A Detailed Performance Analysis of Matrix Converters

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ABSTRACT

As a generator grid interface for wind power systems, switching and quasi-Z-source indirect matrix converters are suggested. Typically for such systems, the voltage of gearless ac generators is low. The electronic power interfaces between the generator and the grid must provide a substantial voltage increase. The Z-Source Switching Inductor Network uses a fast shooting to increase the inverter voltage. The almost Z-source network provides other benefits, such as lower rates of components, less friction from the source and more fast counts of switches and simpler control strategies. In this paper, the interfaces between generators and grids are based on the topology of ultra-solar matrix with a minimum number of semi - circular switches. The boosting networks are between the interfaces, the corrective system and the reverse inverter.

I. INTRODUCTION

Wind energy systems with massive horizontal turbines with a 3-blade axis are a traditional solution to humanity's energy and environmental challenges. The turbines are organized into power plants forming self-sufficient power stations. In accepting such systems, the relation between a wind energy system and the grid is an important public issue. A lightweight, efficient, maintenance-free, secure, and inexpensive grid interface must be provided. Also, a generator, typically a permanent magnet synchro unit, should be operated directly by the wind turbine to prevent a costly and unsafe transmission box. In essence, this means that the generator's low rate and voltage and the voltage of this transformer need to be improved. The review paper [1] The traditional Direct Matrix converter describes many attractive features which do not use a very capable DC link commonly used to convert back-to-back. These matrix converters have an input power unit and a sinusoidal current, but are effectively limited to 0. 866. In nine bidirectional switches, the classical 3-phase matrix converter is integrated. Two unidirectional switches and two dioceses or single switches are given on each switch and on four diodes. In order to reduce switch numbers [2], spare-driven, highly sparse indirect optimization techniques have recently been proposed for converter tops. Direct matrix converters' low benefit disadvantage has been solved by indirect matrix converters. A voltage increase between the input corrections and the output phases of the converter is added in these environments. This role is carried out quite well by the popular Z-source network proposed in [3]. Ge et al. [4] describes a group of three-phase direct Z source converters with various control systems. The indirect sparse matrix converters are given in [5,8] with a similar classic Z-source. Present modulative techniques are being investigated in [9] for indirect Z-source converters. Optimal modulation offers versatility in buck enhancing, minimal switching and fast implementation. This loss of harmonics decreases efficacy and increases thermal load. The higher the material, the more performance is reduced, and therefore the thermal load is increased even at low loads. The mmf and air gaps are not stationary in relation to each other, generated by various harmonics, including fundamental. As a result, pulsating harmonics with a zero average value are produced.

A rotor mmf Wave is produced by the fifth harmonic flux wave series, which reverse five times its synchronous base speed. At the relative speed six times the base of the harmonic fifth rotor mmf and its fundamental air gap, its contact leads 6 times the basic frequency to a pulsating acceleration.

The positive 7th harmonic wave series produces a mmf rotor wave that rotates seven times its key synchronous speed. Since the relative speed of the base air gap wave is six times that of the basic, synchronous speed of the seventh harmonic mmf rotor wave, the pulsating torque is also 6 times higher. The 11th and 13th harmonics both emit nearly twice the torque of the fundamental frequency, however small amplitudes.

Pulses respond to generator rpm variations. The speed changes are small enough due to inertia, if it is sufficiently high at the base frequency. If the generator's base frequency and speed is minimal, major changes in the generator speed leds to a retrenchment of motion. The pulse amplitude depends on the harmonic tension and the response from the generator.

To overcome the limitations, a matrix converter is used to power the induction generator. This is an AC-AC converter in one stage which supplies the induction generator with pure sinusoidal input. The power electronics trend is to boost contact with the electricity grid, provide two-directional power flow, increase the efficiency and size of a drive wiring that operates in the matrix converter profile at

II. MATRIX CONVERTER:

In this paper, the reader does not need to have any special knowledge of matrix converters. Please note that the tri-phase configuration is one of the possible AC-AC topologies not mentioned in this article.

