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REVIEW OF MATRIX CONVERTER FOR FREQUENCY CHANGING APPLICATIONS

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Abstract
It is possible to achieve bi-directional power flow with a Matrix Converter and by controlling the switching devices appropriately; both output voltage and input current can be sinusoidal. This is only true if there are no power fluctuations in the load which would be fed to the input supply with a consequent distortion of the line currents. Switches with the capability of current flow both directions (to and from the load) must be used in order to permit the bi-directional power flow. This is an important issue which has been taken into consideration when looking at the characteristics of any application. In order to optimize the design of the Matrix Converter system, which is going to operate as a power supply for aircraft applications, a detailed analysis using both Saber and Matlab/Simulink software packages were used to select the best topology of Matrix Converter system that could satisfy the specifications. When Saber was used, the Matrix Converter modulation and control were implemented by using the MAST language, which discretised the modulation strategies applied.

Introduction
This work is concerned with the design and implementation of a Matrix Converter for Frequency Changing Power Supply Applications. Typically such units are used to convert between 50/60Hz supplies available in airports to a 400Hz one for aircraft supply when they are parked in their bays. This work will consider the simulation of various matrix converter topologies, A Matrix Converter is a device used for converting directly AC energy into AC energy; the main feature of this device is to convert the magnitude as well as the frequency of the input into a desired magnitude and frequency of the output with an "all-silicon" solution. Mainly, a Matrix Converter consists of nine bi-directional switches, which are required to be commutated in the right way and sequence in order to minimize losses and produce the desired output with a high quality input and output waveforms. After the controlled rectifiers were developed in the early 1930's, it was realized that this provided the possibility of generating alternating currents of variable frequency directly from a fixed frequency AC supply, the positive rectifier supplying the positive half cycles of current and the negative rectifier the negative half cycles. This system was called cycloconverter at its early stage and this proved to be so appropriate that nowadays it is still used in some high power applications because of high power requirements and the Matrix Converter technology is still not available widely

Topologies Of Bidirectional Switches
Bi-directional switches capable of blocking voltage and conducting current in both directions are required by the Matrix Converter. Unfortunately these devices are not widely available. Hence, discrete devices are used to construct suitable bi-directional switch cells and fulfill those requirements. The choice of bi-directional switches also dictates which current commutation methods can be used. This section describe some possible bi-directional switch configurations and the advantages and disadvantages of each arrangement. In the discussion below it has been assumed that the switching device would be an IGBT, but other devices such as MOSFETs, MCTs and IGCTs can be used in the same way.

Diode Bridge Topology
The diode bridge arrangement is the most simple bi-directional switch structure. This arrangement consists of an IGBT at the center of a single phase diode bridge arrangement, as illustrated in Figure 1 The main advantage of this arrangement is that only one active device is need, reducing the cost of the power circuit and the complexity of the control/gate drive circuits. Conduction losses are relatively high since there are three devices in each conduction path. The main disadvantage is that the direction of the current through the switch cannot be controlled. Many of the advanced commutation techniques described later rely on independent control of the current in each direction.

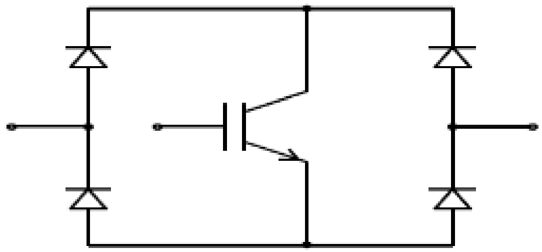

Figure 1: Diode Bridge Bi-directional Switch

Common Emitter Bi-directional Switch.

This switch arrangement consists of two diodes and two IGBTs connected in anti-parallel as shown in Figure 2. The diodes are included to provide the reverse blocking capability. The reverse blocking capability is a weak of the early IGBT technology. There are several advantages in using this arrangement when compared to the diode bridge switch. The first advantage is that it is possible to independency control the direction of the current. Conduction losses are also reduced as only two devices carry the current at any one time. As with the diode bridge switch each bi-directional switch cell requires an isolated power supply.

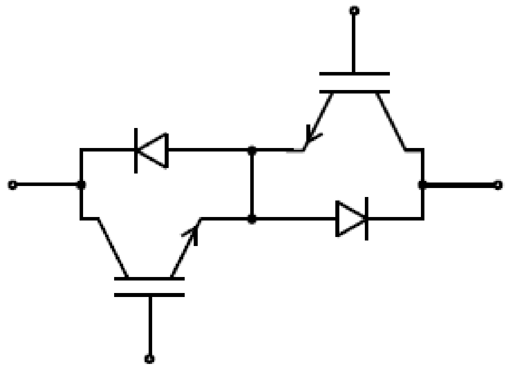

Figure 2: Common Emitter Bi-directional Switch

Common Collector Bi-directional Switch.

This arrangement is similar to the arrangement presented in the previous configuration. The difference is that the IGBTs are arranged in a common collector configuration as shown in Figure 3. The conduction losses are the same as the common emitter configuration. One possible advantage of the common collector configuration is that only six isolated power supplies are required to supply the gate drive signals.

