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Research Article

An Integrate Modeling and Controlling of DC-DC Boost Converter Topology

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Abstract: In this study, an integrate modeling and controlling of DC-DC boost converter topology is proposed. The traditional DC-DC boost converter topology has the major drawback such as the input power supply is an unregulated rectified voltage and the load on converters is affecting the effectiveness of the converter. The proposed boost converter topology is differed from the traditional boost converter topology by addition of the auxiliary switch, coupled inductor, clamp capacitor and feedback controller. The presented auxiliary switch, coupled inductor produces the ripple free input current, soft switching like zero voltage switching and zero current switching. The feedback controller control the operation of the main and auxiliary switches, which generates the controlling pulses by using the input parameters the input current and output load voltage as the input parameters. These actions can enhance the converter efficiency and voltage gain. Then the proposed converter is implemented in the MATLAB/simulink platform and the effectiveness is analyzed by comparing with the different converter topologies. The comparison results demonstrate the superiority of the proposed approach and confirm its potential to solve the problem.

Keywords: DC-DC boost converter, feedback controller, zero current switching, zero voltage switching

INTRODUCTION

Dealing with improving extreme discord related to the limited healthy sources and also the minimal efficiency of energy intake, energy-saving techniques grow to be as critical (Zhao *et al*., 2010; Maldonado *et al*., 2011). To be able to monitor electrical power via a number of power generation devices, it will be important for you to alter the particular electrical energy to excessive voltage dc using the DC-DC converter (Hahn and Lehn, 2012). Currently, a lot of DC-DC converters tend to be designed which have a lot of functional benefits over traditional diode or even thyristor rectifiers (Jiao *et al*., 2011; Kanaan *et al*., 2011; Kumar *et al*., 2013). Quite often, the particular input to the electrical power provides is usually an unregulated rectified voltage and also the load upon converters might also alter just because a distributed electrical power composition has been taken. Most of these concern seen in the particular converter breakdown its efficiency and they might also have a very destabilizing impact on that if the controller seriously isn't intended correctly to address these variations. Thus, converters along with uncertainties seen in that desire any sturdy controller that will robustly refuse agitations, that determine load voltage, for any variance with resource voltage, load and any converter details (Patra *et al*., 2012; Danyali *et al*., 2013). Consequently the power electronic converter technology haven't only to fulfill attributes of the load, but also have the ability to process energy along with excessive efficiency, excessive consistency, excessive electrical power solidity and low cost (River *et al*., 2012).

Usually, converter performs in a pair of fundamental modes of work function that may be Continuous Conduction Mode (CCM) along with Discontinuous Conduction Mode (DCM) Husna *et al*. (2012). The actual hybrid modeling along with control on the converters employed for dealing with low trivial difficulty inside CCM along with DCM operations (Hejri and Giua, 2011). The actual DCM function on the converter limitations the utmost inductor current and prevents this high energy function of that converter (Behjati and Davoudi, 2013). To use some sort of manageable user interface in between some sort of super-capacitor stack and a voltage regulated DC bus, eight-channel interleaved converter was used (De *et al*., 2013). Various procedures happen to be used by this modeling along with control of DC-DC converters (Luca *et al*., 2010). The actual control approach should be to allow this DC-DC converter managing inside the whole array of its developed ranking having actually zero reactive energy with every single bridge. Wide production variety can be obtained by a reconfigurable structure DC-DC converter having extensive production variety along with constant peak power (Weixing and Jovcic, 2013). Control input of DC-DC transferring

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converters is usually provided by a new voltage responses having pulse width modulation (PWM) Takimoto and Kuchii (2009). An integrated controller changes this the two IGBTs using a pair of secondary non-overlapped PWM impulses thereby it defines a clean bi-directional switching (Xuhui *et al*., 2011). The integral control is most effective in the electronic digital PID control method (Kurokawa and Higuchi, 2012). Pulse Shift Modulation (PSM), dynamically manipulates this switching frequency as well as the duty cycle on the control pulse to maintain consistent production in addition to slow up the loss inherent for the two PWM along with PFM methods (Agnihotri *et al*., 2010).

RECENT RESEARCH WORKS: A BRIEF REVIEW

Several related functions happen to be persisted within materials which will be based upon modeling and controlling of DC-DC converter. Some of them assessed the following. Fuentes *et al*. (2011). have offered the particular enhance from the Large Hadron Collider (LHC) trials on CERN sets a new difficulties for that driving of the detectors. One of the driving plans under examination was determined by DC-DC buck converters placed on the front-end modules. The challenging ecological disorders encourage rigorous limitations towards converters regarding low volume, radiation and magnetic field tolerance. Additionally, the sound emission from the switching converters cannot have an effect on the efficiency from the power systems. A report from the sources and also trails regarding sounds of any synchronous buck converter continues to be manufactured for identifying the crucial details to relieve the emissions.