In comparison to traditional power frequency converter style, the matrix converter has several advantages. The waveforms are sinusoidal with minimally higher orders harmonics and no subharmonics; The two-way flow capacity of energy is inherent, the input power factor can be controlled totally. Finally, but not least, it has minimal requirements for energy storage which enables large and life-long energy storage capacitors to be removed. But there are also some drawbacks of the matrix converter. First, for sinuous waveforms and inputs, it has an average voltage transfer ratio of 87%. More semiconductor devices are required than traditional indirect control AC-AC conversion systems since no monolithic two-way devices are available and need to be used for any bidirectional switch.

THE TOPOLOGY

The matrix converter has 9 bidirectional switches which allow connection to all exit phases in each input step. The method is shown in Fig. 1. The converter terminals are connected to the grid, a 3-phase power supply system, while the power output terminal is like an induction generator, to a power supply system. It is necessary to be able to supply the voltage filter side by side and that the inductive filter is supplied on the current side under figure 1. Its measures are inverse proportional to the switching frequency of the matrix converter.

Notice that the bi-directional and symmetry of the input and the output power supply can also be used to create a dual relation with the matrix converter.

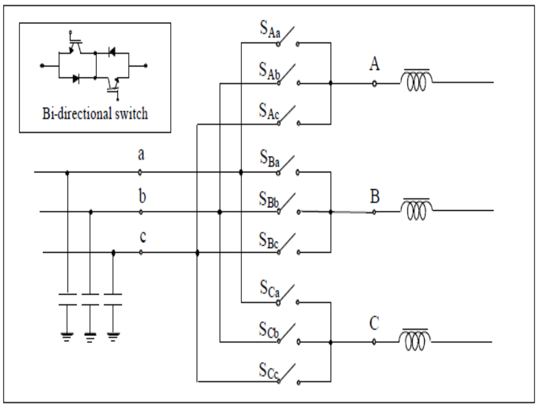


Figure 1: Circuit scheme of a three phase to three phase matrix converter

Technically, the matrix converter accepts 512 separate switching states with nine bi-directional switches. They are, however, not always useful. Regardless of the control method used, the matrix converter switching state combinations have to be selected using two basic principles (from now on matrix-converter configuration). Given the voltage source provided by the transformer and the load is inductive, the input step is either shortened or the output current is disrupted. These rules mean in practice that only a bi-directional switch is always activated per output point. This restriction permits swapping combinations in a 3-phase conversion matrix 27.

THE PERFORMANCE

A brief overview of the output of a matrix converter is available in this section. Any efficiency parameters have to be qualitatively analyzed. There are also numerical findings focused on a simplified matrix converter model.

THE OUTPUT VOLTAGE

As the matrix converter input and output are not power storage elements, the output voltages should be derived directly from the input voltages.

Each waveform voltage will be synthesized with the waveforms for the input voltage sequentially sampled.

The specimen rate needs to be set significantly higher than the input and output frequency, and the time of each sample monitored to monitor the desired waveform of each sample. The output voltages are often placed on the Input Voltage Device envelope because of a direct relationship between input and output. The maximum output voltage is restricted The v3/2 maximum input voltage is generated without entering the over-modulation range: this is an intrinsic matrix converter limit covering any control law.

If a certain distortion of output voltages and input currents is acknowledged, the overmodulation range will achieve a higher voltage transmission. A standard voltage converter wavelength is indicated in Fig. 2 (VSI). Only the positive and the negative DC-bus will take on the output voltage of a VSI, two distinct fixed potentials. The matrix converter anticipates either the voltages of the output a, b or c and its value is non-stop, which results in the harmonics of the switching being decreased.

