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A Current Source Inverter with Advanced External Circuit and Control Method

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***Abstract-* The thyristor based currant source inverter (CSI) fed induction motor is oftan employed in high power applications. A combination of a large current-source inverter and a small voltage-source inverter circuits is analyzed. voltage-source inverter (VSI) is a small power rating the VSI, as an external circuit of the CSI. VSI work on three tasks: 1) thyristors are turn off by the vsi; 2) transfer reactive energy of inductive load; and 3) clamping peak voltages across the load and thyristors. The proposed CSI system uses a voltage source inverter as an auxiliary circuit replacing the bulky ac capacitors used in the conventional drive. Furthermore, the proposed CSI system simple and easy control of the commutation process due to the simple switching operation of the VSI. The VSI works only during the commutation periods of the load currents and stops working in the noncommutation periods. Thus, the VSI with small power rating can be used for the proposed CSI system. The simulation results are presented. Simulation results show that the proposed drive has stable operation even at low speeds.**

***Key words*—Commutation, current-source inverter (CSI), energy recovery, voltage-source inverter (VSI).**

1. INTRODUCTION

Thyristor-based current source inverter (CSI) fed AC motor drives, are often used in high power applications and utility power system applications because of their topological and operational advantages. Due to the economical and reliable characteristics of the thyristors, the CSI topologies

based on thyristors have performance merits such as simplicity, ruggedness, cost effectiveness, and very low switching losses, severity. *Reliability:* Because of using the DC link reactor in the CSI drives, the rate of rise of current under short circuit will be limited. So the drives can be easily protected under short circuit. On the other hand, the presence of DC link reactor will result in slow dynamic response of the drives, hence these drives are used where fast dynamic response is not needed. Due to all these features, the thyristor based current source inverters have been, so far, the favorable power converter topology in high-power applications, its swithing devices are high power ratings. However, the thyristor-based CSI has intrinsic drawbacks because the thyristors cannot be turned off by the gating signals. Therefore, external devices (IGBT) and circuit (VSI) are required to turn off the thyristors by connected the reverse-biased voltages, as well as reactive load energies of inductive loads after turning off the thyristors. Typical forced commutated thyristor-based CSIs are the autosequentially commutated inverters (ASCIs) based on commutation circuits with six ac capacitors and six high-power diodes. Notwithstanding its autocommutating ability, the ASCIs have shown disadvantages : 1) a number of bulky ac capacitors at high voltages; 2) high-voltage stresses across the thyristors and load terminals; 3) power losses incurred by the main diodes; 4) ac capacitance sensitive to load parameters; and 5) limited upper operating frequency due to long commutation delay associated with the ac capacitors.

Paper proposes a thyristor based current source inverter utilizing standalone voltage-source inverter (VSI) as an external circuit. The VSI performs three task: turn off the thyristors in the CSI, transferring the reactive load energy, and limiting load terminal voltage. VSI of the the proposed CSI can execute the required functions related with the commutation processes, The proposed CSI can reduce the overall system complexity. The energy transfer process and commutation are very simple and safe. The VSI operates only during the commutation periods of the load current and stop working in noncommutation periods a VSI with a small power rating can be employed in the proposed system. The proposed CSI system can utilize advantages of the two component inverters containing high-power handling capability of the thyristor-based CSI as well as safely control of the small VSI.

2. TOPOLOGY AND DESCRIPTION OF THYRISTOR BASED CURRENT SOURCE INVERTER (CSI):

The topology or structure of proposed CSI is illustrated in Figure 1.