Tsang and Chan (2012) have executed an easy behaving regenerative dc electronic load based on the SEPIC converter. A straightforward multiloop feedback control system have been layout with the SEPIC converter to realize the key functionality regarding electronic load. As an alternative to discharging through resistive load, the output of the converter was attached to standard rechargeable battery power in ways that released power could be rescued. Circuit implementation with the offered plan was shown in addition to experimental benefits were being bundled to show the effectiveness of the offered layout.

Yang and Do (2013) have proposed some sort of bridgeless SEPIC converter using ripple-free input current. In the suggested converter, the actual input bridge diode ended up being removed and the conduction loss seemed to be lowered. Also, the input current ripple was drastically lowered with the use of an extra winding on the input inductor as well as a auxiliary capacitor. Just like the typical PFC SEPIC converter, the input current in a switching period can be proportional for the input voltage as well as in close proximity to unity power was accomplished. The actual functional principles, steady-state evaluation, as well as layout equations on the proposed converter have been identified in more detail.

Palomo *et al*. (2013) have proposed a family of switching step-down dc-dc converters based on the principle of reduced redundant power processing. In which states that the power transfer from input port to output port on interconnected converters might be reduced, if the non-cascading connection had been used. The basic principle had been a good choice for establishing new converters. The ensuing converters were made by means of a couple of LC systems and also a couple of active switches, additionally they've wide transformation proportions and also quadratic dependence according to the duty rate.

Bhattacharyya (2013) has suggested the actual DC-DC converters looking on the trend associated with design of embedded converters. Beginning from the conventional inductor centered converters to the current trend associated with design of embedded DC-DC converters was discussed. Many concerns which may engage in critical role in the design associated with above converters had been elaborated along with feasible therapies in order to abate the issues to offer the greater overall performance.

Altin and Ozdemi (2013) have suggested about the three-phase single phase grid interactive inverter along with utmost electric power point tracking ability. The system is made of three-level neutral point clamped inverter, LCL output filter, line frequency transformer, PI current regulator and fuzzy logic based maximum power point tracking algorithm. Rate of change of photovoltaic power and voltage were being understood to be input issues and alteration in reference current ended up being understood to be result variable for the fuzzy logic controller. The particular offered utmost electric power point tracking formula was strong regarding parameter variations of photovoltaic system with adaptive feature of fuzzy logic controller. Maximum power point tracking algorithm determines the inverter current reference according to the process circumstances for example irradiation degree and heat and PI regulator shapes your inverter output current. Two capacitors' voltages associated with neutral point clamped inverter may also be stabilized. Additionally, the inverter output current is at sinusoidal waveform and in phase with line frequency and phase.

Taghvaee *et al*. (2013) Photovoltaic (PV) can be a rapid rising segment among Renewable Energy (RE) methods, in whose development will be due to depleting fossil gas and also climate-changing the environmental pollution. PV power output capacity, even so, is lower as well as the affiliated expenses however high, consequently endeavors keep produce PV converter and controller, aiming for higher power-extracting effectiveness and also cost efficiency. Different algorithms have been recommended regarding Maximum Power Point Tracking (MPPT). Considering that the number of suitable converter regarding unique application with a significant effect in perfect overall performance of the photovoltaic technique, this kind of cardstock reviews the particular state-of-the-art with exploration performs with non-isolated DC-DC buck, boost, buck-boost, Cúk and SEPIC converters and also their own characteristics, to get a ideal suiting a credit application using Maximum Power Point Tracking. Assessment displays that there is any issue inside bodies overall performance good style of converter is utilized. This is usually figured the most beneficial number of DC-DC converter which can be actually appropriate and also pertinent inside PV technique would be the buck-boost DC-DC converter given it will be able to accomplishing optimum operation regardless of load value using negotiable overall performance effectiveness and also price issue.

The particular converter topology plays a significant role regarding varies applications such as power, power system and so forth. Mostly, the input power can be an unregulated rectified voltage, along with the fill with converters also can vary given that a distributed power set up is being individualized. In reputation regarding uncertainties, the converter degrades its presentation and may even in addition use a destabilizing end result on it should the controller is not made adequately to adopt problem of the variants. Therefore, converters together with uncertainties present in the item desire a robust controller in order to may firmly refuse agitations, that is regulate load voltage, for any variance in source voltage, load and also every other converter parameters. Distinct conventional solutions to model large order intricate DC-DC converters, switching signal flow graph approach, the state space averaging approach and so forth. Even though switching signal flow graph approach has already been used by many topologies, it isn't suited to the making it controller design. Based on using this method, small signal transfer traits include typically been derivative to design the details regarding traditional controllers such as voltage mode controller and also current mode controller. With this direct design approach, the dynamic response is at rest is concluded because large frequency mechanisms usually are averaged out within the model. This can make the controller not fit regarding large signal dynamic control nevertheless the state space modelling method can be used.