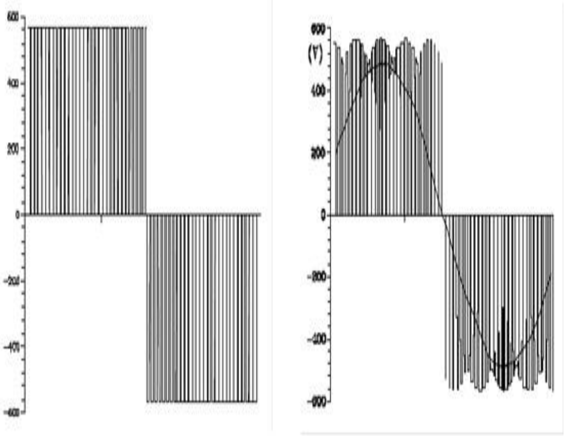


Figure 2: Output voltage waveforms generated by a VSI and a matrix converter

THE INPUT CURRENT

The input currents are also generated directly by output currents with the output voltages and sequentially synthesized by output current shapes. The input current drawn from a converter is sinusoidal when the switching array is set to a much higher frequency than its frequency of input and output: its harmonic range consists of the fundamental component and the harmonic material around the switching frequency. The input current drawn in Fig. 3 is shown with a 2 kHz frequency switching converter. The amplitude of the harmonic components is apparent and switches to their fundamental amplitude. An input filter is obviously important in order to minimise harmonic distortions of the current at an appropriate level in the input line. The process must therefore be used to discuss matrix converters as an all-silicone solution for a direct AC/AC power transmission because some reactive components are needed.

With regard to inputs for a standard diode bridge rectifier VSI converter, the performance of the matrix converter is improved significantly with a harmonious range showing a high degree of low-order harmonies. Given the requirements for power efficiency and the harmonic power supply distortion, the matrix converter has a very appealing feature.

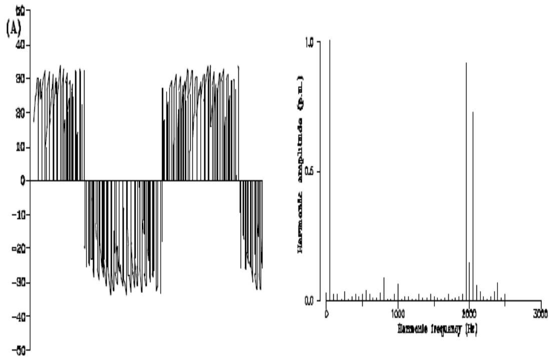


Figure 3: Matrix converter input current and harmonic spectrum

The input power factor control

Another attractive feature of matrix converter is the input power factor control capability, which carries most of the control algorithms proposed in Despite this common ability, there is a fundamental difference with regard to the dependence on load angle of displacement.

For example, the algorithm does not need the knowledge of the charging angle to manage the input power factor in full. In contrast, if the reference power factor is different to unit the algorithm requires the knowledge of the load angle displacement. It is a drawback, from the perspective of an algorithm, since it involves far more calculations.

Implementation of the Matrix Converter

Looking at the basic features of the matrix converter which were already briefly mentioned in previous sections, the fact that this topological converter is not widely used may surprise. Practical implementing problems which hinder the creation of this technology have to be clarified.

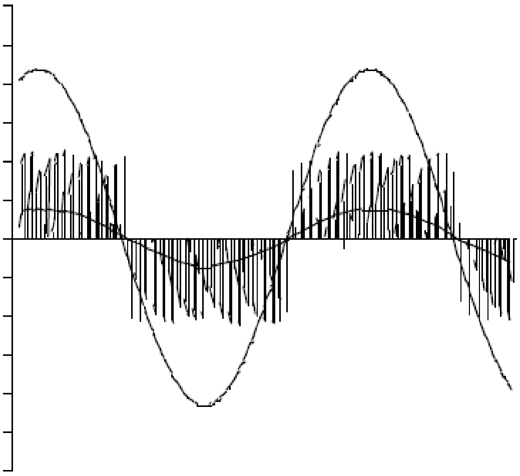
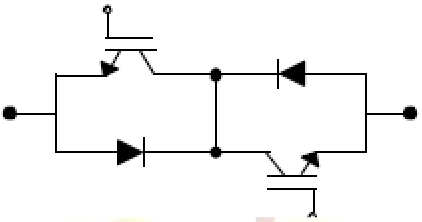


