Dc bus to industry a new way towards energy efficiency

Andre dos Santos Lima[1], Aderaldo Ricarte Guedes[3], Antonio Alisson Alencar Freitas[1], Edilson Mineiro Sá Jr.[2], Fernando Luiz Marcelo Antunes[1]
1 Federal University of Ceara, Depto. Electrical Engineering, Campus do PICI, Brazil
2 Federal Institute of Ceara, GPEM Mechatronic Group, Campus Sobral, Brazil
3 Federal University of Ceara, Electrical Engineering, Campus Sobral, Brazil

Abstract

In this paper, will be discussed an industry dc bus used to supply a group of induction motors, synchronous permanent magnet motors (SPMM) and the recovery of break energy with a supercapacitor energy recovery system. The dc bus supplies inverters connected to motor and could have a big tolerant level of voltage variation. With the utilization of supercapacitor recovery systems, new industry standards should be adopted and bidirectional rectifiers could be left aside once the break energy recovered will be stored and used to a new machine restart. Moreover, bidirectional rectifiers for high current has critical response for motor´s break energy recover and they are expensive and if compared to traditional high current rectifiers.

1. Introduction

The electric energy demand is growing annually leading to the government to increase the generation base. Just build new generator plants in no more a solution. So, other ways to resolve this problem should be studied.

An open industry association called Emerge Alliance created by manufacturers to research and develop standards on power efficiency applied to datacenters, telecommunication plant and home appliances moving the focus towards direct current bus that has be showed more efficient than ac bus[1]–[6]. However, for industry sector any standard has been made. Electric motors in industry consumes about 40% of all electric energy generated [7] in the world, and it has not been considered yet. Manufacturers of electric motors like Brazilian WEG are searching for solutions to achieve better efficiency on their products. According to the manufacturer during the 80´s the efficiency of a 60 hp induction motor had an efficiency around 90 % and today synchronous permanent magnet motors (SPMM) can be better than 95% [8].

The constant development of power electronic technology has changed the way to connect induction motors to ac bus, using more and more inverters to supply and control induction motors from small application to big one. These inverters have rectifier that processes all energy at the input stage. Dc distribution bus can reduce a big number of these conversions, mitigating losses by taking off all inverter´s internal rectifiers by accessing internal dc bus directly and using just a one rectifier for a group of machines [9]. A dc bus can achieve better results when associated to energy recovery system that manage parts of energy delivered to systems. A dc bus use becomes easier to connect renewable power due to the fact they generally come in direct current. In the future, dc power could supply at industrial plants from a solid state transformer installed by the electricity utility.

In this paper, will be discussed an industry dc bus used to supply a group of induction motors, SPMM and the recovery of break energy with a supercapacitor energy recovery system. The dc bus supplies inverters connected to motor and could have a big tolerant level of voltage variation. With the utilization of supercapacitor recovery systems, new industry standards should be adopted and bidirectional rectifiers could be left aside once the break energy recovered will be stored and used to a new machine restart. Moreover, bidirectional rectifiers for high current has critical response for motor´s break energy recover and they are expensive and if compared to traditional high current rectifiers[9].

ISBN 978-3-8007-4424-4

2. Suggested system topology

The topology of the industrial dc bus can see on figure 1. This dc bus can supply 380 Vac(phase to phase) three phase induction motors as well the new technology permanent magnet motors from inverters. The focus on this study is the recovery of energy from machine to the bus that is burned by break resistors. This energy could be used by other machine or simply stored by supercapacitors for future use increasing the hole system power efficiency.

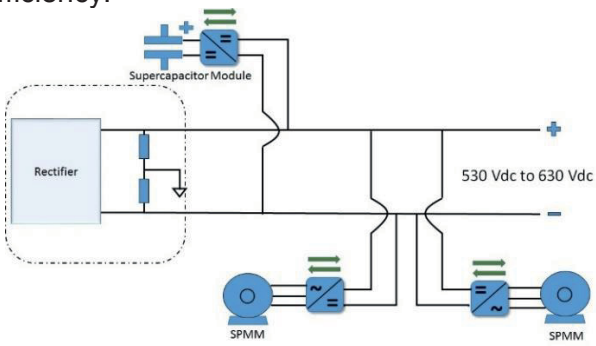

Fig.1: Proposal DC bus on industry

In the most inverters, the manufacturer let access to internal dc bus because they are used to connect break resistor for the motor break. On this dc bus, the voltage can increase to a certain value until the break resistor connection that will “burn” the energy remains. With supercapacitors, the energy remain can be stored for next start use. A portion of the total energy amount can be saved by industries resulting on better efficient consumption process. Figure 2 shows the simulation of power consumption on a start-stop of two 15Hp induction

