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Power Quality Improvement by Using Pulse Based Harmonic Converter for Drive of Induction Motor

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Abstract

Technology and its Migration in these days makes us to give the simplicity in every corner. Increased demand for transportation, housing and industrial needs means that more number of power converters interact with the utility power grid. These converters are non-linear and they draw harmonic currents, significantly affecting power quality. To reduce harmonics, filters, power factor correction circuits and capacitor banks are required. And the development of hybrid technologies and renewable energy power stations trigger a demand for power converters with bi-directional capabilities. Main theme of this paper is to develop a high power quality, bi-directional AC-DC power converter that is a solution to the very inerrable problems. Topology for a high power AC-DC power conversion with transformer isolation. The topology consists of an uncontrolled rectifier followed by a AC-DC converter to produce a set voltage output. A design example of the topology is simulated using the PSIM software package. Critical performance characteristics such as power factor and total harmonic distortion are analyzed.

Keywords: PSIM, AC-DC Link Converter, Thyristors, PWM

1. Introduction

Quality power in a very broad sense can be defined as electrical power supplied to a load as required by it – which could be a specified DC voltage or current, AC voltage or current at a particular frequency, a mix of both – within acceptable tolerances. Power quality measures quantify the deviation of supplied power from the ideal requirement. Some examples of power quality measures are power factor, total harmonic distortion, voltage sag, voltage flicker, and voltage imbalance and frequency deviation.

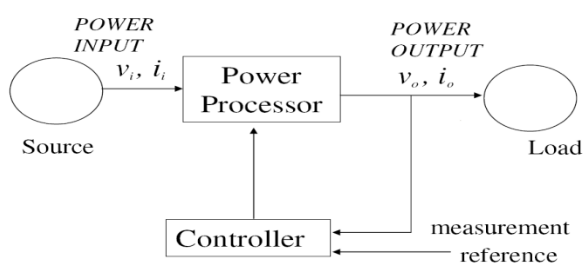

Fig.1.1 View of Power Processor & Controller

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With the good aim to introduce new techniques, to achieve better performance, to be able to control and to transfer more power over the power system and to reduce the power consumption of the loads, also a new topic was introduced: Power Quality. These new techniques consist of non-linear components that are used to control the load current. The current became distorted, i.e. deviates from the ideal sinusoidal waveform, and can be described by harmonic and inter harmonic currents. The goal of power electronics circuits are to convert electrical energy from one form to another, from source to load with highest efficiency, high availability and high reliability with the lowest cost, smallest size and weight.

2. Related work

A matrix converter performs direct ac-ac power conversion from ac utility to ac load, with neither intermediate dc conversion nor dc energy storage elements [7]. Thus, the converter can be realized with greatly reduced size and volume in its structure, compared to the indirect ac-ac power converters grounded on dc-link components. Six-step current-fed converters based on thyristors are favorable in high power applications, because of no PWM operation, very reliable topologies with inexpensive high-power thyristors, and very low switching losses [8]. Controlled converter type utility interface such as a PWM voltage source rectifier (PWM-VSR), or an active power filter (APF) can be employed to solve the harmonic pollution.