Figure 4: Matrix converter input line-to-neutral voltage, instantaneous input current and its average value

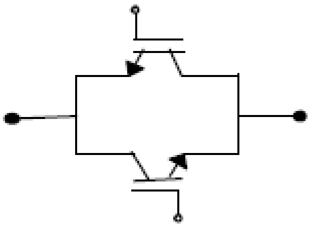
The bi-directional switch realization and commutation

One major first issue is the implementation of two-way switches. Definitely, a bidirectional switch will lead the current and block voltages of the two polarities depending on the control signal. A real bi-directional switch is currently however still not possible and must therefore be achieved by combining traditional single-directional semi-conductor equipment. Fig. 5 displays various bidirectional switch configurations used in the prototype and/or proposed. The problem of commutation is another problem that was closely linked to the introduction of bi-directional switches that posed a major barrier to the matrix converter's industrial success. The key reason for the problem with switching is that the matrix converters lack static freewheel drive tracks. As a result, a safe switching of the timer and sync command signals requires a certain careful timing and synchronization of the current from one bi-directional swap to another.

a) Diode bridge with a single IGBT



b) Two anti-paralleled IGBT



c) Two anti-paralleled NPT IGBT’s with series diodes with reverse blocking capability

Figure 5: Possible discrete implementations of a bi-directional switch

The input filter issue

While the matrix converter also offers the complete silicone solution, it needs a minimum number of reactive components due to the absence of spacioso and costly DC-link conductors of conventional indirect frequency converters.

The film is a connection to AC power supply between the converter matrix (Fig. 6). It is important to prevent an unwanted combination of harmonic currents into AC, that the input voltage of the converter does not vary dramatically during any PWM cycle. The matrix converter is in fact a source of current harmonics that are pumped back to the AC due to discontinuous input currents.. Since these current harmonics cause distortions in voltage affecting the AC system's total operation, these must be minimised. The key way to reduce harmonics generated by static converters is by input filters with reactive storage elements.

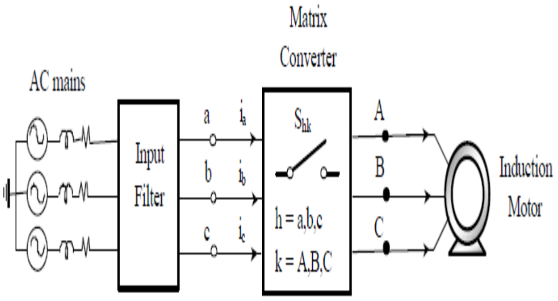
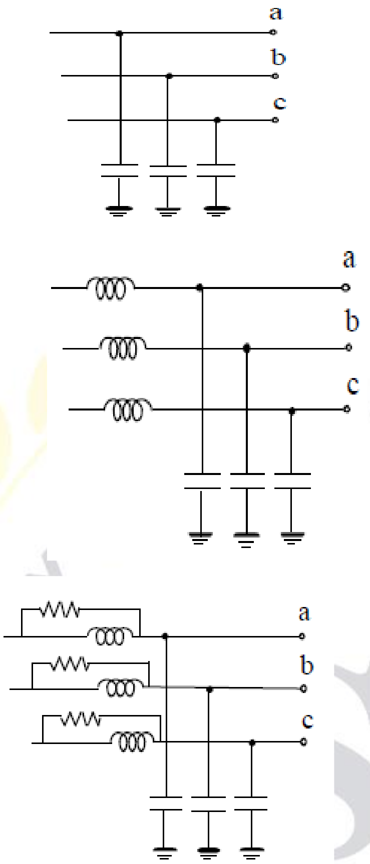


