2.AC-AC converters have the capability to control the load voltage amplitude, the load displacement angle relative to source voltage, the displacement angle between source currents and voltages (input power factor) and the capability to control bi-directional (or only unidirectional) power flow through the converter sinusoidal AC sources,

3.with constant amplitude *US* and constant frequency *fS*. These applied voltages are converted into output voltage waves with set amplitude*UL* , frequency *fL* and displacement angle of the load voltages relative to source voltages *LS*. These output voltages are applied to the load. The load current amplitudes *IL* and phase angles *ϕL* are determined by the impedance characteristic of the loads.

4.The latter classified as indirect structures with main DC energy storage elements, direct structures without DC energy storage element and hybrid structures with small local DC energy storage elements. The first group includes the most popular and widely used in industry and households, i.e. direct frequency converters with voltage source inverters (VSI) or current source inverters (CSI). The second group consists of alternative topologies of direct frequency converters. These topologies have no DC energy storage elements and basically consist of an array of static power switches connected between the source and load terminals. For good performance direct frequency converters have small capacitors and inductors, such as high frequency component filters or small regenerative AC energy storage. The last group is a combination of direct frequency converters with small-sized local DC energy storage elements or an additional module with a DC–DC boost converter.

6.As mentioned above, the groups of direct frequency converters include matrix converter (MC) structures. The MC, depending on the kind of power supply (voltage or current character), can work as a voltage source matrix converter (VSMC) or a current source matrix converter (CSMC), respectively. The main technical papers presented at conferences and in journals concern the matrix converter in VSMC mode, and commonly this structure is referred to as a matrix converter.

The development of MCs started when Venturini and Alesina proposed the basic principles of operation in the early 1980s [135]. The authors proposed in [135] a high switching frequency control algorithm and the development of a rigorous mathematical analysis to describe the low-frequency behaviour of the converter.

7.Generally, the matrix converter is a single-stage converter which has an array of m ×n bi-directional power switches to connect, directly, an m-phase voltage source to an n-phase load.

8.In three-phase systems, an MC is an array of nine bi-directional switches that allow any load phase to be connected to any source phase.

9.For good performance, the VSMC should have a source filter. The source filter is generally needed to minimise the high frequency components in the input currents and reduce the impact of the perturbations from the input grid. Their size is inversely proportional to the matrix converter switching frequency.

The major advantage of matrix converters is the absence of the DC link capacitor, which may increase the efficiency and the lifetime of the converter.

11.The most simple switch cell is a single-phase diode bridge with an IGBT connected at the centre. The main advantage of this switch is that only one active device is needed. This approach reduces the cost of the power circuit and the complexity of the control. Only one transistor gate drive circuit is needed for each switch cell. The disadvantage is that the conduction losses are relatively high. During the conduction stage, the three devices are conducted (two diodes and IGBT transistor). Moreover, the direction of current through the switch cell cannot be controlled.

The two most commonly used configurations of switch cell are named the common emitter antiparalleled IGBT configuration (Fig. 2.10b) and the common collector anti-paralleled IGBT configuration (Fig. 2.10c). Each of these switch cells consist of two diodes and two IGBT switches that are connected in an anti-parallel arrangement. The diodes are included to provide reverse blocking capability, whereas, the IGBTs enable the independent control of the current direction. Compared to the diode bridge switch cell (Fig. 2.10a), here conduction losses are reduced, because only two devices are conducted in each conduction path. Its disadvantage is the requirement of two gate drive circuits for each IGBTs.

The main feature of the RB-IGBT is its reverse voltage blocking capability, which eliminates the use of diodes. For this reason there is a reduction in the number of discrete devices and conduction losses. At any instant, there is only one device conducting current in any direction. In this configuration, 18 gate drive circuits and six isolated power supplies is required. Therefore, an anti-paralleled RB-IGBT configuration is generally preferred for creating matrix converter bi-directional switch cells.

13-14.One of the main issues in control of the MC is the current commutation. The switches have to be capable of being turned on and turned off in such a way as to avoid short circuits and sudden current interruptions. An open circuit results in large voltage spikes across the switches when the output phase is connected to an input phase, both the IGBTs of the bi-directional switch *S*1 have to be turned on simultaneously.

15. In this method the direction of current flow through the commutation cells can be controlled. In order to explain the strategy it is helpful to refer to the simplified commutation circuit shown in the figure. The strategy assumes that when the output

phase is connected to an input phase, both the IGBTs of the bi-directional switch *S*1 have to be turned on simultaneously.

16.Indirect converters are divided into two parts with fictitious DC link. There is a fictitious voltage-fed rectifier on the input side and a fictitious voltage source inverter on the output side. The input rectifier and output inverter are directly connected on theDC side.

17.MCs are inherently bi-directional and therefore can regenerate energy back into

the mains from the load side. However, the DC voltage in an IMC has only positive

polarity. In order to allow bi-directional current flow (four-quadrant operation), in

the input bridge of the IMC bi-directional active switches are needed.