This is possible if the inductances between the devices sharing the same isolated power supply is low. This is the case for Matrix Converter modules where all bi- directional switches are integrated in one package. However, as the power levels increase, the stray inductance of the individual bi-directional switches becomes more important. Therefore at higher power converters it is desirable to package the IGBTs into individual bi-directional switches or complete output legs. Hence the common emitter configuration is usually preferred for higher power levels

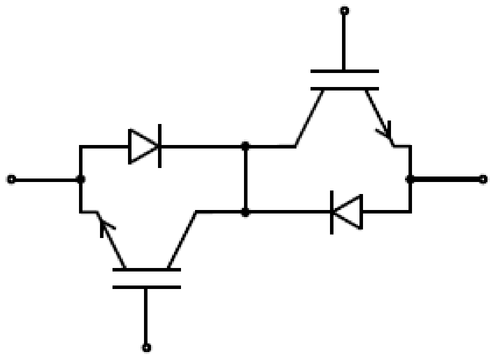

Figure 3: Common Collector Bidirectional Switch

Topologies Of Matrix Converter

Based on the number of input and output phases, a Matrix Converter can fall under the following topologies

1) Single Phase Matrix Converter
2) Two phase to single phase
3) Three Phase to Single Phase Matrix Converter
4) Three phase to Three Phase Matrix Converter

Single Phase Matrix Converter

The Single-Phase Matrix Converter consists of a matrix of input and output lines with four bidirectional switches connecting the single-phase input to the single-phase output at the intersections. It comprises of four ideal switches S_l, S_2, S_3 and S_4 capable of conducting current in both directions, blocking forward and reverse voltages(symmetrical devices) and switching between states without any delays.

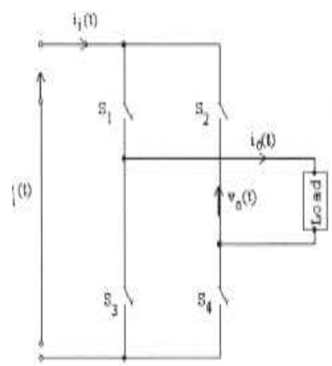

Figure 4:Representation of single phase matrix

Two Phase To Single Phase Matrix Converter

The Fig.5 shows a schematic of a Two Phase to Single Phase Matrix Converter. The converter is composed of two bidirectional switches S_l and S_2.

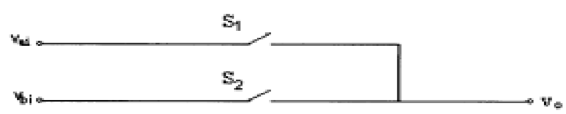

Figure 5: Representation of two phase to single phase

Each switch connects the output line to an input phase. To avoid short-circuit in the source-side and current interruption in the load side (single-phase side), only one switch can and must be on at any time.

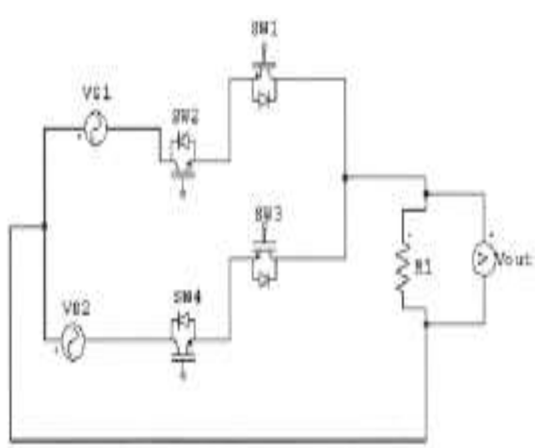

Figure 6: Simulation Circuit of a Two Phase to Single Phase Matrix Converter

The Fig.6 shows the simulation circuit of a Two Phase to Single Phase Matrix Converter. In steady state, both of the devices in the active bidirectional switch cell are gated to allow both directions of current flow. The upper bidirectional switch is closed when a commutation to lower bidirectional switch is required.

Three Phase To Single Phase Matrix Converter

A Three Phase to Single- Phase Matrix Converter is shown in Fig.7. The converter is composed of three bidirectional switches S_1, S_2 and S_3. Each switch connects the output line to an input phase. To avoid short-circuit in the source-side (three-phase side) and current interruption in the load side (single-phase side), only one switch can and must be on at any time. The switches are turned on the off in a sequential. and cyclical pattern. For the jth switching period, if t^j_b t^j_2 and t^j_3 are the on-time intervals of S_1, S_2 and S_3, respectively, we have,

Figure 7: Representation of a Three Phase to Single Phase Matrix Converter

$$t^j_1 + t^j_2 + t^j_3 = T_m = 1 / f_m \quad \text{------------------------} \textbf{(1)}$$

where T_m is the switching period. The output line is connected to an input voltage for a specific period of time. Thus, the output voltage is a concatenation of segments of the three input voltages. Therefore, the output voltage waveform $v_o(t)$ is a function of the three input voltages $V_{ai}(t)$, $V_{bi}(t)$ and $V_{ei}(t)$. In general, the output voltage harmonic components depend also on the input frequency and the switching strategy.