Figure 6: Schematic representation of a matrix converter adjustable speed drive

The input filter design issue has been solved and literature has received various configurations for the matrix converter input filter. Such variations are the product of various design parameters or weighted frequencies and policy modulations. The input filter settings of the matrix converter prototype are presented in



a) Capacitors star b) Second order L-C filter.c) L-C filter with parallel or delta damping resistor

Figure 7: Basic input filter configurations used in matrix converter prototypes

In general, three main criteria have to be met for the design of an input filter for static power converters from an ac power system:

Provide a small input displacement angle between filter input voltage and current;

Ensure total system stability.

Carry out the necessary noise attenuation switching;

In addition to this requirement, the optimised design of the input filter requires a range of considerations concerning costs, voltage reduction, device performance and the variance of filter parameters.

EMI control requirements are usually the first prerequisite: the input-filter must reduce to a less than a given value the total harmonic distortion of input and output current. To achieve this result, the sounding frequency of the filter must conform to its PWM pattern and the frequency of the conversion switch. The resonance frequency of a filter, where no undesired harmonic component is known to be the harmonic flow induced by the converter, usually the range from the fundamental frequency to the frequencies of switching, exists. In reality, certain unwanted or unspecific harmonics with a small amplitude can occur in the area due to imperfections and asymmetries of gating signals and imprint. The filter will intensify the undesirable harmonics to inappropriate levels if no damping is done. The damp filter, on the other hand, did not meet the harmonic attenuation requirements.

In the case of the matrix converter, Fig. 7 shows that single-phase filter settings have been used for harmonic attenuation, but either those settings are not required to fulfil current or potential EMI requirements or are economically convenient. The reactive storage elements in the filter are observed in relation to the second request. As can be seen in Figure 7, the filter input often changes step by voltage of the line-to-neutral to the filter capacitance. Therefore, the capacitor size must be decreased to maintain a high input power factor. The condenser value of the filter is normally high.

However, the restriction of the condenser size has many consequences. The inductor size of a filter increases to meet the requisite reductions, thus increasing the filter size overall. In addition, it is more difficult to monitor the output impedance of the input filter associated with the total filter power. With regard to the matrix converter, due to the input filter capacitance a high input line current displacement angle can be compensated for with the matrix converter and the input power reference angle can be set. However, the voltage transmission ratio of the converter would be significantly reduced. The upper limit for the input filter, therefore, is also set to the matrix converter according to the minimum permitted AC factor.

Lastly, but not least, it is essential to monitor the interaction between the impedance filter and the converter. As opposed to the converter input, the filter output impedance should usually be as low as possible. Due to the increase of the filter condensers power, the filter output impedance is reduced. In reality, the lower border of the condenser value is determined by the impedance interaction of the constraints. In order to achieve small filter output impedances for all the frequencies, proper pole damping of the filter is of great importance and therefore overall stability of the system. The stability issue has not appeared in the literature in question as regards the matrix transducer but is not exempt. Finally, a successful design of the filter input converter is a challenging task since the solution is dependent on the stage of the device and can be regarded as an exemplary task in the light of the recent harmonic and EMI reductions.

The protection issue

Also, any other static converter must be shielded from the overvoltages and over current which may be damaging for its semiconductor units. The installation of a secure and efficient power converter plays an important role in a successful and strong safety scheme. For the use of the matrix converters as an AC drive the voltages can externally be caused by voltage spikes on the AC or internal because of switching errors or timing errors causing power generation to be disrupted. This switching risk is unique for the matrix converter that doesn't have any automatic, static freewheeling path for output generator currents unlike the conventional DC link converter. Today's two-way switching method does not need freewheeling paths for the secure switching in a standard operating condition of output current or snubber circuit. A free-wheel drive is only required if the generator is switched off due to a conversion emergency shut-down. A freewheel path to generator currents should be provided in this case, in order to avoid disruptive matrix overvoltages. In terms of current, they can be converted from one line-to-line or line-to-earth output from the short circuit either by converter of two input tensions.

