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Evaluated Performance of Dc Motor Drive Injected by the High Step Down Single Stage Single Switch Ac/Dc Converter without Transformer

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ABSTRACT:

In this paper we improved the performance of the dc motor drive by using dc supply. The supply is injected from the single stage switch boost converter. It is decreasing the supply based on the switching operation of the ac/dc converter. The topology integrates a buck-type power-factor correction (PFC) cell with a buck–boost dc/dc cell and part of the input power is coupled to the output directly after the first power processing. Actually the dc machines are used for power processing applications. With this direct power transfer feature and sharing capacitor voltages, the converter is able to achieve efficient power conversion, high power factor, low voltage stress on intermediate bus (less than 130 V) and low output voltage without a high step-down transformer. In this paper we obtained specified speed and torque from the dc motor by the MATLAB/SIMULINK.

IndexTerms—***AC-DC converters, harmonic reduction, improved power quality, power-factor correction, switch-mode rectifiers (SMRs).***

I.INTRODUCTION

SOLID-STATE ac-dc conversion of electric power is widely used in adjustable-speed drives (ASDs), switch-mode power supplies (SMPSs), uninterrupted power supplies (UPSs), and utility interface with nonconventional energy sources such as solar PV, etc., battery energy storage systems (BESSs), in process technology such as electroplating, welding units, etc., battery charging for electric vehicles, and power supplies for telecommunication systems, measurement and test equipments [1]—[25]. Conventionally, ac-dc converters, which are also called rectifiers, are developed using diodes and thyristors to provide controlled and uncontrolled dc power with unidirectional and bidirectional power flow. They have the demerits of poor power quality in terms of injected current harmonics, caused voltage distortion and poor power factor at input ac mains and slow varying rippled dc output at load end, low efficiency and large size of ac and dc filters. In light of their increased applications, a new breed of rectifiers has been developed using new solid state self commutating devices such as MOSFETs, insulated gate bipolar transistors (IGBTs), gate turn-off thyristors (GTO), etc., even some of which have either not been thought or not possible to be developed earlier using diodes and thyristors. Such pieces of equipment are generally known as converters, but specifically named as switch-mode rectifiers (SMRs), power-factor correctors (PFCs), pulsewidth-modulation (PWM) rectifiers, multilevel rectifiers, etc. Because of strict requirement of power quality at input ac mains several standards [1]-[3] have been developed and are being enforced on the consumers. Because of severity of power quality problems some other options such as passive filters, active filters (AFs), and hybrid filters [6]-[8] along with conventional rectifiers, have been extensively developed especially in high power rating and already existing installations. However, these filters are quite costly, heavy, and bulky and have reasonable losses which reduce overall efficiency of the complete

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system. Even in some cases the rating of converter used in AF is almost close to the rating of the load. Under these observations, it is considered better option to include such converters as an inherent part of the system of ac-dc conversion, which provides reduced size, higher efficiency, and well controlled and regulated dc to provide comfortable and flexible operation of the system. Moreover, these new types of ac-dc converters are being included in the new text books [9]-[22] and several comparative topologies are reported in recent publications [23]-[25]. Therefore, it is considered a timely attempt to present a broad perspective on the status of ac-dc converters technology for the engineers working on them dealing with power quality issues. This paper deals with a comprehensive survey on the topic of SMR converters. More than 450 publications [1]-[463] are reviewed and classified into four major categories. Some of them are further classified into several subcategories. The first one [1]—[25] is generally on power quality standards, other options, texts, and some survey and comparative topology publications. These converters are subclassified as boost [26]-[250], buck [251]-[306], buck-boost [307]-[427], and multilevel [428]-[463] with unidirectional and bidirectional power flow. The total number of configurations of these converters is divided into eight categories. Some publications belong to more than one category and have been included in the more dominant contribution. The paper is divided into nine sections. Starting with Section I, the others sections cover the state of the art of IPQC technology, configurations, control approaches, components selection, and integration of IPQCs, comparative features and others options for power quality improvement, selection considerations for specific applications, latest trends and future developments in IPQC technology, and conclusive observations. Apart from reducing the intermediate bus voltage, the con-verter in [19] employs resonant technique to further increase the step-down ratio based on a buck converter to eliminate the use of intermediate storage capacitor. The converter features with zero-current switching to reduce the switching loss. However, without the intermediate storage, the converter cannot provide hold-up time and presents substantial low-frequency ripples on its output voltage. Besides, the duty cycle of the converter for high-line input application is very narrow, i.e., < 10%. This greatly increases the difficulty in its implementation due to the minimum on-time of pulse-width modulation (PWM) IC and rise/fall time of MOSFET. More details on comparing different approaches will be given in the Section V. In this paper, an integrated buck–buck–boost (IBuBuBo) converter with low output voltage is proposed. The converter utilizes a buck converter as a PFC cell. It is able to reduce the bus voltage below the line input voltage effectively. In addition, by sharing voltages between the intermediate bus and output capacitors, further reduction of the bus voltage can be achieved. Therefore, a transformer is not needed to obtain the low output voltage.

