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A Comparison Review of 2-Phase & 3-Phase Interleaved Boost Converters used in Renewable Energy Sources

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ABSTRACT

The power level of a power electronic converter is limited due to several factors, increase in current causes an increase in the stress on switching devices. Besides, the diode reverse recovery current and parasitic resonance current become greater than the main switch can handle. Hence, the size of the boost inductor should be increased to avoid saturation and overheating problems. In order to advance the power level significantly the methods, including device paralleling, module paralleling and interleaving are widely utilized. For some applications, boost stages are designed modularly such that the converter stages can be connected in parallel to meet the increasing power requirement. This method is preferable as it is easy to increase the power rating by simply stacking converters with increased redundancy. The drawbacks of the method are it's relatively high cost, large volume covered, and cooling difficulties. This paper reviews the ripple input current and output voltage of 2 and 3 phase Interleaved Boost Converter (IBC).

***Keywords—* Renewable Energy Systems, Solar Photo Voltaic,Wind Turbine Generator Artificial Neural Network, PhaseShift Modulation, Interleaved Boost Converter,Hybrid Power System.**

I INTRODUCTION

Generating electricity from systems based on Renewable Energy Systems(RES) applications like Photo-Voltaic (PV) cell ,fuel cell ,wind etc are one of the reliable remedies to conserve energy[1].For PV cell, PV model[2-5] is generated and analyzed in conjunction with power electronic switches for a maximum power point tracker[6-7][63].While considering fuel cells[8],it has been used as the phenomenon sources of distributed energy. Because of the high efficiency, low environmental impact and scalability [9], the fuel cell based supply system converts its generated low dc voltage using power conditioner [10].Hence it is used for residential application.

The battery model system is implemented using effective equivalent circuit model structure featuring lead-acid batteries[11-13].Diesel Wind Turbine is another application of RES which satisfies the power demand [14].These are superior when compared to the conventional sources like fossil fuels ,RES will fulfill the world's energy demand.

Paralleling two or more switching devices is a widely utilized approach to increase the current handling capability of switches. The advantages of the parallel converters scheme is to implicit proper design, dynamic response, robustness and tight steady state [19-21].In high power high density converters, the power MOSFETs is being used in parallel as the main switch to meet the current rating requirement, also it increase the switching frequency and reduce the power loss. Proper gating by PWM signal is applied to devices in order to reduce switching losses and switch currents are shared [22].This method is useful in devices with positive temperature constant (PTC) such as MOSFETs. The device paralleling method is not practical for all applications. The power stage of the converter consists of semiconductor switches and magnetic components.

This paper is organized as follows. The wind generator and wind turbine characteristics are described in section II, modeling of proposed system is analyzed in III, MPPT algorithm is analyzed in section IV, simulation result is analyzed in V, Conclusion in section VI.

II 2-PHASE INTERLEAVED BOOST CONVERTER

During the last few decades, power electronics research has focused on the development of multi-phase parallel DC-DC converters. It is useful to obtain the regulated output voltage from several input power sources such as a solar array, wind generator, fuel cell[26].Among the various topologies, interleaved boost converter (IBC) is considered as a better solution for fuel cell systems[65-66], due to improved electrical performance, reduced weight and size[66].This provides positive output voltage without any additional transformer and it is capable of bidirectional operation, increase the power processing capability and improves the reliability of the power electronic system[25]. While comparing conventional single input converters, this topology minimizes the total number of components [27] and has simple circuit structure [28].

2.1 Advantages of Interleaved Boost Converter

The advantages of constructing a power converter by means of interleaved parallel connected converters [29] are ripple cancellation in both the input and output waveforms to a maximum extent, and lower value of ripple amplitude and higher ripple frequency in the resulting input and output waveforms [30-31].By splitting the current into many power paths, conduction losses (I^2R) can be reduced, increasing overall efficiency [32].Multi-phase interleaved boost converter created by paralleling several phase legs and inductors to share the input current. Main asset of this configuration is to increase the power quality of the converter and the input current ripple is significantly reduced with the increase in number of phases [33].Designing converter with very stringent power quality, high current, low harmonic distortion [34] requires this configuration. Increasing the phase inductance is more essential in interleaved configuration [33].

Mathematically there is no limit for the number of interleaved power branches. But in practice as the phase number increases, the system complexity increases and maintenance becomes difficult. The input/ EMI filter size and output capacitor size are reduced in proportion with the ripple reduction [35-36].The disadvantage of the interleaving method is the increase in the gate driving logic complexity, but necessarily the size and cost of the gate drive [35]. Logic signals to all the gates are equally phase shifted by the amount defined in (1)

$$\text{Phase shift} = k*2/N \qquad (1)$$

In Equation (1), '*N*' denotes the number of interleaved branches and '*k*' denotes the order of discrete interleaved branches (*k = 1,…, N).*Coupled inductor is one of the main components in power electronics circuits, plays an important role in DC/DC converters[37].

From the literature review **,**the various configurations of the IBCs such as uncoupled, directly coupled and inversely coupled it is reported that the directly coupled IBC [42][62][86] gives a reduced input current ripple[40] ,output voltage ripple, responds fast.[39] than the other two systems and it is best suited for renewable energy applications [15][38].The soft switching dc-dc converter with the coupling inductor suppress the overvoltage [41].