DC-DC BOOST CONVERTER MODELING AND CONTROLLING TOPOLOGY

In general the boost converters are used to improve the output voltage into the specified level compare to the input voltage. The DC-DC converter power conversion process is usually achieved by appropriate

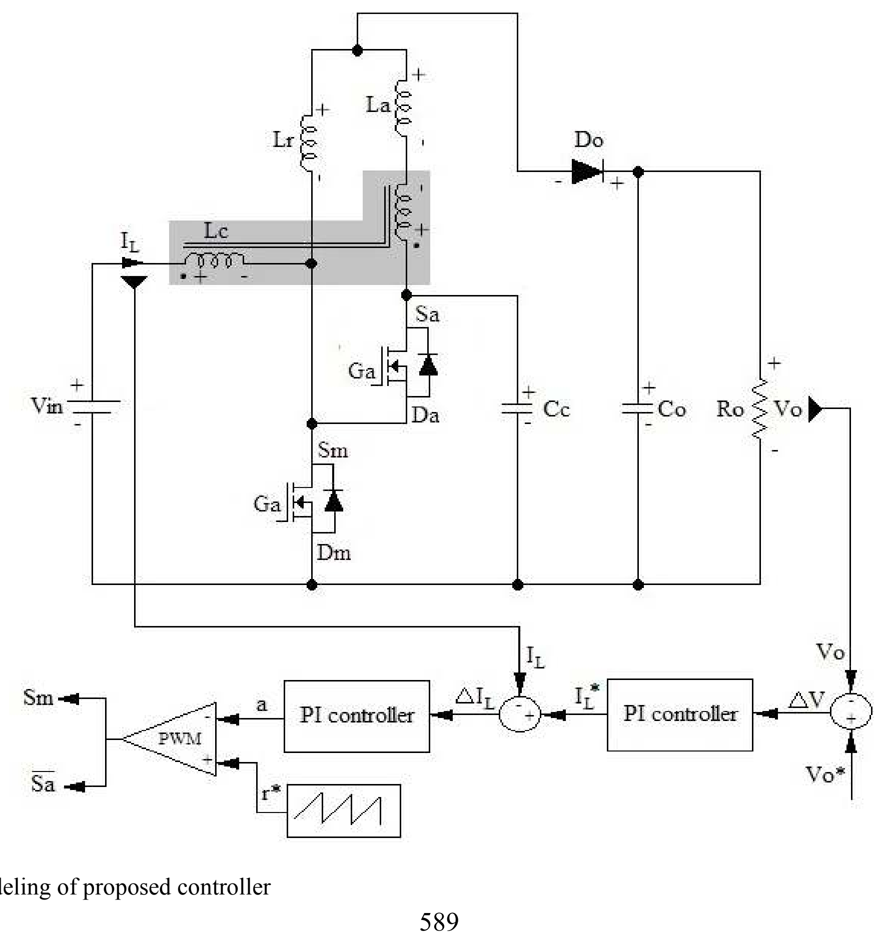

Fig. 1: System modeling of proposed controller

circuit components and the proper operation of the semiconductor switches (Dhali *et al*., 2012). Here, the DC-DC converters work under the steady state condition only, but in practical case, this condition may not possible. This change makes the deviation and the outcomes of the circuit considerably varied from the nominal value. During this disturbance operation the designed controller may protect all the components present in the circuit and limiting the stress on them. This section describes about the proposed integrated modeling and controlling topology of the DC-DC boost converter. The proposed DC-DC boost converter differs from the nominal boost converter (Abubakkar and Shangeetha, 2012), i.e., it presented with the coupled inductor, clamped capacitor, the auxiliary IGBT switch and auxiliary inductor, which makes the ripple free input current and ZVS operation of the main and auxiliary switches. The controller effectively maintains the stability and improves the efficiency and voltage gain of the circuit. The controlling structure is described in the following Fig. 1.

The proposed DC-DC boost converter has the coupled inductor L_c, which has the advantages like single magnetic component and ripple free input current. It also includes the components like resonant inductor L_r, auxiliary inductor L_a and active clamp cell consisting of auxiliary switch S_a with clamp capacitor. The proposed integrate controller design requires the output voltage V_o of the DC-DC boost converter and input current I_L of the converter to control the switches. Here, the output voltage is compared with the reference output voltage V_o^*. The difference between the actual output voltage V_o and the reference output voltage V_o^* is mentioned as ΔV, which is led to the input of the Proportional Integral (PI) controller. The PI controller of the integral term causes to reduce the steady state error to zero. The lack of derivative term is used to maintain the system steady during the steady state condition. The output of the PI controller is reference input current I_L^*, which is compared with the actual input current I_L. The difference current ΔI_L is regulated using the PI controller and allowed as one of the input of PWM generator. The PWM generator takes the reference ramp signals r^* to make the controlling pulses of the main and auxiliary switch S_m and S_a, i.e., PWM output is allowed as main switch S_m and inverse of PWM is allowed as auxiliary switch S_a. Then the controller action depends on the proposed converter model.