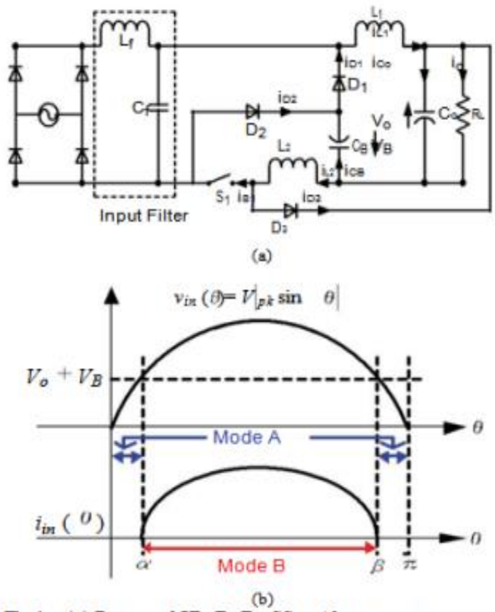

Fig.1. (a) Proposed IBuBuBo SS ac/dc converter.
(b) Input voltage and current waveforms.

To sum up, the converter is able to achieve:

- ➢ Low intermediate bus and output voltages in the absence of transformer;
- ➢ Simple control structure with a single-switch;
- ➢ Positive output voltage;
- ➢ High conversion efficiency due to part of input power is processed once and
- ➢ Input surge current protection because of series connection of input source and switch.

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The paper is organized as follows: operation principle of the proposed IBuBuBo converter is depicted in Section II and fol-lowed by design consideration with key equations in Section III. Experimental result and discussion of the converter are given in Section IV and V, respectively. Finally, conclusion is stated in Section VI.

II. UNDER LIGHT LOAD

Switching loss of power semiconductors is the major cause of low efficiency of single-stage PFC converters under a light-load condition. Due to the dead angle of the input current of the buck PFC cell, it is possible to use this duration to turn OFF the PFC cell to reduce the switching loss of power semiconductors and the conduction loss of passive devices. This section hence explores the possibility of reducing the switching loss by different PWM patterns, while maintaining output voltage (Vo) regulation and dc-bus voltage (VB) control. Note that it is common in single-stage PFC converters that the bus voltage cannot be regulated but only be controlled within a certain range due to the lack of an extra control device in the simplified converter structure; the power MOSFET can achieve only 1-D control which is the output voltage regulation. Here introduces a possible approach to turning OFF the PFC stage in single-switch S2PFC converters similar to that in the two-stage approach [1] as shown in Fig 5. The idea takes the advantages of varying the input voltage and dead angle of input current characteristic of the ac/dc converter. The buck or buck derived PFC converter inherently has such characteristic as there are times during a line cycle when the input voltage is smaller than the output voltage and the PFC stage is effectively turned OFF.