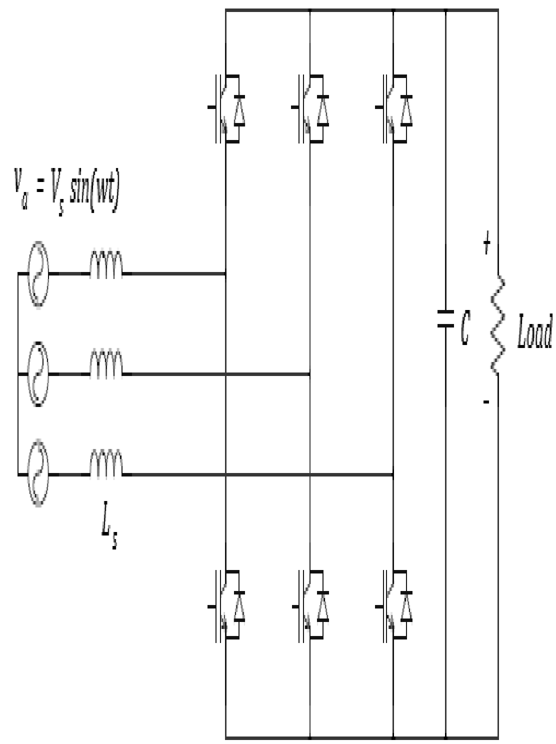

Fig. 2.1 Voltage AC-DC PWM rectifier

During acceleration and normal cruising, the powers from the battery powered electric motor and the ICE are used to drive the vehicle. During deceleration, the braking power is regenerated and the energy is transferred to the battery. The power converter supplying power to the motor should be highly efficient and should have bi-directional capabilities for this to be possible. Besides hybrid electric vehicles, other applications like flywheel energy storage and regenerative braking systems

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employ similar techniques for power transfer in both directions.

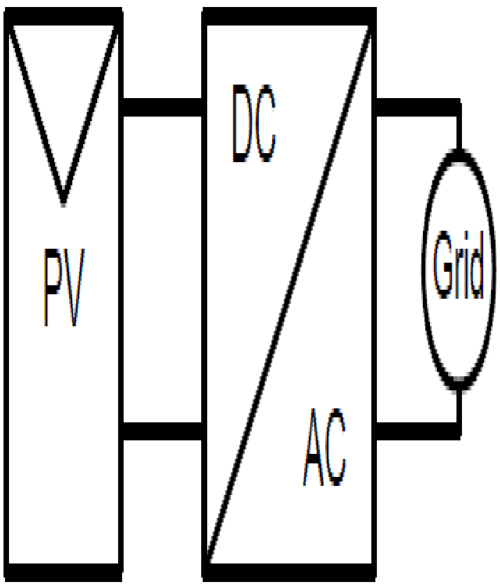

Fig. 2.1 PV module, and connected with the grid in the AC-DC link

3. Methods

The presence of harmonics decreases the power factor of the system. Low power factor reduces the real power available to the load and customers who draw power at power factor lower than 0.95 lagging stand to pay hefty penalties to the regulatory authority. These factors make high power quality a necessity. These converters should draw power at high power factors, introduce minimum amount of harmonics into the supply, provide minimum distortion power to the load and are better in efficiency.

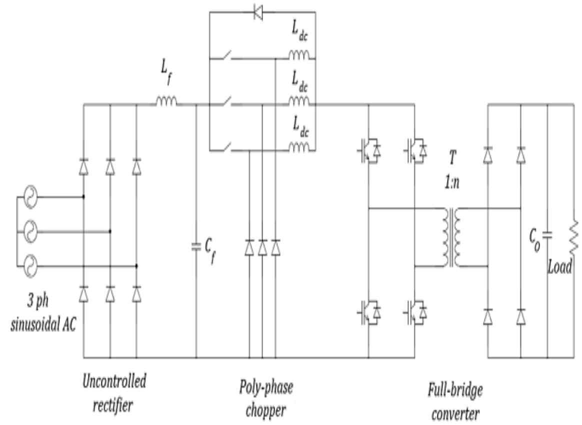

Fig.3.1 full-bridge AC-DC converter with three-phase AC supply

The poly-phase (three-phase in this example) chopper produces a constant current from the constant voltage output of the uncontrolled rectifier, the maximum value of current being limited by the transformer and switch ratings. Using an m-section poly-phase chopper reduces the actual switching frequency m-fold from the required switching frequency.

With the advancement of semiconductor technology, solid state transformer (SST) with high voltage fast switching SiC power devices is becoming a valid option to replace the conventional transformers in the power substation. The main advantages to replace the conventional transformers with the solid state transformer are reduction in size and power quality improvement. The 3 phase solid state transformer consists of three stages AC/DC rectifier, a dual active bridge converter with a high frequency transformer and a DC/AC inverter, for each phase.