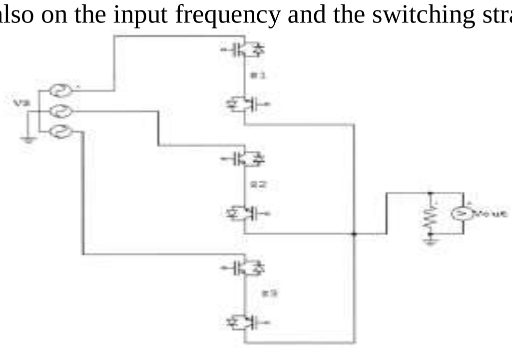

Figure 8:Simulation Circuit of a Three Phase to Single Phase Matrix Converter

The simulation circuit of a Three Phase is Single Phase Matrix Converter is shown in Fig. 8 The analysis is started assuming that S_1 is initially on when S_2 and S_3 have been off. The Circuit operation is analyzed for a complete switching sequence assuming that S_1 is on followed by commutation to S_2, then to S_3 and finally back to S_1.

Three Phase To Three Phase Matrix Converter

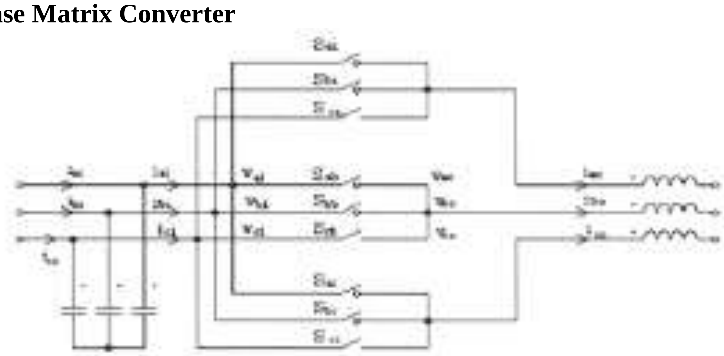

Figure 9: Representation of a Three Phase to Three Phase Matrix Converter

A Three-Phase to Three-Phase Matrix Converter is structured based on the Three-Phase to Single-Phase Matrix Converter. If three sets of the single-output Matrix Converters are connected to the same input voltages, a three-output Matrix Converter is constructed. The structure of a three-phase to three-phase Matrix Converter is shown in Fig. 5.12 The converter consists of nine bidirectional switches (S_{aa}, S_{ba}, and S_{ee}) whose operations are coordinated by a number of switching functions.

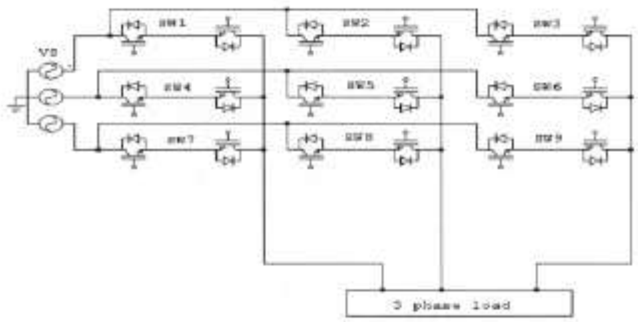

Figure :10Simulation Circuit of a Three Phase to Three Phase Matrix Converter

The Matrix Converter can represent a symmetric electrical system, if a proper switching strategy is used. The simulation circuit of a Three Phase to Three Phase Matrix Converter is shown in Fig. 5.13 S_{aa}, S_{ba}, and S_{ee} must be switched with a phase delay of 120' with respect to S_{aa}, S_{ba}, and S_{ee}.. Also, a 240" phase delay must be considered for the switches S_{aa}, S_{ba} to get a three phase output.

Conclusion

The work presented in this paper has made an exciting contribution to the research applications of Matrix Converters. One interesting aspect of the development of Matrix Converter driven power supplies is the power electronics employed to drive loads which operate under different conditions. The novelty introduced by the work is to offer an alternative topology of power converter, the Matrix Converter, to drive loads in different condition of operation, instead of the conventional Voltage Source Inverter (VSI) currently used in most power supply systems. In the conventional VSI, the multi-pulse (12 or 18) rectification stage, the DC link and associated input filters add volume and complexity, for example, electrolytic capacitors are temperature sensitive and therefore unreliable in the target application where the typical ambient temperature range varies between -55±C to +70±C. To create the equivalent capacitance sized for the DC link using ¯lm capacitors would require a considerable amount of space compared to electrolytic capacitors. This space is usually around 30% more of that used for the electrolytic capacitors. As it has been shown that Matrix Converters are able to offer direct conversion, thus avoiding DC conversion stage. The absence of a DC link in a Matrix Converter allows for an increase in the power density of the converter.

It is possible to achieve bi-directional power flow with a Matrix Converter and by controlling the switching devices appropriately, both output voltage and input current can be sinusoidal. This is only true if there are no power fluctuations in the load which would be fed to the input supply with a consequent distortion of the line currents. Switches with the capability of current flow both directions (to and from the load) must be used in order to permit the bi-directional power flow. This is an important issue which has been taken into consideration when looking at the characteristics of any application.

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