Operation Principle

Here uses a similar concept to burst mode control [1], [2]. But instead of having a random pattern of pulses, the proposed light-load power management has deterministic patterns of pulses as described as follows. There are four distinctive PWM patterns to operate the single-stage buck- derived PFC converters under a light-load condition. In all cases, the output voltage is regulated by a voltage-mode controller

- ➔ The first scheme (M1) does not use any specific switching pattern. The converter operates at fixed switching frequency and the duty cycle reduces when the load decreases. This scheme is used as a reference for comparison of the proposed power management schemes (M2 toM4).
- ➔ The second scheme (M2) operates the converter in the zero crossing region of rectified input voltage where the buck PFC cell is inactive (i.e., Mode A). Note that the duration of Mode A is defined by the voltage conversion ratio and is given by arcsin[(Vo + VB)=Vpk] according to Fig.2(b) .

  However, if operating in Mode A only, the dc-bus voltage will decrease to zero gradually as the charge is taken away from the bus capacitor by owing into the buck PFC cell in order to charge the bus capacitor. Therefore, in order to control the bus voltage, the converter will continue to operate and enter Mode B for a short duration so that the buck PFC cell is active. Hence, the bus capacitor can be recharged to maintain its voltage, but at a lower level.
- ➔ The third scheme (M3) operates the converter around the peak input voltage only. Both buck PFC cell and buck boost dc/dc cell are in active states (i.e., Mode B). Apart from the output regulation, with this method, the dc-bus voltage is somehow controlled as charging and discharging of the bus capacitor occur simultaneously.
- ➔ The fourth scheme (M4) combines the two schemes above; the converter operates at both the zero crossing and peak input voltage regions.

Unlike scheme M2, however, the converter will not operate just beyond the dead angle of input current except for the region around the peak input voltage

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duration. This method also allows for bus-voltage control and output voltage regulation. The schemes M2M4 define when the converter operates to generate the burst mode patterns.

For every burst duration, fixed-frequency PWM pulses are used. The full logic function of the proposed three lightload power management schemes can be summarized by the following Boolean equality

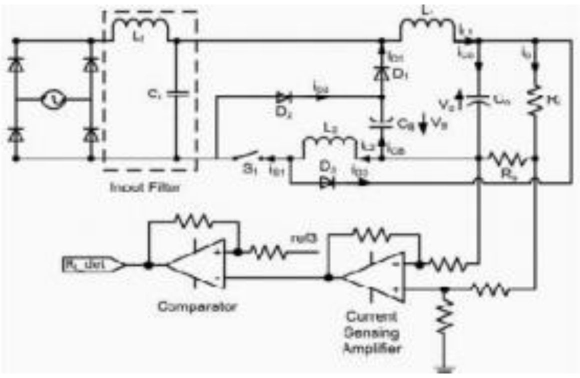

Figure 2: Converter which combines a buck PFC cell and a buck boost dc/dc cell.

III. SOFT SWITCHING- UNDER NORMAL LOAD

Soft switching the voltage and currents are to be varied at different times. In turning on of a device, first voltage decreased to zero and then current is increased. In turning off of a device, first current decreased to zero and then voltage is increased.So in soft switching the power loss can be reduced because there is no presence of voltage and current at the same time during the switching operation .