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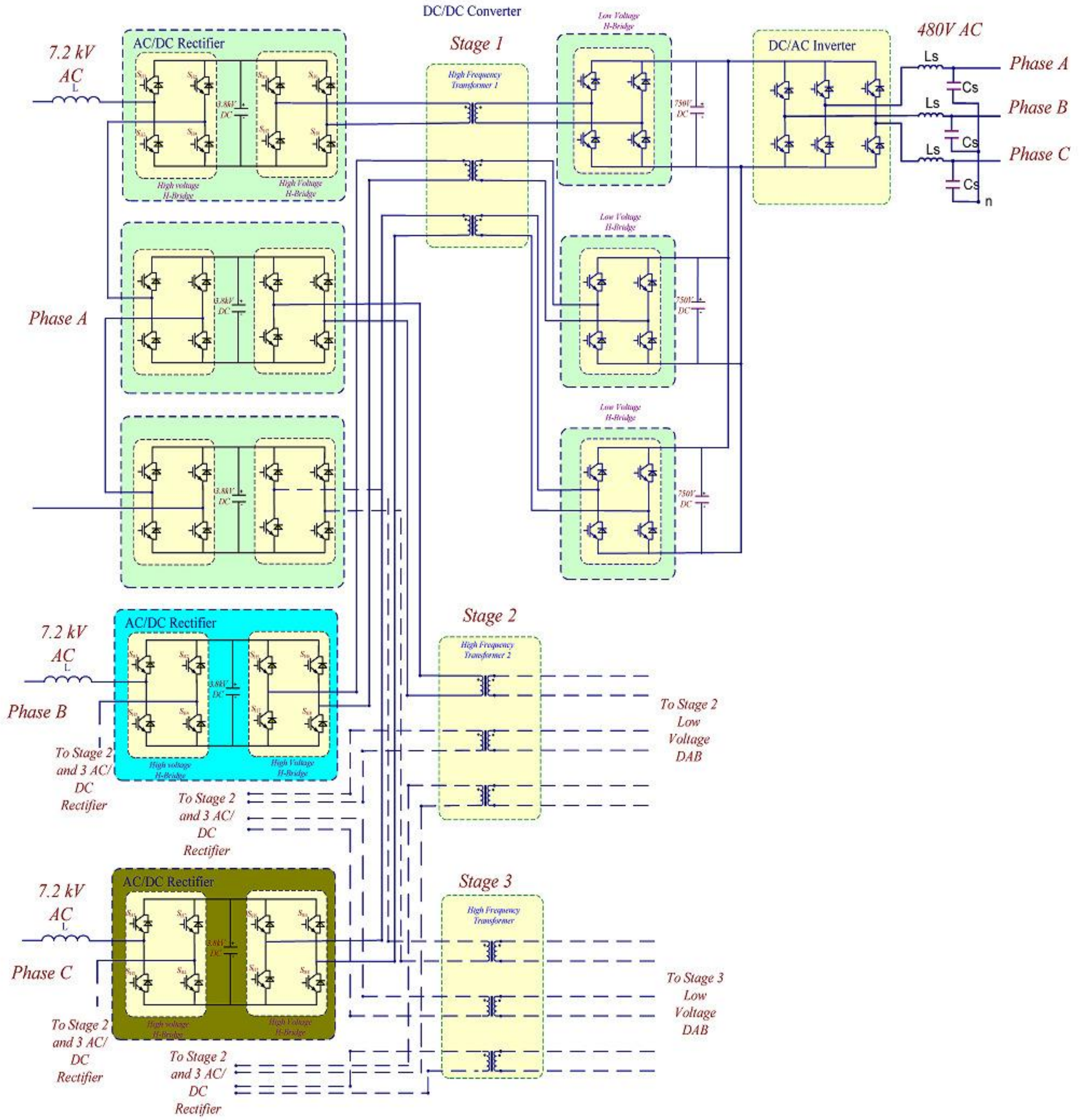