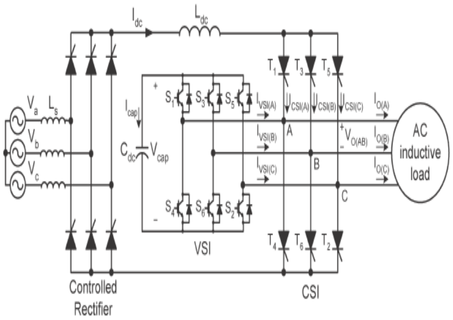


Fig. 1. Circuit diagram of proposed CSI system

Fig. 1: Diagram of using thyristor-based CSI

This proposed system is connected two different types of inverters configurations, a CSI and a VSI. The CSI has a dc-link inductor and a three phase controlled rectifier, While the VSI is fed through a dc capacitor as it energy storage element. The large thyristor based CSI is used as the main inverter to feed and control inductive loads such as induction motors. On the other hand, the small rating of VSI, connected in parallel with the CSI, is worked as an auxiliary inverter which is performed the commutation process of the CSI because of the no self commutation capability of the CSI. The VSI operate only during the commutation periods of the load currents in order to turn off the thyristers of the CSI as well as transfer the reactive load energy.

During the commutation process the VSI works the reverse-baised voltage on an out-going thyristor is turn it off. In addition the VSI absorbs the inductive energy of an outgoing load phase to the dc capacitor. The switching process of the VSI then recovers the reactive load energy in the dc capacitor to an incoming load phase. Consequently, the load currents in the outgoing and incoming phases gradually decrease and increase, respectively. Most of the load currents are supplied by the CSI and therefore the VSI currents show a very small fraction of the entire load currents because the VSI works only during the commutation periods. Thus, the VSI with much smaller power rating than the CSI can be applied in this scheme. The VSI performs three functions including:

A: Turning off Thyristors in CSI

At every commutation periods of the CSI, the VSI applies the reverse-baised dc voltage across an outgoing thyristor for the short time duration. Therefore successfully turn off the thyristor in CSI based on the voltage of the VSI dc capacitor.

B. Transfer of Reactive Load Energy

In this drive,the VSI flow the current paths gradually increase and decay the load currents during the load-current commutation. The dc capacitor absorbs the reactive energy from the outgoing load phase and recovers the energy to the incoming load phase. As a consequence, the load reactive energy is transferred from the outgoing phase to the incoming phase via the VSI. The dc voltage in the VSI is also maintained to the constant voltage level at steady state by dc capacitor .Energy transfer process is work into two parts called the "active energy-transfer stage" and "freewheeling energy transfer stage."

C. Clamping of Voltages Across Load Terminals and Thyristers

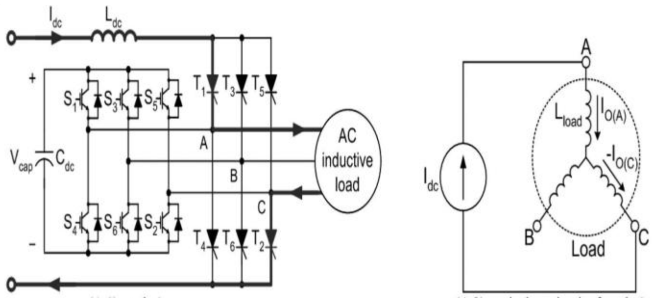
In the VSI (voltage source inverter) the dc capacitor is work as a voltage clamper. The peak line-to-line voltage across the loads and the peak voltage stresses of the thyristors are limited to the VSI dc voltage by dc capacitor. The dc capacitor can be controlled with the time duration of the active energy-transfer stage. Therefore, the peak load terminal voltage and the peak thyristor voltage stresses can also be adjusted through the VSI operation. Therefore, the excessive high-voltage stresses on the load terminals and the thyristers can be eliminated.

3. OPERATION PRINCIPLE-

In fig.2 the operation modes of the current source inverter with the current flow path. In fig.2, the proposed system executes current commutation from the load phase *A* to *B* by turning off the thyristor *T*1 and turning on *T*3, with *T*2 being on. Equivalent circuits of each modes are also shows.

A. Mode 1

In fig. 2(A.1) shows a steady-state condition with the load phases *A* and *C* being conducted. In the CSI thyristors *T*1 and *T*2 are on. During this noncommutating periods, in the VSI all switches are off. so that no current flows into the VSI. The equivalent circuit of mode 1 is show in Fig. 2(A.2). During this noncommutating periods the VSI does not work. All current flow through the CSI.