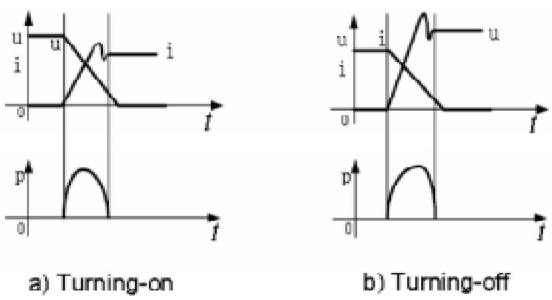

Figure 3: The Process Of Power Semiconductor Device Hard Switching

IV. CONTROL STRATEGIES

The control strategy is the heart of IPQCs and normally implemented in three parts. In the first part of control, the essential variables used in control are sensed and scaled to feed to the processors for the use in control algorithm as the feedbacks. These signals are input ac mains voltage, supply current, output dc voltage, and, in some cases, additional voltages such as capacitor voltage and inductor current, which are used in the intermediate stage of the converters. The ac voltage signal is sensed using potential transformers (PTs). Hall-effect voltage sensors, isolation amplifiers, and low-cost optocouplers are used to sense dc voltages, especially in small power supplies. These voltage signals are scaled and conditioned to the proper magnitude to feed to the processors via ADC channels or as the synchronizing signals for zero-crossing detection. The current signals are sensed using current transformers (CTs), Hall-effect current sensors, and low-cost shunt resistors or tapped isolated winding in the inductors to reduce the cost. These current signals are also conditioned and used as the feedbacks at different stages of control either in control algorithm or in current control stage such as in PWM controllers or in both stages of control. These signals are sometimes filtered either through analog hardware circuits or through software in the processor to avoid noise problems in the control. These sensed voltage and current signals are also used sometimes to monitor, measure, protect, record and display the various performance indices such as THD, displacement factor, distortion factor, power factor, crest factor, individual harmonics, ripple factor, percentage ripples, sag and swell, surges and spikes, components stresses, etc. The cost of these sensing devices such as Hall-effect sensors and other components used in sensing are drastically reducing day by day because of mass manufacturing and competition among the manufacturers. Moreover, some indirect sensing of these signals is also used through additional feedback nodes (terminal) in the IPM of MOSFETs and IGBTs to reduce the cost and to enhance the reliability of the converter. The second stage of control, which is the heart of the control strategy, is the control algorithm responsible for the high-level transient and steady-state performance of the IPQCs. The control algorithms are implemented through analog controllers, low-cost microcontrollers, fast high number of bits DSPs, application- specific integrated circuits (ASICs) depending upon the rating, customer requirements, cost, and types of converters. Normally, dc output voltage of the converters is the system output used as feedback as in outer closed loop control and various control approaches such as PI controller, proportional-integral-derivative (PID) controller, sliding-mode control (SMC) [196], [230], [342], [385] also known as variable-structure control (VSC), fuzzy logic controllers (FLCs) [77], [147], adaptive controllers, neural-network (NN)-based controllers [54] are employed to provide fast dynamic response while maintaining the stability of the converter system over the wide operating range. The output of this voltage controller is normally considered the amplitude of the ac mains input current or indirect derived current such as inductor current and multiplied with unit template derived in phase of ac voltage to generate the desired reference unity power factor, sinusoidal supply current. The third stage of the control strategy of the IPQCs is to derive the gating signals for the solid-state devices of the converters. The reference supply current along with sensed supply current is used in the current controller, which directly generates the switching signals. A number of current controllers namely hysteresis, PWM current or PWM voltage control through proportional, PI, PID, SMC, FLC, and NN-based controllers, are implemented either through hardware (analog and digital ICs) or through software in the same processors (DSPs or microcontrollers, which are used in the second stage) to derive the gating signals. Nowadays, processors are available which are developed only for power electronics applications and have dedicated PWM controllers as an inbuilt feature to implement concurrently all three stages of the control strategy for improving the transient and steady-state performance of the IPQCs. Moreover, in some control approaches, the second and third parts of the control strategy of IPQCs are implemented in the integrated manner over the sensed voltage and current signal. The voltage and/or current or derived power signals are used in the closed loop controllers to derive reference current or voltage signals for generating directly gating signals. The concurrent and integrated implementation of three stages of control algorithm provides cost-effective, compact, and fast response of the IPQCs. The derived gating signals, obtained either through digital output from the processors or dedicated hardware, are normally fed to the optocoupler for isolation, and then amplified to the required level before giving them to the power devices of IPQCs. There are some dedicated driver ICs for this purpose, which result in compact and clean interfacing between control and power stages of the hardware. Moreover, nowadays, IPMs are developed which provide inherent inbuilt derivers along with protection in the power modules. However, the complete integration of control, interfacing and power module of the IPQCs are on the race of development to provide compact, cost-effective, reliable, reduced-weight, and high-efficiency ac-dc converters. Because of heavy application potential of some of the IPQCs, many semiconductor manufacturers have developed dedicated ICs, namely, Unitrode (UC3854), Motorola (MC34261), Analog Devices (ADMC 401), Siemens (TDA 16 888), Texas (TMS320F240), etc., for the control of these converters.

