Design Implementation of Regenerative Control System for Energy Efficient Motor Drive Based On Cascaded Multi Level Inverters

R.Chander
Research Scholar
Department of Electrical Engineering
University College of Engineering (A)
Osmania University, Hyderabad
Telangana, India

Bandari Anitha
M.Tech student, P.E.
Department of Electrical Engineering
Chaitanya Institute Of Technology And Science,
Warangal, Telangana,India

Abstract: This paper presents a cascaded-multilevel-inverter based motor drive system with integrated segmented energy storage. In particular, it can achieve an effective real power distribution between the energy source, the energy storage, and the electric motor by an autonomous power regenerative control system. .An autonomous power regenerative control system including voltage balancing control of segmented energy storage is developed to reduce the adverse effect of power transients on energy sources, recover the regenerative power from the motor, and improve the system dynamic performance and power quality, perform the smooth power transition between different operation modes and provide accurate speed tracking .

Keywords: Self-Governing Regenerative Control, Cascaded Multi-level Inverters, Energy Storage, Voltage Balance Control and Electric Motor.

I. INTRODUCTION

It is well known that the efficiency and dynamic performance of the motor drive system can be improved by using energy storage devices as they can recover the regenerative energy and supply peak power during transients. The power semiconductor technology as provided a favourable approach to achieve the power management among the energy source and energy storage in the drive system. [1] – [7] presents a typical drive system configurations where DC-DC to converters are used to interface the energy source and energy storage. These configurations provide flexibility in power distribution among energy source, energy storage and electric motor. These also avoid adverse effects of voltage variations but require two stage energy conversions between energy source, energy storage and electric motor. Moreover conduction and switching loses are more in DC-DC converters when used in high power application, which in turn reduces the system efficiency. This will lead to high system cost and complexities and increases stability issues.

The cascaded multi-level inverter find applications in synchronous compensation, hybrid renewable energy system, electric motor drive system [11] – [17]. They have desirable advantages in high power applications and heavy duty hybrid electric vehicles. They are cost effective due to their modular structure. They exhibit low electro-magnetic interference, good power quality, transformerless topology, fault tolerance capability etc. These configurations provide good efficiency as they are involved with single stage energy conversion between energy source and electric motor. It also provides provision for connecting segmented energy source or energystorage to suit high voltage and high power application with modular structure. Recently cascaded inverters with single source and multiple capacitors has storage for motor drive system are reported [13] – [15], but here capacitors are used for harmonic cancellation and real power management was not achieved, which limited its function.

This paper proposes a cascaded-multilevel-inverterbased motor drive system integrating energy sources and segmented energy storage. In particular. Accordingly, the proposed energy storage-voltage balancing method will enable energy storage to provide not only harmonic compensation during steady state but also real power compensation during the acceleration and deceleration modes of a motor it can achieve an effective real power distribution between the energy source, the energy storage, and the electric motor by an autonomous power regenerative control system. An autonomous power regenerative control system including voltage balancing control of segmented energy storage is developed to perform the smooth power transition between different operation modes and provide accurate speed tracking

II. BACKGROUND WORKS

The voltage ratio is selected based on the consideration to achieve the best power quality by maximizing the number of synthesized voltage levels. Another consideration for the voltage ratio selection is to minimize the circulating energy among the cascaded inverters and to increase the efficiency of the overall system. Finally, in order to allow the output-voltage harmonics generated around the frequency multiples of the 2n switching frequency of auxiliary inverters, the output voltage should be synthesized with the same adjacent voltage step.

The proposed technology finds application in next generation electric ship by improving efficiency, dynamic performance and power quality of high power motor drive system. It will also be beneficial for heavy duty electric vehicles with large electric drive train, since the isolated energy source could be implemented with individual battery packs and isolated energy storage can be achieved by segmented super-capacitors. The segmented energy storage will help to reduce the rating of the battery and allow the low voltage battery usage resulting in lower cost of the battery. The cascaded structure also enables the use of lower voltage supercapacitor which is one of the advantages. Since SC exhibits high energy and high power density, long life span it is preferred over the use of battery as energy storage. It also features fast rate of charging and discharging and is very efficient in capturing regenerative energy when it is used with the cascaded structure to interface with the battery. It results in extended life span of the batter, faster system dynamics and better fuel economy which in turn reduces battery loss.