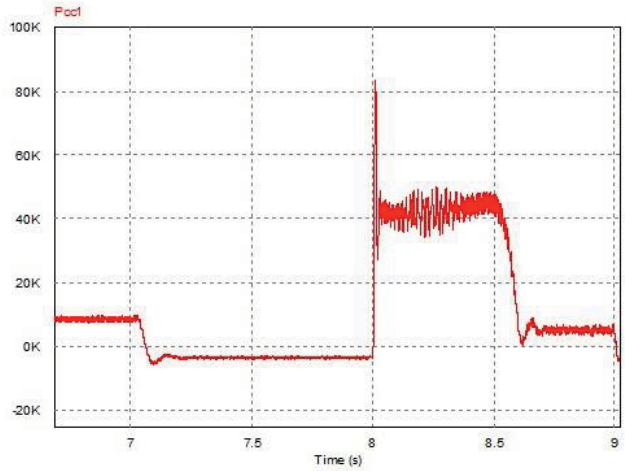

Fig. 2. Power changes in watts of two equal machines connected to same dc bus.

motors connected by inverters to a dc bus in different moment. Until 7 seconds the first was on and is stopped. We can see the energy returning to the dc bus from 7s to 8s when the second motor is started. A portion of the energy came from motor 1 to motor 2 to supply the start. After the inrush of second motor the total power measured is lower than single motor 1 consumption. Figure 3 shows experimental result of inverter´s dc bus voltage and current in which is connected a 23 kW SPMM in injection molding machine (model GEK220/S). On the breaking time the voltage increase to 623 V, limited by breaking resistor. The breaking total time is about 55 ms because this kind of motor has a very low inertia moment. Figure 4 shows the industrial machine used to take all experimental measurements results.

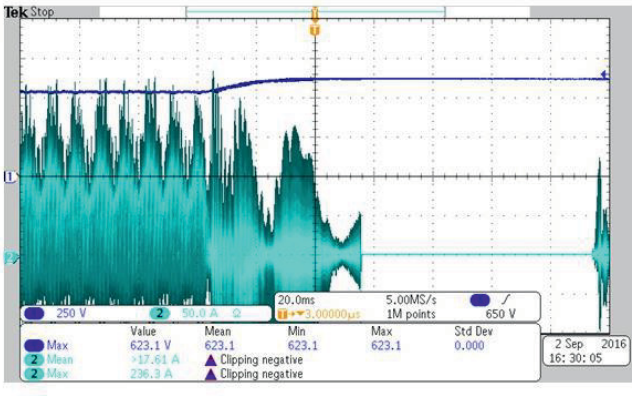

Fig. 3. Experimental result of inverter´s dc bus voltage and current

Fig. 4. Operation of experimental setup.

2.1. Energy recovery process

The use of supercapacitor connected to the dc bus of the internal inverter drive for recovering of break energy It has been proposed in [10]. The voltage swings across internal inverter dc bus, this variation occurs due to energy returning from machine to dc bus. When this voltage reaches 630

ISBN 978-3-8007-4424-4

Vdc a break resistor is turned on to “burn” energy until lead a secure voltage level to protect the inverter. This amount of energy theoretically could be recovered. However, the injection molding machine studied works on a specific job that a little amount of energy is waste. Considering the high cost of purchasing the supercapacitor and the energy involved on whole recovery process, the total costs will not be covered. Figure 5 shows the voltage variation and the voltage on break resistor.

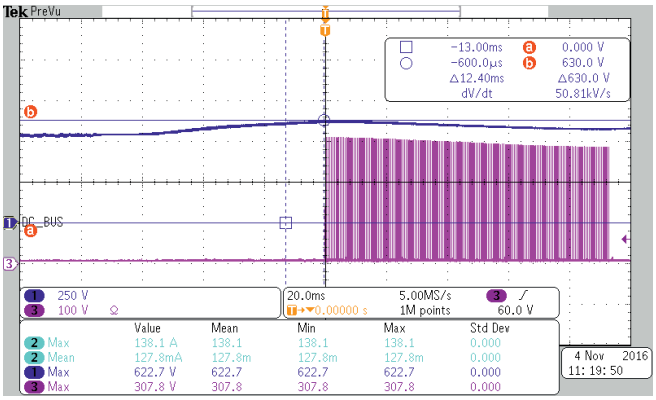

Fig. 5. Measurement of inverter´s dc bus voltage and voltage on break resistor

The energy dissipated by break resistor for the whole process can be calculated as in 2.1.