V. COMPONENTS SELECTION AND INTEGRATION OF IPQCS FOR SPECIFIC APPLICATIONS

The selection of components of the IPQCs is very important to achieve a high level performance of ac-dc converters. The main and costly component of the IPQCs is the solid-state power device. In small power rating converters, normally MOSFETs are used resulting in reasonably high efficiency even at high switching frequency responsible to reduce the size of magnetics. In medium power rating IPQCs, IGBTs are invariably used because of their good gating characteristics and capability to operate in wide switching frequency range to make optimum balance between magnetics, size of filter components and switching losses. In a high power rating, GTOs are normally used with advantages of self-commutating and reverse voltage-blocking capability. The concepts of power module, IPM, smart devices, etc., have given a real boost to IPQCs technology because of circuit integration, compactness, cost reduction, reduced noise, and high efficiency. With the several power devices in one module along with their gating and protection integration, it has become possible to develop small-sized and lightweight IPQCs. In many cases, the complete control of IPQCs is also integrated in the same module along with the required modifications to suit for specific applications. Another set of components of IPQCs is the energy storage elements such as inductors, capacitors and other devices used in filters, protection circuits and resonating circuits. For example, a series inductor at the input of a PFC or VSI bridge working as bidirectional boost converter is normally employed as the buffer element between ac mains voltage and PWM voltage generated by the converter to shape the input current into desired manner. The value of this inductor is quite crucial in the performance of IPQCs. With the small value of this inductor the large switching ripples are injected in to supply current, and large value of it does not allow shaping the ac mains current in the desired fashion. Therefore, the optimum selection of this inductor is essential to achieve satisfactory performance of the IPQCs. Similarly, the value of capacitor and inductor as an input filter in buck converter is also quite important for proper response, stability and optimum design of the IPQCs. Moreover, the design of the inductors is also very important to avoid saturation and reducing losses under ac, dc, and mixed excitation. The value of dc-bus capacitor in boost converters and LC filters in buck converters is quite crucial as it affects the response, cost, stability, size and efficiency. A small value of the capacitor results in large ripple in steady state and big dip and rise in dc-link voltage under transient conditions. A high value of it reduces the dc voltage ripple but increases cost, size, and weight. Transformers operating at high frequency are used in power supplies in which transformer weight, size, and rating are quite important. There are continuous attempts to reduce their size and cost through new configurations. The high-frequency transformers are also used in isolated topologies of IPQCs and their design is very important to reduce size, cost and losses. The use of newer magnetic materials and operating frequency plays an important role to revolutionize the technology of IPQCs especially in some power supplies. Some of the IPQCs are developed as an integral part of total converter system for few typical applications. In case of high-frequency electronic ballasts for lighting systems, PFC-based IPQCs are the integral part of high frequency converter system because of compactness for reducing total number of solid-state devices and their control. Similarly, a PFC-based IPQC is also an integral part of switch-mode power supplies, battery chargers, inverter-fed variable-speed drives, etc. Since IPQCs are used as an input front-end converter to feed number of converter and inverter systems for many applications, it is now a very common feature to integrate IPQCs with the second stage converter, resulting ina single-stage and/or compact, high-power-density, lightweight, reduced-cost, efficient complete converter system. Moreover, dedicated controllers are also available for an integrated unit to reduce the cost and to enhance the reliability of total system.

VIII. LATEST TRENDS AND FUTURE DEVELOPMENTS IN IPQCs TECHNOLOGY

IPQCs technology has been developed to a mature level and is finding widespread applications in fraction of watt power supplies to megawatt converter systems in ac-dc-ac link, BESSs, ASDs, etc. However, there are consistent new developments in IPQCs for further improvements in their performance. Some of the new trends are soft-switching techniques to reduce switching losses in IPQCs even at high switching frequency to enhance the dynamic response and to reduce the size of energy storage elements (filters at input and output, high-frequency transformers). The concept of interleaved and multicell is used in the development of PFC-based IPQCs to improve performance and to eliminate EMI passive filters. The