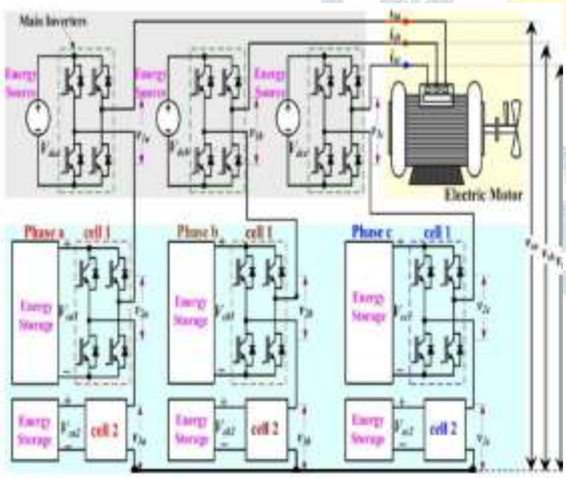


Fig. 1. Proposed Cascaded Multi-Level Inverter Based Drive System Configuration with Segmented Energy Storage

III. SYSTEM CONFIGURATION

Proposed Power Management Strategy and Operation Mode Analysis The typical driving cycle of power management strategy is presented in Fig. 2. The Power of the energy source, energy storage and electric motor is defined PSource, P Storage and PMotor respectively. The PSource is controlled to be uni-directional, so it can be thought to use an energy
source which has slow dynamics. It also beneficial to
use a bi-directional energy source such as battery since its features poor performance in recovering regenerative energy and also slower dynamics when compared to SC. Battery can be controlled from not absorbing regenerative power. Battery allows fast power change when SC is selected as the energy storage. As a result the energy source can be designed with the reduced size and cost with improved efficiency. The reduced stress during transients will result in reduced battery loss which will improve its life span. In the proposed system the energy source produces a small amount of power during start-up to the storage which will avoid the use of additional charger to the storage and further reduces system cost.

In the Figure 2 during start-up mode the energy source supplies small amount of power to the electric motor so that it can start with the low speed and together it supplies the storage to charge it upto the desired value. The dotted line between energy storage and motor means that there is no exchange of power between them. During the acceleration mode the energy source is assisted by the storage to provide the peak power to the electric motor. The voltage of the storage will decrease during this interval due to discharging. During constant speed the power required by the electric motor is supplied by the source alone and source supplies a small amount of power to the storage at the end of the accelerating mode. During deceleration mode the regenerative energy from the motor is restored into the storage so that the voltage of the storage will increase. This stored energy will be released in the next acceleration mode. During the stand-still mode a small amount of energy is supplied to the storage by the source to maintain its minimum voltage.

Energy Storage Design: The Energy Storage being a very important system component affects the dynamic performance of the electric motor and energy source. So, the design of energy storage becomes very prominent. Once the power management strategy is designed the energy storage can be designed accordingly.

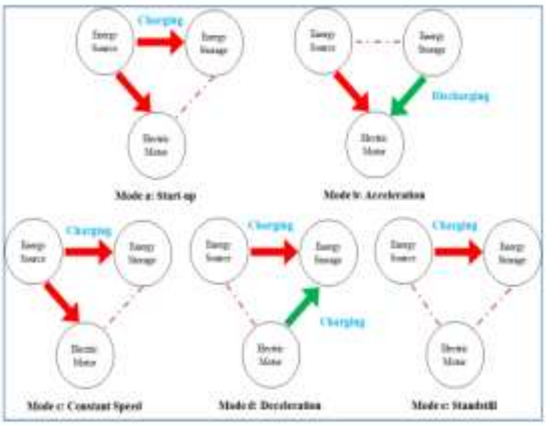
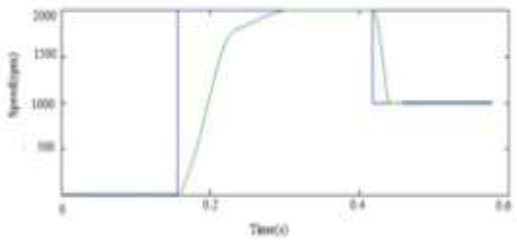