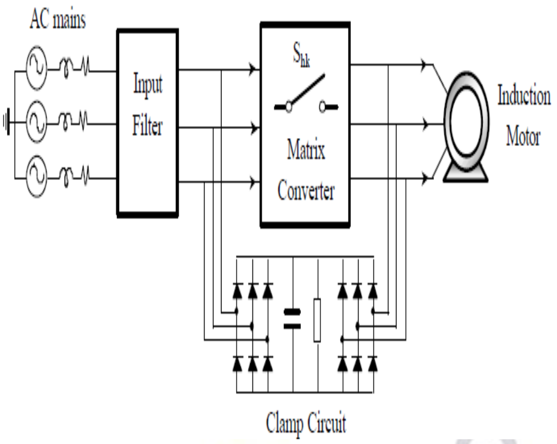


Figure 8: Clamp circuit as common protection for all matrix converter bi-directional switches

In both cases, the normal safety technique consists of shutting off all switches by monitoring the currents and by making power semiconductors resist and switch significantly on the non-repetitive current over current. It is clear that this safety technique can only be used when the generation currents have a freewheeling direction.

The first safety scheme suggested a series of clamps consisting of one or two condensers connected with two diode bridges to both the input and output lines (Fig. 8).Both nine two-way switches are fitted to the clamping circuit. It protects the switches from the AC line input and the output side push that is caused otherwise if an emergency converter is needed. In the last example, the load capacity is transferred to the clamp condenser when the generator induction currents are disrupted and when the condenser is large enough no tensions occur. The clamp circuit also prevents output voltage spikes induced by parasite inductions of the power switch matrix during switches commutation and inevitable time inaccuracies. Because the condenser voltage increases with any change operation, certain methods are needed to unload the condenser.

A power supply method is effective in using the clamp energy in the power supplies, even though it is possibly necessary to supply backup power because of the matrix converter's short ride-out capacity. The advantages of this security system are that they are very easy; their hardware needs are limited and their operating conditions are stable. It also has some inconveniences: the number of necessary half production equipment is increased to 12 quick recovery diodes, which can be reduced to 6 by a few diodes of the two-directional power switches, it increases the number of reactive components required. The second passive safety scheme for low-energy applications recently proposed relies on a triangular arrangement of three varistors added on the converter's input and output side, as shown in fig. 9.

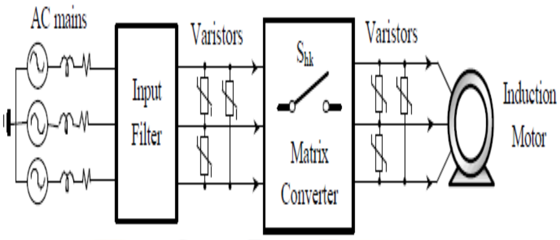


Figure 9: Matrix converter with varistors protection.

The input triangle must prevent voltage spikes from being caused by the AC mains. On the output side, the chance of overvoltages is caused again due to an emergency stop or a converter fault by a difficult convertor shutdown. The energy contained in the generator leakage inductance needs to be controlled to avoid the increase of the voltages at the destructive stage, providing a freewheeling path towards generator currents. Given the small amount of stored energy, the varistors can be instruments that allow freewheel path to generator currents and absorb energy. The losses of the varistors during normal service are not noteworthys. But the varistor triangles are not enough in themselves to provide reliable security from IGBT matrixes during the conversion shutdown: an issue arises when a bidirectional turnaround switch exceeds its blocking potential at a certain time. In this situation, the switches already switched off will over voltage completely and are destroyed. A simple circuit composed of a deleterious diode is attached to every IGBT to secure the single IGBT. In fig. 10 you can see the basic scheme of the added circuit.