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new developments toward single-stage conversion have resulted in increased efficiency, reduced size, high reliability, and compactness of IPQCs. Sensor reduction has also revolutionized the IPQC technology to reduce the cost and enhance the reliability. Dedicated ASICs for the control of IPQCs are finding wide spread use in the new applications. The new approaches in multilevel converters are offering high efficiency, reduced stress on devices, and reduced high-frequency noise. The further improvement in solid-state device technology in terms of low conduction losses, higher permissible switching frequency, ease in gating process, and new devices especially with low voltage drop and reduced switching losses will give a real boost for IPQCs in low-voltage dc power applications required for high-frequency products. The multiple device integration into a single power module as a cell for direct use as a configuration of IPQCs will result in size reduction, increased efficiency, and a low-cost option. The sensors, control, gating, and protection integration in the IPM will provide a new direction in the development of IPQCs. Dedicated processors and ASICs development for IPQCs are also expected in the near future to reduce their cost, ease in control, and compact and efficient ac-dc conversion. Soft-switching technology is also to be a big hope to relieve thermal design, size reduction, and improving the efficiency of ac-dc converters. The invention of new configurations and conversion stage reduction in IPQCs will explore a number of newer applications.

SIMULATION RESULTS

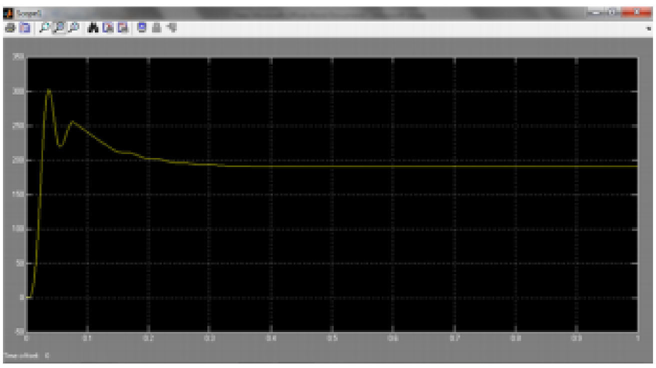

Fig: Output voltage 190 volts for R-Load Vi=390V

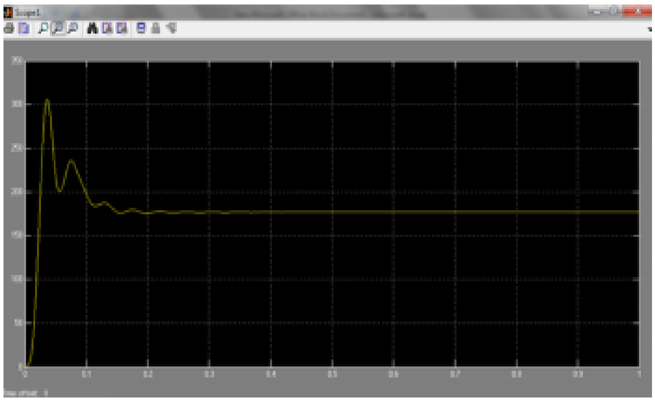

Fig: Output voltage 190 volts for Separately excited DC motor -Load Vi=390V

IX. CONCLUSION

An exhaustive review of IPQCs has been presented to explore a wide perspective of various configurations of IPQCs to researchers, designers, application engineers, and end users of ac-dc converters. A broad classification of IPQCs into eight categories with further subclassification of various circuits is expected to provide easy selection of an appropriate converter for a particular application. These IPQCs can be considered to be a better alternative for power quality improvement because of reduced size of overall converter, higher efficiency, lower cost, and enhanced reliability compared to other means of power quality improvement. These converters provide improved power quality not only at the input ac mains but also at dc output for the better overall design of equipment. These converters have given the feature of universal input to the number of products which can have input power either from ac mains of a varying voltage of 90 to 300 V with a varying frequency from 40 to 70 Hz or dc input Moreover, the use of these IPQCs results in equipment behaving as a linear resistive load at the ac mains. The new developments in device technology, processors, magnetics, and control algorithms will give a real boost to these IPQCs in the near future. It is hoped that this survey on IPQCs will be a useful reference to the designers, users, manufacturers, and researchers working on ac-dc converters.

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