Fig.3.1 Topology of High frequency Voltage in the Path of AC-DC link

Each phase of the SST consists of a three cascaded high voltage high frequency AC/DC rectifier that converts 50 Hz, 5.2 kV AC to three 3.4 kV DC buses, three high

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voltage high frequency DC-DC converters that convert 3.84 kV to 750V with the help of the high frequency transformer, the 750V DC bus is converted to 480V AC40 Hz, 480 V, 3
phase/3 wires by a voltage source inverter (VSI).

In the waveform of Voltage which lead to quality can be described by a series of sine and cosine functions.

$$u(t) = U_{dc} + \sum_{n=1}^{\infty}\left(U_{(n)s}\sin(n\omega t) + U_{(n)c}\cos(n\omega t)\right) \qquad (2.1)$$

The coefficients are obtained as follows:

$$U_{(n)s} = \frac{1}{\pi}\int_0^{2\pi} u(t)\sin(n\omega t)d\omega t \qquad (2.2)$$

$$U_{(n)c} = \frac{1}{\pi}\int_0^{2\pi} u(t)\cos(n\omega t)d\omega t \qquad (2.3)$$

where n is an integer and $\omega = 2\pi/T$. T is the fundamental period time.

Total demand distortion, only for the current

$$TDD_I = \frac{\sqrt{\sum_{n=2}^{\infty} I_{(n)}^2}}{I_{(1)\text{rated}}} \qquad (2.4)$$

Effective value

$$U_{RMS} = \sqrt{\frac{1}{T}\int_0^T u(t)^2\,dt} = U_{(1)}\sqrt{1 + THD_U^2} \qquad (2.5)$$

$$I_{RMS} = \sqrt{\frac{1}{T}\int_0^T i(t)^2\,dt} = I_{(1)}\sqrt{1 + THD_I^2} \qquad (2.6)$$

4. Simulation Results

Simulation Results gives which we have shown that a large variety of harmonic current distortion exists due to three-phase rectifiers in low voltage networks. The type of distortion is strongly related to the DC-link: the size of the capacitor and the presence and size of the smoothing inductor. The amount of active power flow on the dc-side, of a rectifier with a smoothing inductor, can also affect the current distortion. A large power flow reduces the current THD and a small power flow increases the THD, but the current harmonics in ampere follows of course the power flow. Sometimes the switching pattern in the VSI can contribute to the distortion of the line current.

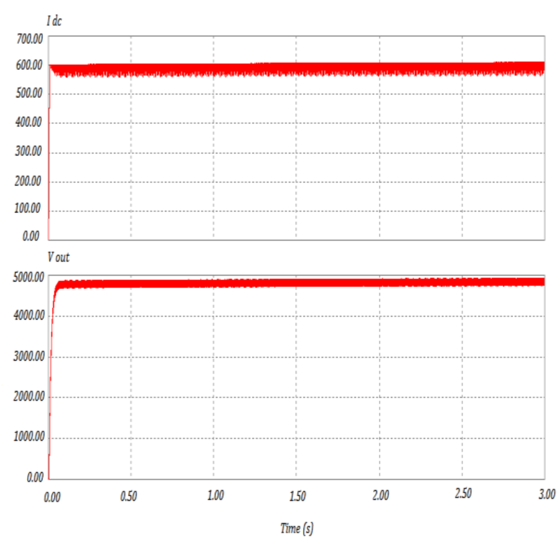

Fig.4.1 DC link current and converter DC output voltage with 5% ripple, at full load

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Table 1: Content of input current AC harmonics, normalized with respect to the DC link Current

