ABSTRACT

The main objective of this paper is to replace autotransformers and transformers in industrial applications by switched capacitor three phase AC-AC converters. The control system is not required in case of open loop operation of AC-AC converters. In this paper, by employing closed loop system, the advantages such as accuracy, reduced error, reliability, fast response and less noise can be ensured. In switched capacitor principle, three different modes of operation are employed. These modes are complete charge, partial charge and no charge. In order to step up or step down the output voltage, partial charge mode is described in this paper. The closed loop control always implies the use of a feedback control. In such a way the accuracy of the output thus depends on the feedback path which in general can be made accurate within the electronic control systems and circuits. Thus the closed loop control is achieved by a PI Controller.

Key Words: AC-AC Converter, PI Controller, Switched Capacitor, Three Phase.

1. INTRODUCTION

The ac-ac converter operates in a switched capacitor(SC) principle. This converters can carry a bidirectional operation[1]. This three phase ac-ac converters having only capacitors and switches in it’s power circuit. Because of this reasons it having low weight, small size and power density is high. The main purposes in power electronics is the development of switching mode converters with the absence of inductors and transformers[2]. The converter does not contains any magnetic elements. In this paper the converter operates in two modes and there are step up converter and step down converter. By using the SC principle, in order to step up or step down the output voltage partial charging mode is employed. The principle of switched capacitor is when the switches are open and close, it can charge and discharge.

The structure of this converter is same that of a multilevel inverter with series parallel SC connections. So it does not need any inductors. The changes of the converter output voltage (step down or step up) is determined by switching the capacitors in series and in parallel connection[3]. A solid state direct AC-AC converter is an another solution to replace conventional autotransformers and transformers[4].

Less number of switching devices used in the SC converter than the conventional multilevel inverter. By using this series parallel conversion the capacitors voltage ripple is reduced and that will improve the power conversion efficiency[5]. A switched capacitor circuit is a promising one compare with the various active cell balancing circuits, because it’s advantages and that are less cost and small size[6].

The converter approach a sinusoidal input and output and having the most important merits of less manufacturing cost[7]. Due to the step up and step down configurations, the capacitor appears as a main energy storage element. The main focal point of this paper is the bidirectional operation[8]. This converter configured as ac-ac(three phase) are reliable. By changing the control scheme the switches are turned on at zero voltage and have a soft turn off[9]. Another studies in switched capacitor(SC) field is coupled inductors with SC[10].

2. SYSTEM CONFIGURATION

The system presents a closed loop control system. The PI controller is used for a closed loop control. The controller compares the reference voltage and the output voltage and detect the error of the system and eliminate. Then the output of
the controllers is given to the driver circuit. The driver circuit gives the gate signal to the converter and that will increase the ON time of the converter so that the output will increase. Then the output of the converter is given to load without any deviation from the reference value.

The closed loop system always requires a feedback control. The system accuracy will depend on the feedback path, which can be made accurate within the circuits, feedback control is mostly used than open-loop or feed forward control.

![Block Diagram](image)

The block diagram shows that the three phase ac supply is given to the converter. If the ac-ac converter is a step up configuration means, the particular two capacitors are connected in parallel and multiplies the input voltage by two and then given to the load. Normally, the converter results are not accurate due to some disturbances in the circuit. So that converter output is given to the load means, the load voltage or output voltage will get inaccurate result. This problem is normally occurring in an open loop system. But in closed loop system, it compares the actual output with the desired output and reduce the error, then bring the output of the system back to the original or desired response.

3. OPERATION

The direct ac-ac converters are separated into three modules like a diode clamped multilevel inverter that are made employing terminals 1-3, 4-6 and 7-9. Each module having 4 bidirectional switches and 3 capacitors. Here the MOSFET(CoolMOS IXKH70N60C5 and the resistance $R_{DS(on)}$ value of 45mΩ) switch are used for the bidirectional operation. In this the input voltage are connected at the points 1,4,7 and output voltage are connected at the points of 2,5,8. The three modules are connected as delta connection in input side which means the output of first module is connected as the input of the next module. In this system the representation of a switched capacitor is c1, c4 and c7 and other than this switched capacitor, there are 2 capacitors for each module for charging and discharging when the switches are opened and closed. The switches are represented between s1 to s12 and capacitors are represented between c1 to c9. The duty cycle is fixed as 0.5.

![Operation Diagram](image)
The operation of this converter is that the gate drive signal is first given to all the odd switches (consider a first module). At that time the switch s1 and s3 are conducting and the capacitors c1 and c2 are connected in parallel in a step down configuration and divides the input voltage by two then it giving that voltage to the load. If the converter is operating in step up configuration means, the capacitors c1 and c2 are connected in series and then multiplies the voltage by two, then giving that voltage to the load. The difference between the step down and a step up configuration is that, in step up configuration the points of source and load are changed their position.

After its complementary signal is applied in all the even switches. At that time the switch s2 and s4 are in conduction and the capacitors c1 and c3 are gets charging and the capacitor c2 is discharging.

The system operates in a closed loop control. Closed-loop systems are used to maintain the desired output by comparing it with the actual condition, so as to reduce the system error and bring the output of the system back to a desired value. Mainly the PI controller is used in this system for a fast response and no offset.

3.1 Modes Of Switched Capacitor

The switched capacitor converters are operating in three different modes and there are complete charge, partial charge and no charge. The operation of a partial charge and a no charge modes are having higher efficiency and the lower current peaks and the high operation frequency and large capacitances are required by a no charge mode. So the system consists of partial charge mode for the operation.

3.2 Capacitance Calculation

The capacitors C1 to C9 are calculated to attend the specification of the power factor. The maximum capacitance Cp is defined as,

\[ c = \frac{1}{6V_i^2 \pi f} \sqrt{\frac{P_i^2}{F_p}} \leq 31.7 \mu F \]  

(2)

Using equation 3, the maximum capacitance value for c1 to c9 is,

\[ c = \frac{1}{27V_i^2 \pi f} \sqrt{\frac{P_i^2}{F_p}} \leq 10.6 \mu F \]  

(3)

4. SIMULATION RESULTS

4.1 Step Down Configuration

(i) Input Voltage

(ii) Output Voltage

\[ c_{eq} = 3c \]  

(3)

\[ c = \frac{1}{27V_i^2 \pi f} \sqrt{\frac{P_i^2}{F_p}} \leq 10.6 \mu F \]  

(4)
(iii) Input Line to Line and Output Line to Neutral Voltage
Fig 3: Output Waveform For Step Down Configuration

4.2 Step Up Configuration

(i) Input Line to Line Voltage

(ii) Input Line to Neutral Voltage

(iii) Output Voltage
Fig 4: Output Waveform For Step Up Configuration

5. CONTROL CIRCUIT

The control circuit mainly represents the pi controller, pwm generator and the sawtooth generator. By using this control circuit the time period of the system is reduced compared with open loop system.

6. HARMONIC ANALYSER

Fig 6: Harmonic analyser for step up configuration

7. CONCLUSION

In the Proposed System by using PI controller based closed loop system, two modes of configuration is achieved. As interpreted from the diagram 4.8, the input line voltage which is around 550V is stepped down to around 270V(line to line). In step up configuration mode the line to line input voltage is stepped up as depicted in the figure 4(iii). Thus the step up and step down configurations are realized. Further, by employing closed loop system, the advantages such as
accuracy, reduced error, reliability and fast response have been ensured.

REFERENCES


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