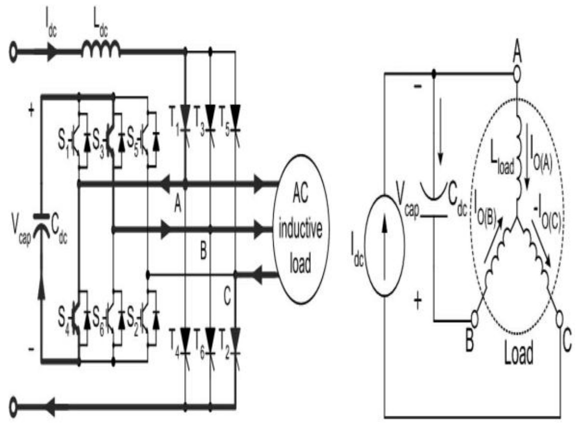


(A.1) mode 1 (A.2) equivalent circuit of mode 1

B. Mode 2: Active Energy-Transfer Stage

In mode 2 as shown in Fig. 2(B.1). In this mode is to decrease the current *IO*(*A*) and increase the current *IO*(*B*) using active VSI switching. In the VSI *S*3 and *S*4 switches are turn on. the negative and the positive dc voltage of the VSI are applied to the outgoing phase *A* and the incoming phase *B*, The dc-link current *I*dc through the thyristor *T*1 is split from load phase *A* to phase *B* through the voltage source inverter.

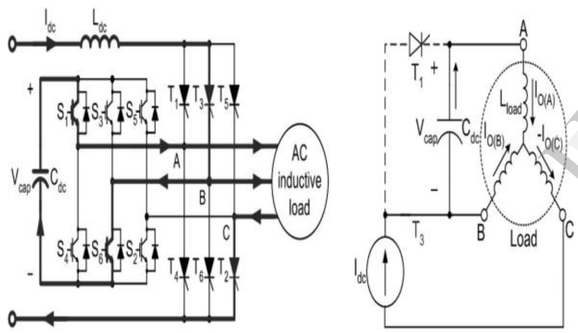
The dc capacitor *C*dc discharges, and the current *IO*(*B*) rises with the discharging energy of the capacitor. Fig. 2(B.2) shows the equivalent circuit of mode 2. Thus, the reactive energy in the dc capacitor transfers to the incoming load phase, increase of the current *IO*(*B*). Since the load current and energy are transferred through the active switching components, this mode is termed as "active energy-transfer stage."



(B.1) mode 2 (B.2) equivalent circuit of mode 2

C. Mode 3: Thyristor Turn-off Stage

After a few time period, in the CSI the incoming thyristor *T*3 is fired. In addition in the VSI *S*1 and *S*6 are turn on in mode 3. In this mode the outgoing thyristor *T*1 is turn off through reverse voltage across the dc capacitor. After T1 is turn off the entire dc-link current *I*dc switches to the incoming thyristor *T*3.



(C.1) mode 3 (C.2) equivalent circuit of mode 3

D. Mode 4: Freewheeling Energy-Transfer Stage

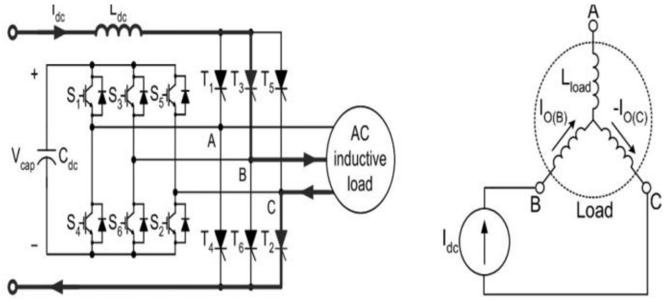
After a short time interval of mode 3. In mode 4 in the VSI all switches are turned off. In the load inductance forces the load current to flow through the freewheeling diodes of the switches *S*3 and *S*4,in active switches in mode 2. This mode is called “freewheeling energy-transfer stage. because the reactive energy and the load current are flow through the free-wheeling diodes of the VSI. In the VSI dc capacitor is charged.