Analysis of the proposed DC-DC boost converter: The proposed DC-DC boost converter's equivalent circuit is described in the following Fig. 2. Here the coupled inductor L_c is modeled as the magnetizing inductance L_m and an ideal transformer with the turn's ratio 1: n. The main S_m and auxiliary switches S_a present in the circuit has the body diode D_m and D_a with parasitic capacitance C_m and C_a. The operation of the converter in the one switching period is divided into 5 modes. For simplification, the capacitor present in the converter C_a, C_o and C_c are considered as large and the voltage ripples are ignored. During the operation condition the switches present in the circuit works asymmetrical manner depending on the duty ratio of the main switch S_m.

The above circuit describes the proposed equivalent circuit of the proposed converter. The output of the proposed circuit is the boost voltage, which is obtained by the possibility of high voltage gain. The proposed converter voltage gain is explained in the following Eq. (1). The waveform of the proposed converter is described in the following Fig. 3:

$$M = \frac{V_o}{V_{in}}\left(1 + kD + \frac{(1-k)DL_a}{L_a + L_r}\right) \quad (1)$$

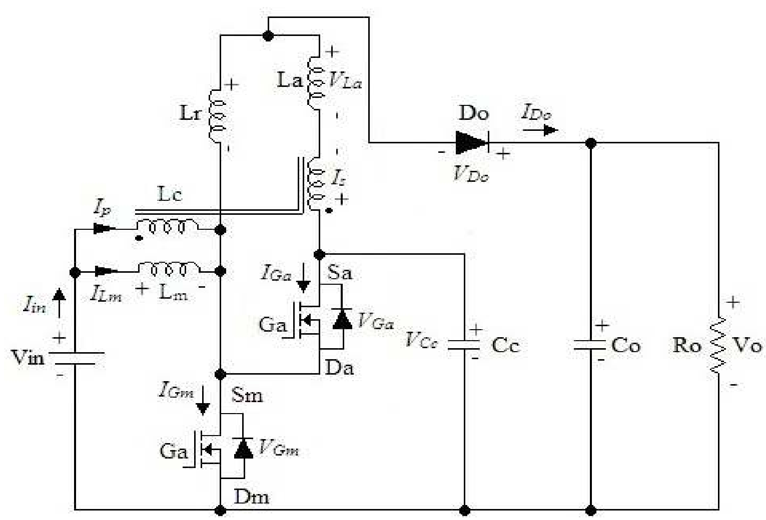

Fig. 2: Equivalent circuit of proposed converter

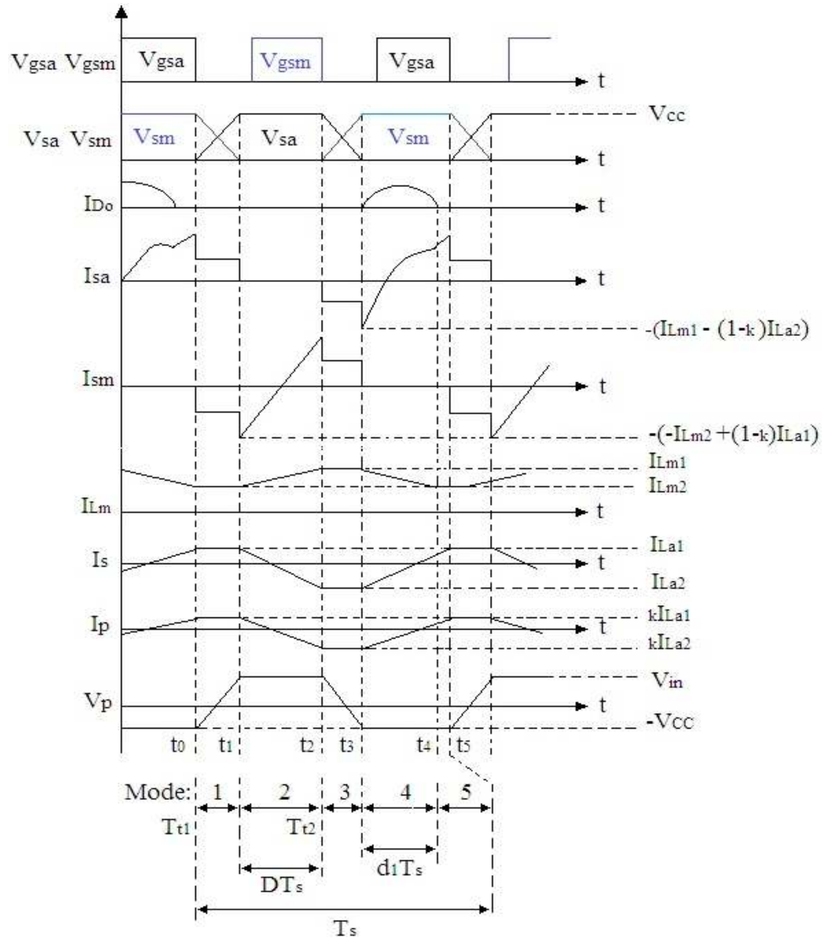

Fig. 3: Waveform of the proposed converter

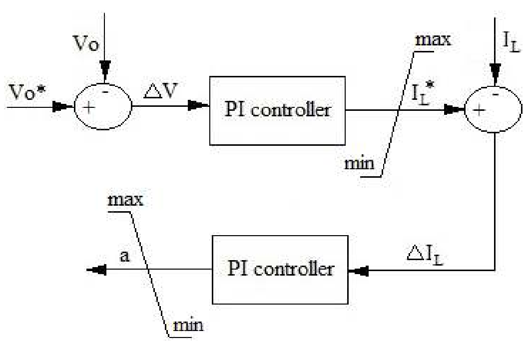

Fig. 4: Structure of the controller

Table 1: Implementation parameters

Parameter	Value
Input voltage (V_i)	60V
Output voltage (V_o)	100V
Auxiliary Inductors (L_a)	34.5μH
Resonant inductor (L_r)	1.1μH
Clamp capacitor (C_c)	1μF
Load capacitor (C_o)	1μF
Load resistance (R_o)	10 Ω

Feedback controller: This section describes about the feedback controller of the proposed DC-DC boost converter. Here, the proposed converter input current I_L and the output voltage V_o are compared with reference values, i.e., reference input current I_L^* and reference output voltage V_o^*. The difference between the reference and actual quantity is measured, which is ΔV and ΔI_L. These values are used for the generation of the controlling pulses. The controlling structure is explained in the following Fig. 4.

EXPERIMENTAL RESULTS AND DISCUSSION

The proposed mutual method is implemented in MATLAB/simulink 7.10.0 (R2012a) platform, 4GB RAM and Intel(R) core(TM) i5. The proposed boost converter topology is differed from the traditional boost converter topology by addition of the auxiliary switch, coupled inductor, clamp capacitor and feedback controller. The mentioned arrangements can effectively maintain the proposed converter voltage gain and the efficiency. Here, the proposed converter's effectiveness is tested with different topologies like traditional boost converter, proposed converter without controller, i.e., the Pulse Width Modulation (PWM) scheme is utilized for the main and auxiliary switches. The simulated proposed converter model with controller is described

