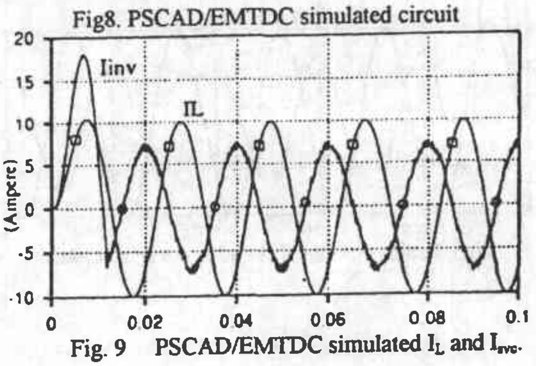


Fig. 9 PSCAD/EMTDC simulated $I_L$ and $I_{inv}$.

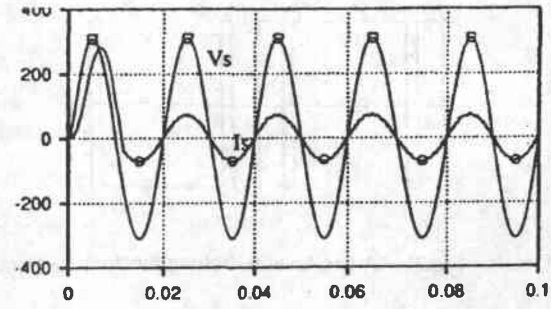


Fig. 10 PSCAD/EMTDC simulated $I_s$ and $V_s$.

## D. Simulation of VSI as an ACTIVE FILTER

Active filter is known as a very suitable system in compensation for harmonics and reactive power demand of loads [5]. These systems are categorized as parallel and series active filters. Parallel active filters due to simpler control circuit and better operation in compensation of loads are more general than series one.

In this section the operation of a VSI.as a parallel active filter is simulated by TF concept of VSI. Related subcircuits are just as mentioned in section II. The power circuit is as shown in figure 4 but the load is changed with two parallel connected current sources as shown in fig.11.

The $i_{R1}(t)$ is a sinusoidal current source with fundamental frequency of 50 Hz and 45 degree phase lag relation to the phase "R" of utility voltage. This current source simulates the reactive power demand of load. The $i_{R5}(t)$ is an example for simulation of current harmonics that is generated by load. The $i_{R5}(t)$ is a sinusoidal current source with the frequency of 250 Hz, the magnitude of one half of fundamental frequency and 90 degree phase lag relation to the phase "R" of utility voltage.The current sources in phases "S" and "T" have -120 and +120 degree phase shift relation to the current sources in phase "R" respectively.

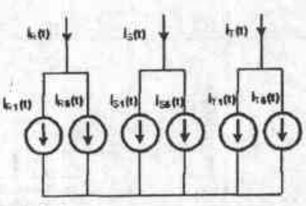

Fig. 11 Model of a non-linear and reactive power consumer load in each of phases

For compensation of this load the "value" command in the 3HYS subcircuit is modified in such a way that the operation of VSI be as an active filter. In this case, Pspice simulation results are shown in figures 12 to 14. Fig. 12 shows the load current $I_L$ and VSI current $I_{inv}$ respectively. Fig. 13 shows the source current Is, and source voltage $V_s$. This figure shows the ability of active filter in compensation for reactive power and harmonics of a non-linear load.

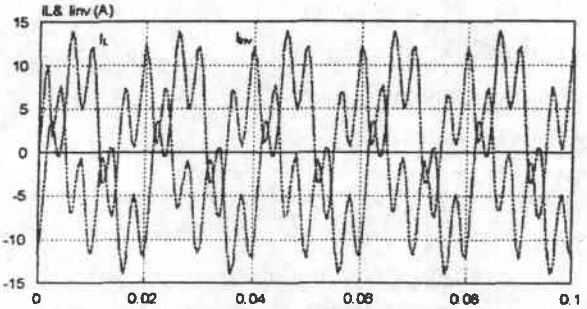


Fig. 12 Pspice simulated $I_L$ and $I_{svc}$.

The upmentioned power system (with parallel connection of current sources) is used in simulation by PSCAD/EMTDC too. The power and control circuits of VSI are just as shown in fig. 8. The results of active filter simulation by PSCAD/EMTDC are shown in figures 14 and 15. These results confirm the results of VSI simulation by TF concept of VSI.

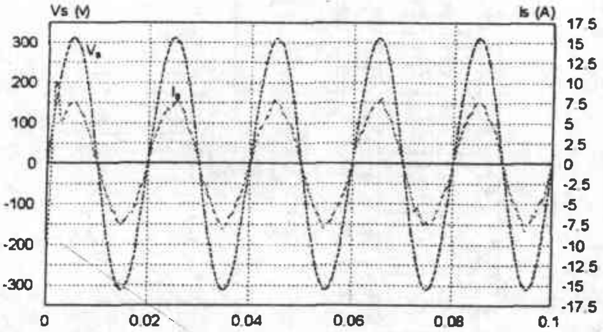


Fig. 13 Pspice simulated $I_S$ and $V_s$

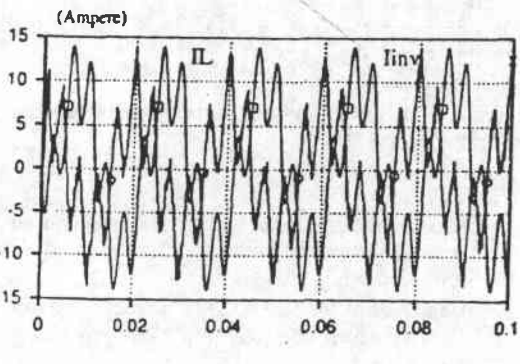


Fig. 14 PSCAD/EMTDC simulated $I_L$ and $I_{svc}$.

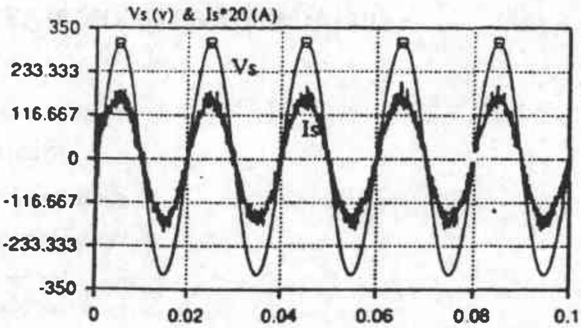


Fig. 15. PSCAD/EMTDC simulated $I_S$ and $V_s$.

## E. CONCLUSION

In this paper TF concept of VSI is used to simulate a VSI as a SVC and a parallel active filter. The results of simulation show the ability of this idea in simulation of upmentioned systems by a student version of Pspice. The validity of results is checked by PSCAD/EMTDC. A new method for on/off control of GTO switches in PSCAD/EMTDC simulation is presented. The obtained results confirm the results of Pspice simulation of SVC and parallel active filter by TF concept of VSI.

## F. REFERENCES

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