Fig. 2. Power Flow between Energy Source, Storage and Motor for different operating mode

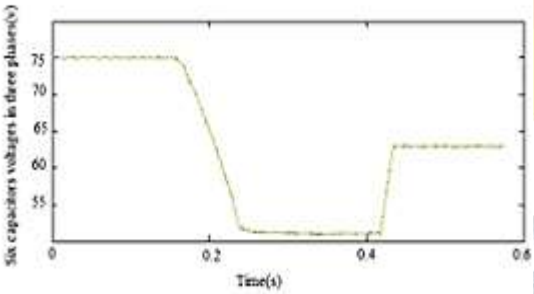
In this paper SC is selected as the energy storage due to its high power density which leads to good dynamic performance. In Fig. 2 it can be observed the SC has to transfer sufficient amount of energy to the electric motor to meet the requirement during power transitions. Hence the rating of the SC depends on the maximum energy that is transferred to the electric motor.

IV. SIMULATION RESULTS

Figs.shows simulation results over a typical driving cycle including acceleration, deceleration, and constantspeed modes. The constant load torque of 10 N • m is mused in this driving cycle.



(a) speed



(b) Six capacitors output voltage

Fig. (b) shows the corresponding six capacitor voltages. The capacitor voltage is 75 V before the starting acceleration mode. During the acceleration period, the capacitors are discharged to provide required peak power; thus, the voltages decrease from 75 to 51.5 V The capacitors then receive a small power from dc sources to keep 51.5 V at a constant-speed period. During deceleration period, the capacitors recover regenerative energy from PMSM; thus, the capacitor voltages increase from 51.5 to 62.5 V.

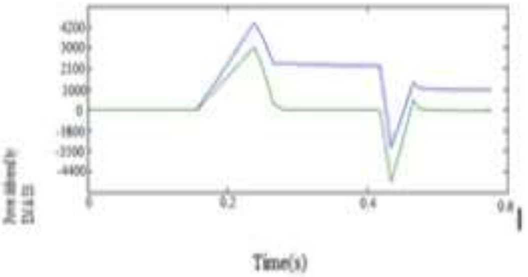


Fig (c) PMotor requires 4200-W peak power during the acceleration mode where up to 3000Wis provided by capacitors and the rest of the power is from dc sources. The capacitors continuously provide power to the PMSM in about 0.12 s until the speed reaches 2000 r/min.

V. CONCLUSION

A power-distribution strategy between the energy source, the energy storage, and the electric motor has been developed and carry out by a proposed autonomous power regenerative control system to perform smooth power transition between different operation modes and provide accurate speed tracking. In the proposed motor drive system, the energy storage has been designed not only to provide harmonic compensation but also to be capable of recovering regenerative energy during the deceleration mode and reapplying this energy during acceleration transients which improves the efficiency & power quality.

REFERENCES

. [1] Liming Liu, Hui Li, Seon-Hwan Hwang, and JangMok Kim, "A Systematic motor drive with Autonomous power control based on cascading multilevel inverters using SPWM," IEEE Trans. Power Electron., vol. 49, no. 1, pp. 178–188, Jan. 2013.

[2] Z. Du, B. Ozpineci, L. M. Tolbert, and J. N. Chiasson, "DC–AC cascaded H-bridge multilevel boost inverter with no inductors for electric/hybrid electric vehicle applications," IEEE Trans. Ind. Appl., vol. 45, no. 3, pp. 963–970, May/Jun. 2009.

[3] L. Maharjan, S. Inoue, and H. Akagi, "State-ofCharge (SOC)-balancing control of a battery energy storage system based on a cascaded PWM converter," IEEE Trans. Power Electron., vol. 24, no. 6, pp. 1628– 1636, Jun. 2009.

[4] C. C. Chan, "The state of the art of electric, hybrid, and fuel cell vehicles," Proc. IEEE, vol. 95, no. 4, pp. 704–718, Apr. 2007.