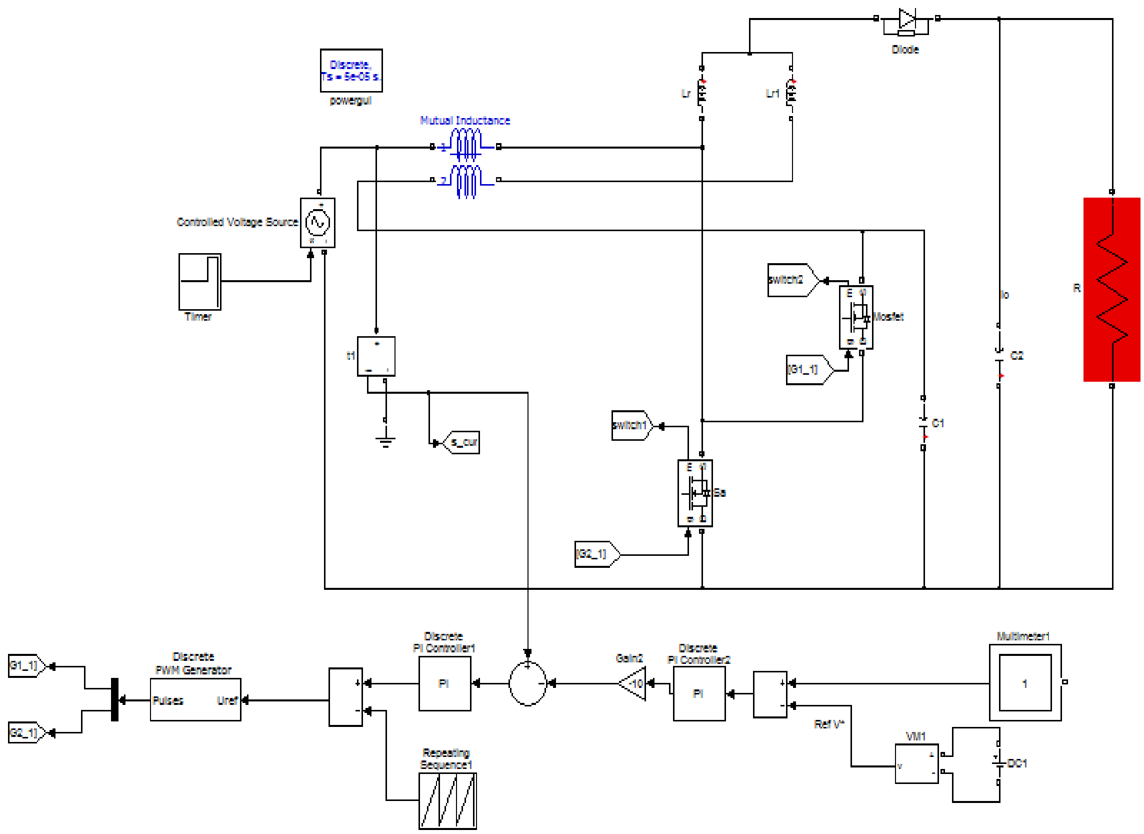

Fig. 5: Proposed converter topology with controller

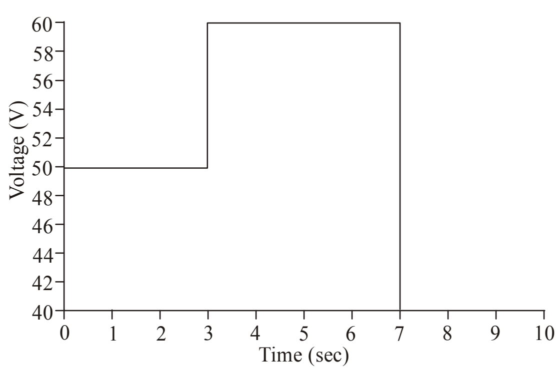

Fig. 6: DC-DC converter input voltage variation

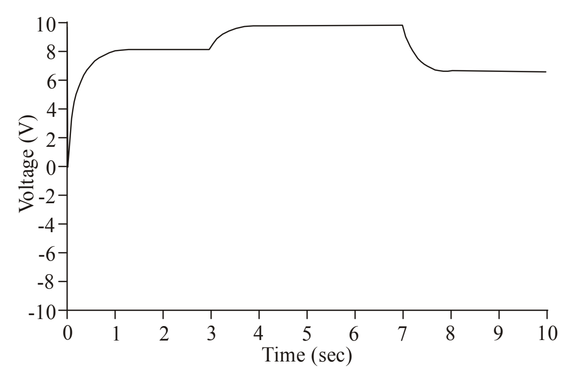

Fig. 8: Inductor current of the proposed converter topology

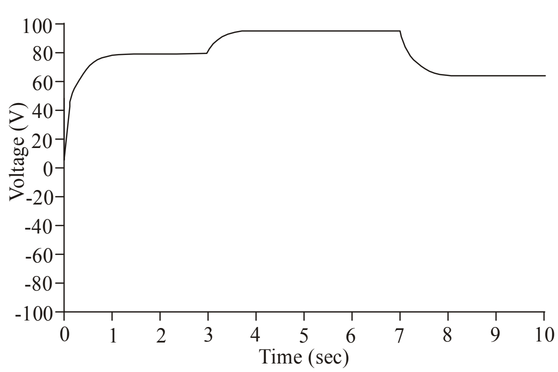

Fig. 7: Output voltage of the proposed converter

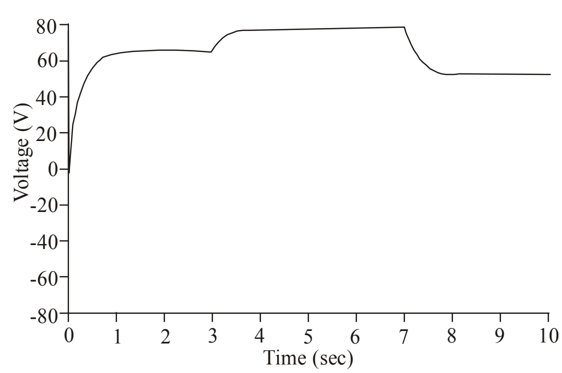

Fig. 9: Capacitor voltage of the proposed converter topology

in the following Fig. 5. The converter utilized components configurations are presented in the following Table 1 and the results of the mentioned topologies are displayed in the following.

The proposed converter's effectiveness is tested under two types of analysis, i.e., analysis by the input voltage variation and analysis by the load variation. The first type of analysis has been done by different types of input voltages with full load. The converter performance has been simulated at the time interval Ts = 10 sec. Here, the initial simulation time 0 to 3 has 50V input supply, after 3 to 7 sec, the input voltage could be increased at 60V and finally simulation time 7 to 10 contains 40V DC input voltage. It was described in the following Fig. 6.

The proposed converter topology (Fig. 5) with the above Table 1 mentioned configuration is tested for the wide range of input voltage variation. According to the input voltage variation the obtained proposed converter topology output voltage is mentioned in the following Fig. 7. It is clearly shown that the initial input voltage has improved to 80V and afterwards changed into 95V due to the increased input voltage. Finally it reaches the 62V for the reduction of the input voltage period. The output voltage of the converter has been a smooth curve, because of the auxiliary switch, coupled inductor and the feedback controller. The proposed converter topology output current is given in the Fig. 8, which illustrates that the current has been 9A at the maximum input voltage profile. The capacitor voltage and the inductor current have been explained in the following Fig. 9 and 10. From the figure, we can clearly identify that the better variation of the voltage and current quantities are attained due to the presence of ripple free arrangement and the controller circuit. Then the performances of the three circuits according to the input voltage variation are compared in the Fig. 11 and 12. Here, the output voltage of the traditional converter, proposed converter without controller and proposed converter topology is compared in the Fig. 11. Similarly the output current of the converters are described in the Fig. 12. It was clearly displayed that the proposed method contains the improved voltage conversion performance and the reliable variations.