5. SIMULATION RESULTS

The proposed CSI system was simulated using a 1-hp induction motor to investigate the feasibility of the proposed topology and control principle. The output frequency was set at 50 Hz.

E. Mode 5

When the mode 4 ends, the load current and corresponding in phase A the reactive energy diminish to zero. The current *IO*(*B*) is increases to the dc link current *I*dc. This leads to mode 5. Because all load energy has been transferred from the outgoing phase to the incoming phase, the VSI stops operating until the next commutation process. The CSI entirely deals with the load currents.



(E.1) mode 5 (E.2) equivalent circuit of mode 5

4. FEATURES AND DESIGN CONSIDERATIONS

It is desirable to employ a small VSI and a large CSI in the proposed CSI system. The thyristor based current source inverter operates to feed loads. A rating factor η is discuss with the ratio of two inverter ratings. Because both the VSI and CSI identically share the load phase voltage at the output terminals. the rating factor is directly proportional to the ratio of the rms values of their output currents.

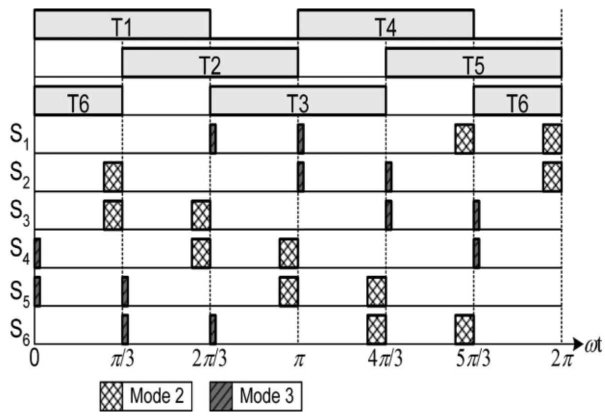


Fig. 2. Control signals of CSI and VSI.