The inserted diode has a high voltage zener diode characteristic. If the voltage for the IGBT collector is higher than that of the suppressor diode, the IGBT in the non-saturated zone is recharged and conductive. This is a high IGBT loss technique; however, it only lasts until all IGBT's are off and therefore the chip is not damaged. The diode protective system requires some hardware modifications compared to the clamp-circuit solution, but the benefit of this approach is that it does not need additional power semiconductors and reactive Storage components, thereby providing a more compact and cost-effective solution.

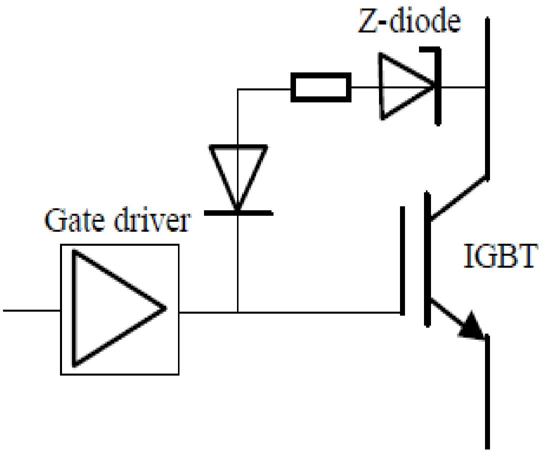


Figure 10: Gate driver with suppressor protection

For a clamping circuit to pick the suitable varistors, the equivalent circuit parameters of the generator must be understood. An interesting and elegant safety scheme was suggested for the first time and recently deployed to avoid voltage output side over voltages due to a hard converter shutdown. The device consists simply of an appropriate control technique for unidirectional matrix switches, which can be done until the emergency stop control is set and until the converter is switched off. The control strategy's main goal is to maintain the same working conditions as the traditional DC-link tension converter. When all of the switches are disabled, the free-wheeling diode provides the static free-wheeling path to the generator stream in the standard DC-link voltage converter (Fig 11).

Via these paths, the generator energy stored can be transferred automatically to DC-connecting energy storage components without over tension and dangerous currents. Since the matrix converter can not use a statical free-wheeling direction, this must be implemented actively. The most negative and positive feedback is the positive and negative DC direction. The unidirectional matrix switches that provide a clear flow path from and to the positive and bad rails must be allowed to activate any output line.

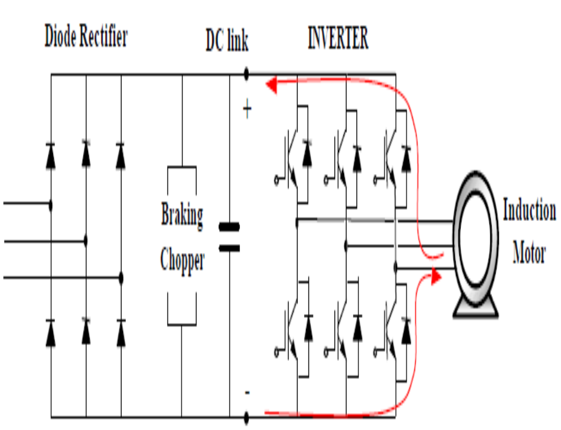


Figure 11: Conventional topology of a diode rectifier-Voltage Source Inverter

This solution does not require more hardware or reactive modules compared to previous security systems, it is robust and elegant. It does not prevent the converter, however, from rising voltage and can cause serious problems when a temporary power break takes place during rolling free operations. The use of three Stelar varistors on the input of the matrix switches is a potential reaction to these negatives.

III. CONCLUSION

In the topology of ultrasparse matrix converter, interface with a low-voltage wind turbine with the grid can be done by switching inductor and close z-source circuits. Due to the limited number of electronic power changers, the efficiency of the proposed converters is expected to be high. Furthermore, the fired condition no longer represents a threat which increases converters' performance.

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