[5] W. Lhomme, P. Delarue, P. Barrade, A. Bouscayrol, and A. Rufer, "Design and control of a supercapacitor storage system for traction applications," in Conf. Rec. 40th IEEE IAS Annu. Meeting, Oct. 2–6, 2005, pp. 2013–2020.

[6] M. D. Manjrekar, P. K. Steimer, and T. A. Lipo, "Hybrid multilevel power conversion system: A competitive solution for high-power applications," IEEE Trans. Ind. Appl., vol. 36, no. 3, pp. 834–841, May/Jun. 2000.

[7] L. M. Tolbert, F. Z. Peng, T. Cunnyngham, and J. N. Chiasson, "Charge balance control schemes for cascaded multilevel converter in hybrid electric vehicles," IEEE

Trans. Ind. Electron., vol. 49, no. 5, pp. 1058–1064, Oct. 2002.

[8] C. Rech and J. R. Pinherio, “Hybrid multilevel converters: Unifed analysis and design considerations,” IEEE Trans. Ind. Electron., vol. 54, no. 2, pp. 1092–1104, Apr. 2007.

[9] K. C. Tseng and T. J. Liang, “Novel highefficiency step-up converter,”Proc. Ind. Elect. Eng.—Elect. Power Appl., vol. 151, no. 2, pp. 182–190,Mar. 2004.

[10] F. Z. Peng, M. S. Shen, and K. Holland, “Application of Z-source inverter for traction drive of fuel cell—Battery hybrid electric vehicles,” IEEE Trans. Power Electron., vol. 22, no. 3, pp. 1054–1061, May 2007.

[11] J. Rodriguez, J. S. Lai, and F. Z. Peng, “Multilevel inverters: A survey of topologies, controls and applications,” IEEE Trans. Ind. Electron., vol. 49, no. 4, pp. 724–738, Aug. 2002.

[12] M. D. Manjrekar, P. K. Steimer, and T. A. Lipo, “Hybrid multilevel power conversion system: A competitive solution for high-power applications,”IEEE Trans. Ind. Appl., vol. 36, no.

3, pp. 834–841, May/Jun. 2000.

[13] S. Lu, K. Corzine, and M. Ferdowsi, “High power motor drives based on hybrid multilevel converters and direct torque control,” in Proc. IEEE APEC, 2007, pp. 1077–1083.

[14] J. N. Chiasson, B. Ozpineci, L. M. Tolbert, and Z. Du, “Conditions for capacitor voltage regulation in a five-level cascade multilevel inverter: Application to voltage-boost in a PM drive,” in Proc. IEEE IEMDC, 2007, vol. 1, pp. 731–735.

[15] Z. Du, B. Ozpineci, L. M. Tolbert, and J. N. Chiasson, “DC–AC cascaded H-bridge multilevel boost inverter with no inductors for electric/hybrid electric vehicle applications,” IEEE Trans. Ind. Appl., vol. 45, no. 3, pp. 963–970, May/Jun. 2009.

[16] L. Maharjan, S. Inoue, and H. Akagi, “State-ofCharge (SOC)-balancing control of a battery energy storage system based on a cascaded PWM converter,” IEEE Trans. Power Electron., vol. 24, no. 6, pp. 1628–1636, Jun. 2009.

[17] H. Akagi, S. Inoue, and T. Yoshii, “Control and performance of a transformerless cascaded PWM STATCOM with star configuration,” IEEE Trans. Ind. Appl., vol. 43, no. 4, pp. 1041–1049, Jul./Aug. 2007.

[18] L. Maharjan, S. Inoue, and H. Akagi, “A transformerless energy storage system based on a cascade multilevel PWM converter with star configuration,” IEEE Trans. Ind. Appl., vol. 44, no. 5, pp. 1621–1630, Sep./Oct. 2008.

Authors:

R.Chander, Research Scholar from Department of Electrical Engineering in University College of Engineering (A), Osmania University, Hyderabad, Telangana, India.

Bandari Anitha Pursuing M.Tech (PE), Department of Electrical Engineering from Chaitanya Institute Of Technology And Science, Kakatiya University, Hanamkonda, Warangal, Telangana, India.