5.1 OUTPUT LINE VOLTAGE AND CURRENT WAVEFORMS WITH VSI OPERATION

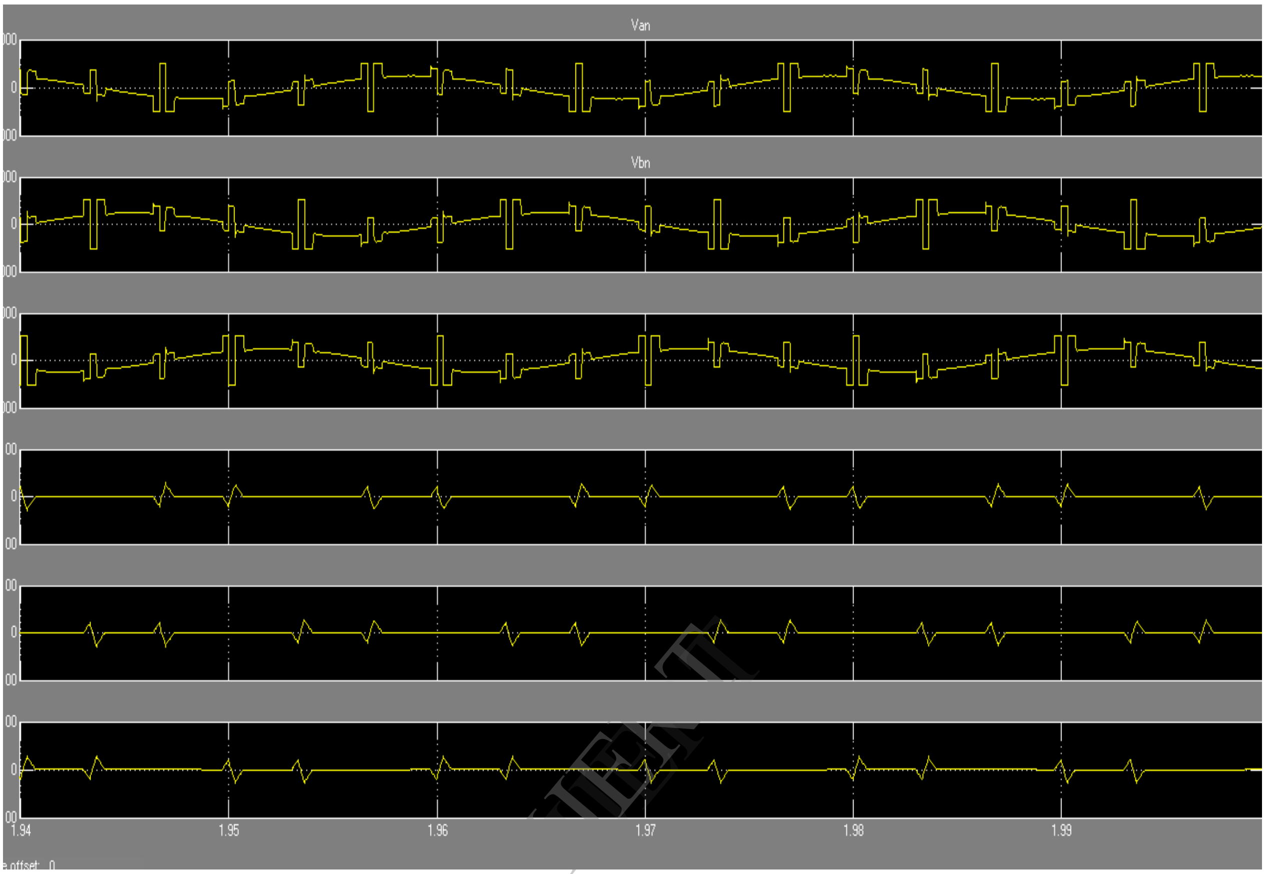


FIG. 3. Output line voltage and current waveforms with 300 τ = 300 μs.

The output line voltages during the commutations are obtained by the dc capacitor voltage. The line voltages fluctuate between positive and negative dc capacitor voltages, similarly to the bipolar pulse width modulation of the VSI. the output voltages produced by the VSI operation with time length τ *. It is seen that, with the* rises of the time duration τ *, the notch of the line-to-line* output voltages is reduced with the decreased dc voltage level. Note that the increased τ *results in more gradual energy transfer* from off-going to on-coming phases, yielding smoother load current waveforms. As a result, the increase of τ *can achieve* lower dc voltage level, reduced peak voltages across thrusters and load decreased notch in output voltages, and smoother load-current waveforms, at the cost of the increased VSI rating.