Then the mentioned converters are tested by constant input voltage 50V different types of load values, i.e., 60%, 80% and full load. This condition is simulated under Ts = 5 sec. The traditional converter output voltage according to the load variation is described in the Fig. 13. Depending on the load variation the output voltage profile has been changed. The output current of the traditional converter with the load variation is given in the following Fig. 14. Here, the 60% load has 8.5A, which is reduced into 6.25A at the 80% load; finally it is 5A at the full load condition. The load variation is applied into the proposed converter without controller circuit. The output voltage and current of the proposed converter without controller is described in the following Fig. 15 and 16. The output performance of the proposed converter without

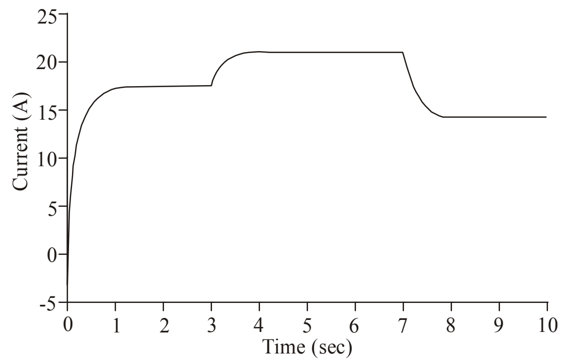

Fig. 10: Inductor current of the proposed converter topology

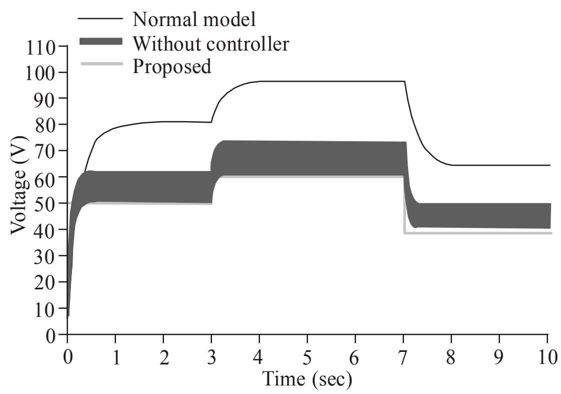

Fig. 11: Comparison of the converter output voltage

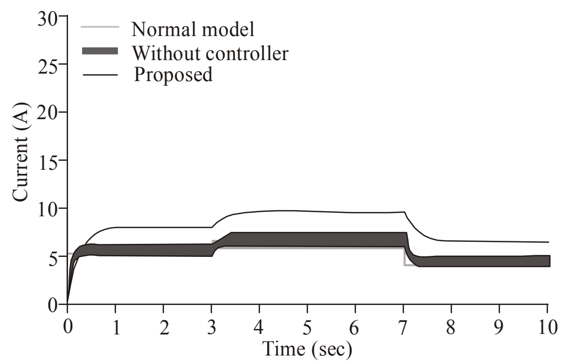

Fig. 12: Comparison of the converter output current

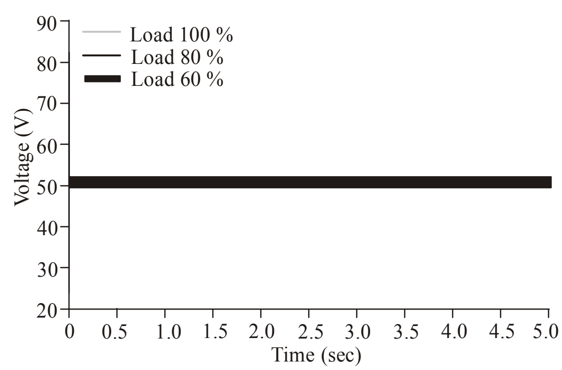

Fig. 13: Output voltage of the traditional converter

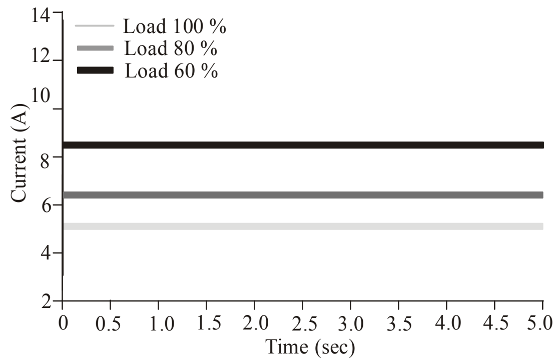

Fig. 14: Output current of the traditional converter

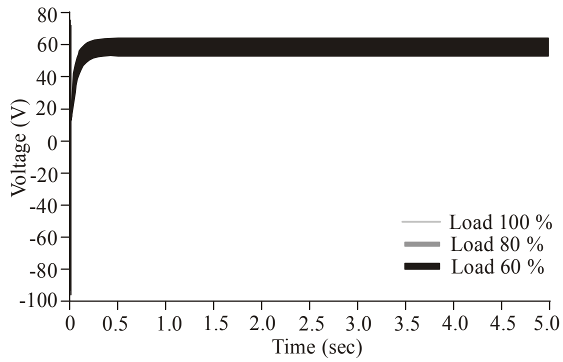

Fig. 15: Output voltage of the converter without controller

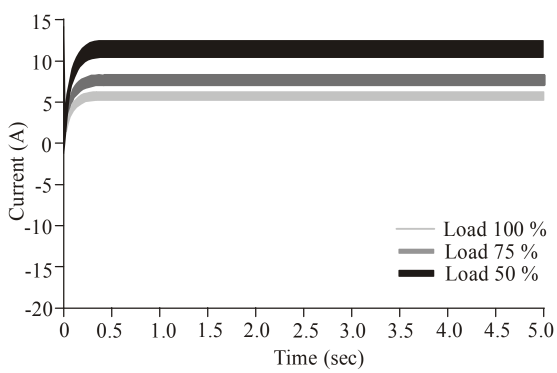

Fig. 16: Output current of the converter without controller

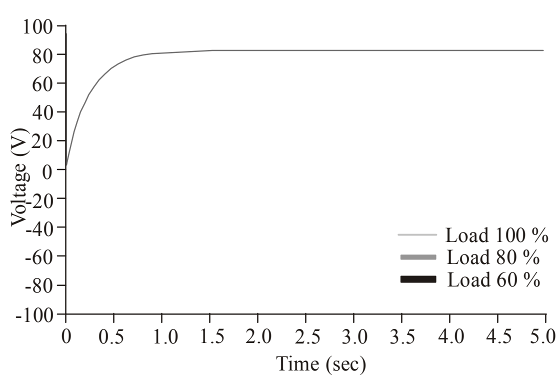

Fig. 17: Output voltage of the proposed converter

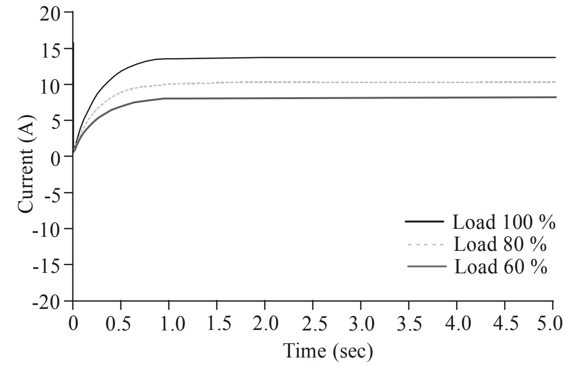

Fig. 18: Output current of the proposed converter

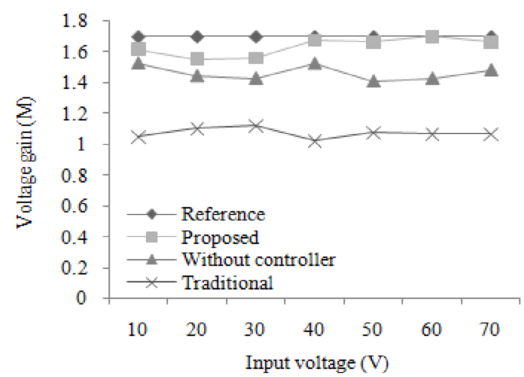

Fig. 19: Voltage gain comparison

controller is affected by the disturbances, because of the load variation. The traditional converter and the proposed converter without controllers cannot produce smooth curves according to the load variations. Similar types of load variations are applied to the proposed converter topology, which outcomes are noted in the