DC link current	Converter input AC current harmonics, normalized to the fundamental									
Load level (p.u)	Fundamental (60)	5th (300)	7th (420)	11th (660)	13th (780)	17th (1020)	19th (1140)	23rd (1380)	25th (1500)	29th (1740)
1	1	0.30	0.41	0.43	0.29	0.02	0.08	0.05	0.04	0.000
0.73	0.850	0.29	0.37	0.46	0.31	0.03	0.08	0.04	0.02	0.000
0.51	0.588	0.30	0.34	0.34	0.22	0.07	0.08	0.03	0.02	0.011
0.375	0.433	0.32	0.32	0.26	0.17	0.09	0.07	0.02	0.01	0.012
0.28	0.331	0.30	0.28	0.20	0.16	0.09	0.06	0.02	0.01	0.015
0.225	0.263	0.24	0.22	0.16	0.13	0.08	0.05	0.02	0.01	0.012
0.18	0.210	0.20	0.18	0.13	0.11	0.06	0.04	0.02	0.01	0.009
0.17	0.199	0.18	0.17	0.13	0.11	0.06	0.04	0.02	0.01	0.010
0.14	0.162	0.15	0.14	0.11	0.09	0.05	0.04	0.01	0.01	0.007
0.125	0.139	0.13	0.12	0.09	0.08	0.05	0.03	0.01	0.01	0.006

The current is discontinuous and non-symmetrical, the smoothing inductor is absent. It includes both even and inter-harmonics and a DC-offset. The irregular behavior of the current is due to the intermittent power consumption of the servo load. The line voltage is not affected.

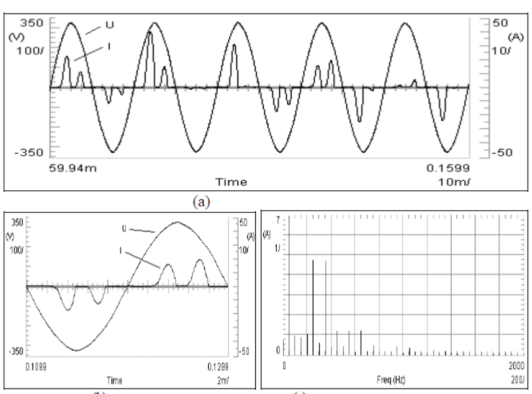

Fig.4.2(a) Discontinuous non-symmetrical current. (b) Analyzed period, which is not representative for the frequency spectrum of any other period. (c) Frequency spectrum of the current (one cycle).

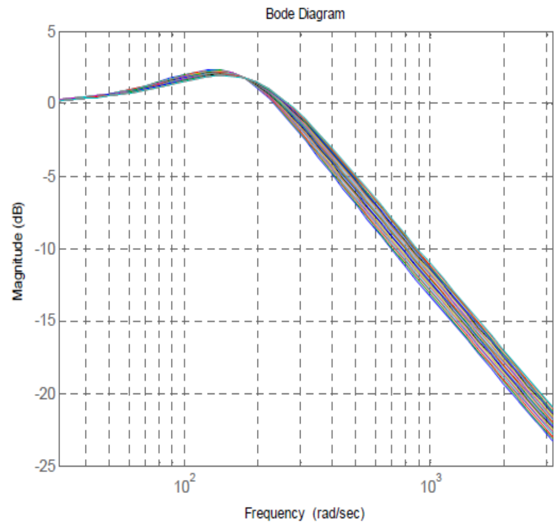

Fig. 4.3.Showing plot of the Magnitude, with frequency having voltage range from 175 V to 370 V.

5. Conclusion

PSIM and the performance characteristics such as input power factor and total harmonic distortion are observed. The converter draws a high amount of lower order harmonics and as a result the input power factor is low. Power factor correction could require heavy filters or additional power factor correction circuits. The front end fully controlled rectifier could be mirrored on the other side of the DC link inductor to form a matrix converter, making it suitable for AC motor drives and transformer emulation topologies.

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