5.2 VOLTAGE AND CURRENT WAVEFORMS OF PROPOSED CSI

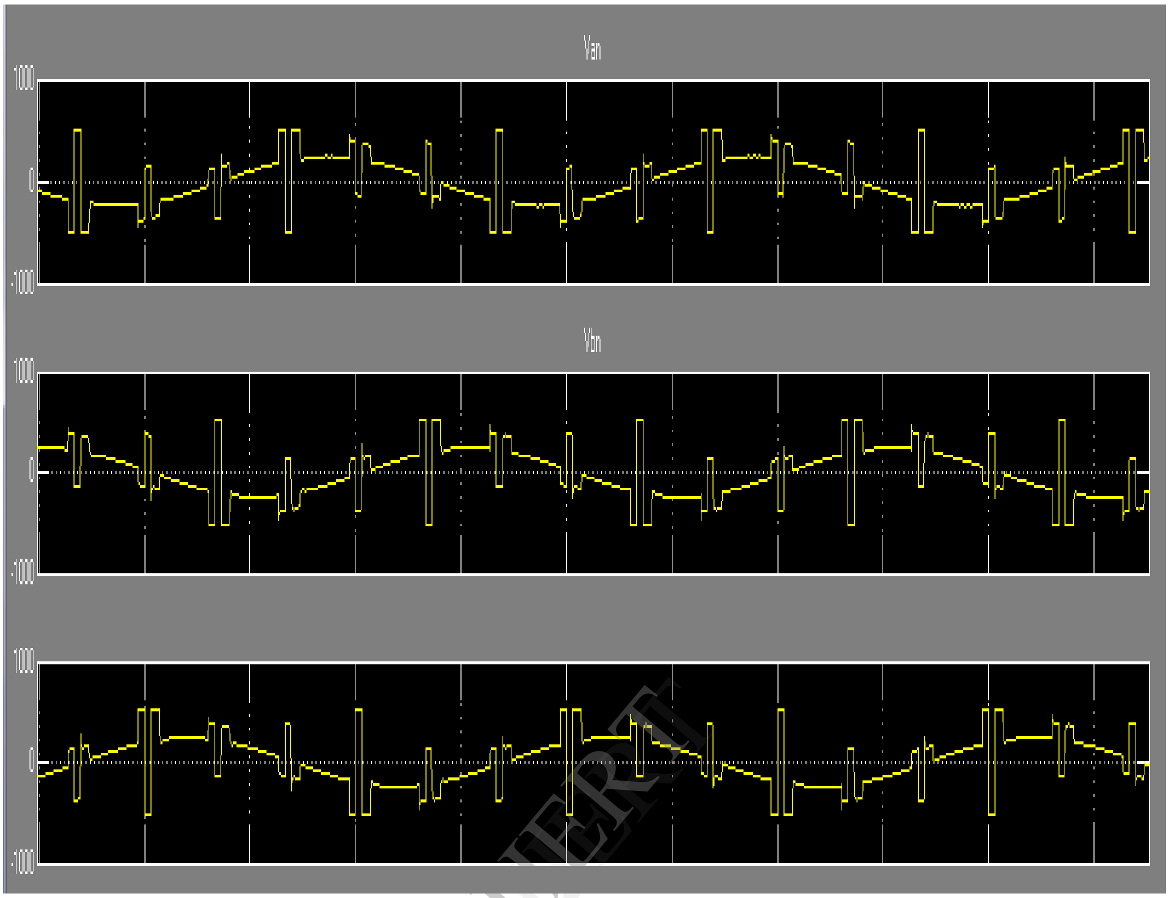


FIG.4 Voltage waveforms of CSI

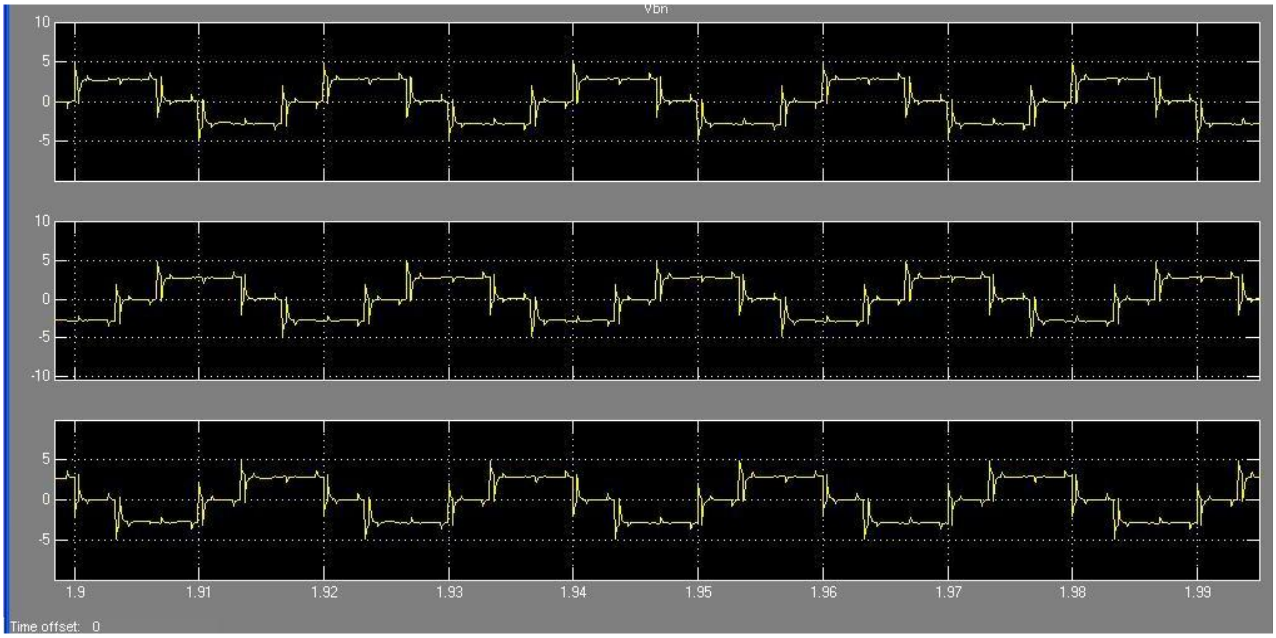


FIG. 5 Current waveforms of CSI

the current and voltage waveforms of the proposed CSI. It is seen that the commutations of turning off the thyristors and load current are obtained based on the VSI operation. The load current smoothly changes during commutation