$$P_i = \frac{V_{dc}^2}{R} \qquad 2.1$$

Where:

P_i is instantaneous dissipated power

R is break resistance of 33 Ohms;

V_{dc} is the dc bus voltage;

The instantaneous dissipated power is calculated in 2.2.

$$P_i = \frac{614^2}{33} = 11.42\ kW \qquad 2.2$$

The whole cycle of machine operation has 20s in which the break is turned on 3 times by 90ms. Thus, the total energy that can recovered by a day is in 2.3.

$$P_d = \frac{11.42kW \times 0.27s \times 3}{3600} \times 24 = \frac{61.6\ Wh}{day} \qquad 2.3$$

Although the supercapacitor module not be necessary to recovery energy, it could be installed to manage machine starts to mitigate stresses on rectifier system and voltage drops, when the bus is on low level of energy. The changes of energy between machines connected on the same dc bus occurs naturally once there are in each inverter a capacitor module linked to dc bus working as an energy reservoir.

3. Conclusion

The dc voltage on internal inverter bus increase caused by the motor breaking. SPMM have a low inertia moment resulting short time for energy recovery in the breaking process. Bidirectional rectifiers are not suitable for high current levels in a short period like as seen on breaking of the injection molding machine.

In a microgrid, voltages are usually standardized and have a constant level. In this work for industrial applications dc bus voltage can be suffer variations due to high energy recovery in a short time. Voltage variations is usual on inverter´s internal dc bus. A part of the energy is absorbed by the capacitor bus. Meanwhile major energy part is dissipated in the breaking resistor.

This work purpose a dc bus for a group of inverters with just one supercapacitor converter to absorb the energy dissipated by breaking resistor while the voltage increase over a limit. If the supercapacitor is full of charge a burn resistor will work as protection. The calculation of the supercapacitor size to recover burned energy was not necessary because the type of work the injection molding machine is not appropriated. Some others studies should be done with different molding machine to determinate the real necessity of supercapacitor use.

4. References

[1] G. Ailee and W. Tschudi, “Edison Redux,” *IEEE Power and Energy Magazine*, no. October 2012, pp. 50–59, 2012.

[2] A. S. Oliver, “Addressing 400-Vdc power in advanced industrial and data-center apps,” 2014. [Online]. Available: http://www.powersystemsdesign.com/addressing-400-vdc-power-in-advanced-industrial-and-data-center-apps. [Accessed: 26-Jan-2016].

[3] F. Nejabatkhah, S. Member, Y. Wei Li, and S. Member, “Overview of Power Management Strategies of Hybrid AC/DC Microgrid,” *IEEE Trans. POWER Electron.*,

ISBN 978-3-8007-4424-4

vol. 30, no. 12, 2015.

[4] M. Saeedifard, M. Graovac, R. F. Dias, and R. Iravani, “DC power systems: Challenges and opportunities,” *Power Energy Soc. Gen. Meet. 2010 IEEE*, pp. 1–7, 2010.

[5] D. J. Becker and B. J. Sonnenberg, “DC microgrids in buildings and data centers,” *2011 IEEE 33rd Int. Telecommun. Energy Conf.*, pp. 1–7, 2011.

[6] K. Garbesi, V. Vossos, and H. Shen, “Catalog of DC Appliances and Power Systems,” no. October, 2011.

[7] A. Bonanomi, “Electric Motors : Market Trends and Service Business,” *Power Transmission World*, Milan - Italy, p. 82, 2016.

[8] A. C. P. (WEG) and A. C. da S. (Diretor de Marketing Corporativo WEG), Eds., “A fonte mais barata de energia elétrica,” *WEG em revista*, Sep-2014. [Online]. Available: http://www.weg.net/files/weg-em-revista/WR-76.pdf. [Accessed: 18-Aug-2016].

[9] Z. Cao, H. Fahnert, J. Schiele, J. Solanki, N. Fröhleke, and J. Böcker, “System Concept and Model-Based Optimization of High-Current Variable-Voltage Chopper-Rectifiers,” no. May, pp. 10–12, 2016.

[10] K. Takahashi, M. Okamoto, E. Hiraki, and T. Tanaka, “Simulation analysis of energy-saving effect of an energy recovery system for electric motor drive system in the injection molding machine,” *Proc. 14th Int. Power Electron. Motion Control Conf. EPE-PEMC 2010*, pp. 118–122, 2010.

ISBN 978-3-8007-4424-4