following Fig. 17 and 18. The output voltage of the proposed converter topology is smooth curve and it enhances the converter performance according to the load changes. The 60% load has 14A, which is reduced into 10A at the 80% load; finally it is 7A at the full load condition. It finalizes that the proposed converter effectively controls the main and auxiliary switches, which provides the ripple free outcome, improved voltage gain and efficiency. The voltage gains of the mentioned converters are calculated by using the following equation (Do, 2012) (2):

$$Voltage\ \ gain\ (M) = \frac{V_o}{V_{in}} \approx \frac{1+D}{1-D} \tag{2}$$

The voltage gain of the traditional converter, proposed converter without controller and the proposed converter topology is compared with the reference voltage gain 1.7, which is described Fig. 19. Here, the proposed method is always near to the reference voltage gain depending on the input voltage variation. From the figure it can be finalized that the proposed converter topology has improved voltage gain compared to the other topologies.

CONCLUSION

This study proposed an integrate modeling and controlling of DC-DC boost converter topology. Here, the proposed converter is differed with the traditional converter by the addition of auxiliary switch, coupled inductor, clamp capacitor and the feedback controller. The feedback controller generates the control pulses depending on the converter output voltage and the input current. The advantage of the proposed converter topology is ripple free input current, enhanced voltage gain and efficiency. The performance of the proposed method is tested under different topologies like traditional boost converter and proposed method without controller. Here, the converter input voltage and the load value is varied for different levels and the output performance of the converter was evaluated. The analysis results proved that the proposed converter topology is the most effective topology for different voltage and load conditions, which is competent over the other topologies.

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