instants due to the energy transfer by the VSI. On the other hand, the CSI commutation is executed based on VSI switching operation, imposing the dc capacitor voltage in the reverse-biased direction for a very short interval. It is seen that mode 3, in turning off the thyristors, is very short compared with mode 2 and 4.

5.3 DC CAPACITOR VOLTAGE

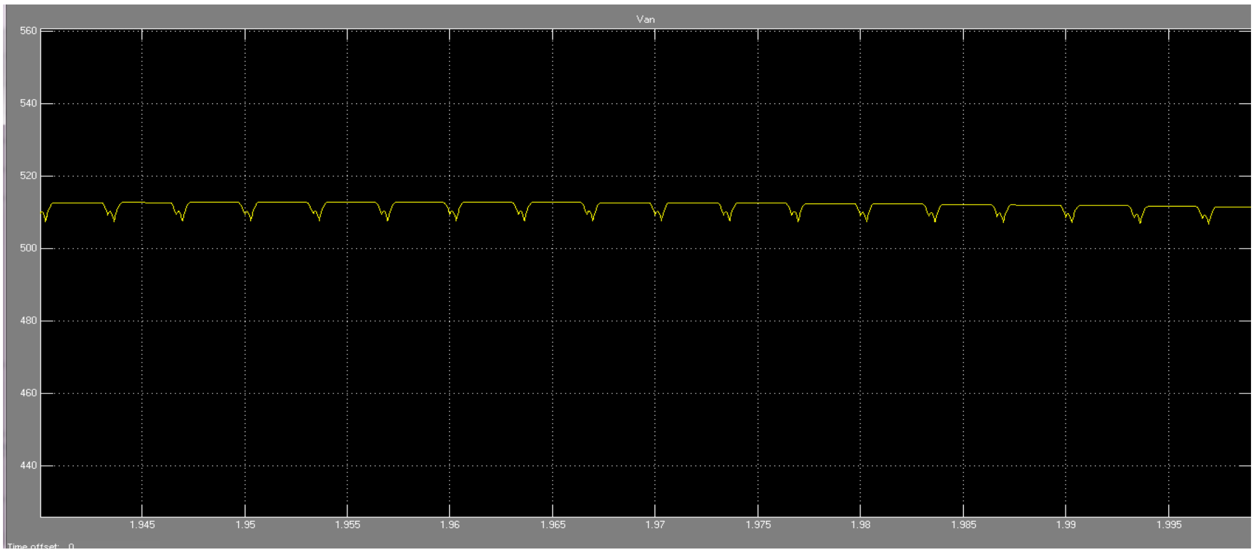
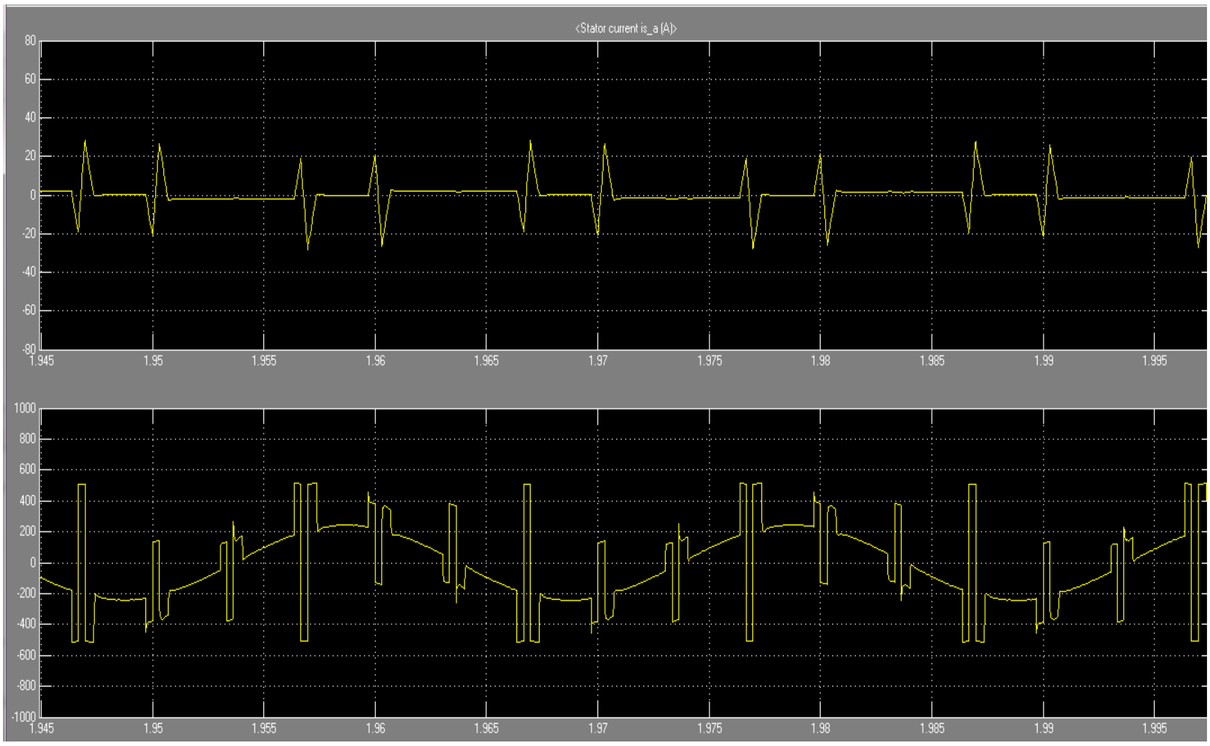


Fig 6 DC CAPACITOR VOLTAGE

The CSI commutation is executed based on VSI switching operation, imposing the dc capacitor voltage in the reverse-biased direction for a very short interval ε. The VSI dc capacitor voltage discharges and charges to transfer the reactive load energy from the outgoing phase to the incoming phase during the commutation instants. A 10-μF *dc capacitor was used for* this simulation. With a larger dc capacitor, the variation of the capacitor voltage for the commutation periods is reduced.

This voltage level can be controlled by adjusting the time duration of mode 2 τ *, which can be controlled by the VSI.*

load line current and voltage



6 CONCLUSION

Paper has presented a thyristor based current source inverter forced commutated employing a small VSI as an external circuit. The VSI works only during the commutation periods and stop working in non commutation periods. Owing to its discontinuous operation, the power rating of the VSI is greatly reduced.

During the commutation periods of the load current, in the CSI turning off the thyristor by the VSI. And transfer the reactive load energy from outgoing phase to the incoming phase. The VSI dc capacitor voltage imposed in the reverse biased direction is turn off the outgoing thyristors. the reactive energy of the outgoing phase is temporarily stored in the dc capacitor of the VSI and then transferred to the incoming phase during the load current commutation. The energy transfer processes and turning off the thyristor are simple and easy due to the VSI operation using the self-controlled devices. The peak voltages across the thyristors and load are limited to the dc capacitor voltage level of the VSI, By the VSI operation which can adjusted.

7. REFERENCES

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