2.2 Ripple Analysis in 2-Phase IBC

In a two-phase converter, there are two output stages that are driven 180 degrees out of phase. By splitting the current into two power paths, conduction (I^2R) losses can be reduced, increasing overall efficiency compared to a single-phase converter. Because the two phases are combined at the output capacitor, effective ripple frequency is doubled, making ripple voltage reduction much easier. Likewise, power pulses drawn from the input capacitor are staggered, reducing ripple current requirements. To overcome these limitations multiphase interleaving technique is used [47].

Multiphase dc-dc converters are widely used in high power applications[65] ranging from automotive to distributed generation [56][59-60][81] compared to single phase converters[48] .This topology uses a coupled inductor in the place of main inductors of the conventional IBC [48][51][69]By coupling the main inductors, the input current ripple and switching loss[58][64][67-68] can be reduced more further[38][48][53], improves the dynamic performance[52], efficiency[65][69], switching speed[49] and output voltage[54].Moreover the power density can be easily achieved because there is only one core adopted[50][62] .In case of high output power and low output voltage it is typically beneficial to use paralleled converters[61].

The circuit of the coupled inductor is shown in Fig.1

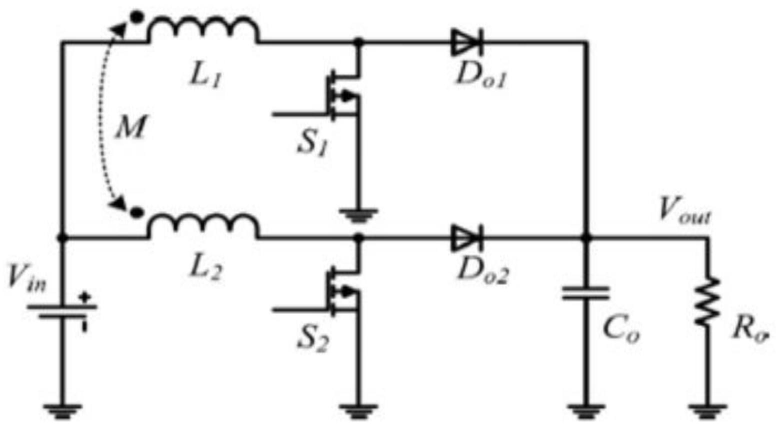

Fig. 1. Circuit diagram of 2-phase IBC

TABLE I

Parameter N=2	I_{min}	I_{max}	I
Ripple in Inductor 1	4.08	4.24	0.16
Ripple in Inductor 2	4.09	4.27	0.18
Input Source Current Ripple	8.28	8.36	0.08

Table 1 shows the output ripple voltage of the 2 phase IBC for all the RES. Figure 2 shows the corresponding wave form.

III 3-PHASE INTERLEAVED BOOST CONVERTER

A three-phase high power dc/dc converter with an active clamp is capable of increased power transfer due to its three-phase power configuration, and it reduces the rms current per phase which is imposed into fuel cells thus reducing conduction losses compared to other conventional boost converters [84-85].Parallel control method of three-phase interleaved dc-dc converters can be used for the battery test system and it is used for improving the unbalance factor. Here the current sharing control method is used for maintaining dc-dc converter current equal [70].

Three phase interleaved DC-DC converter [82] can be connected with electric vehicle to operate motors and inverters [71].The input ripple current is minimized by three phase interleaved operation and the transformer turn ratio is reduced by its inherent boost mode operation effectively [72]. The interleaved structure of the current source port can provide the desired small current ripple to benefit the PV panel to achieve the maximum power point tracking (MPPT).The MPPT and power flow regulations are realized by duty cycle control and phase-shift angle control, and the zero-voltage switching can be guaranteed in the PV application even when the dc-link voltage varies [73]. The input ripple current is minimized by three phases interleave operation, and the transformer turn ratio is reduced by its inherent boost mode operation

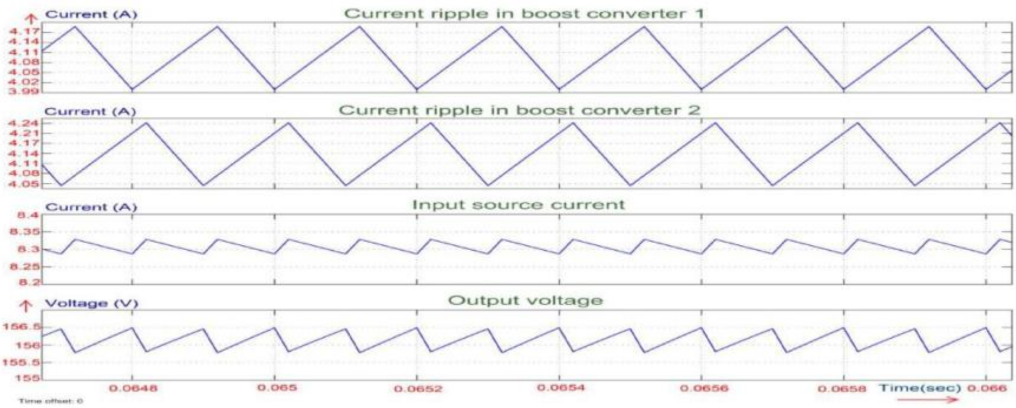

Fig. 2. Ripple waveforms of 2-phase IBC

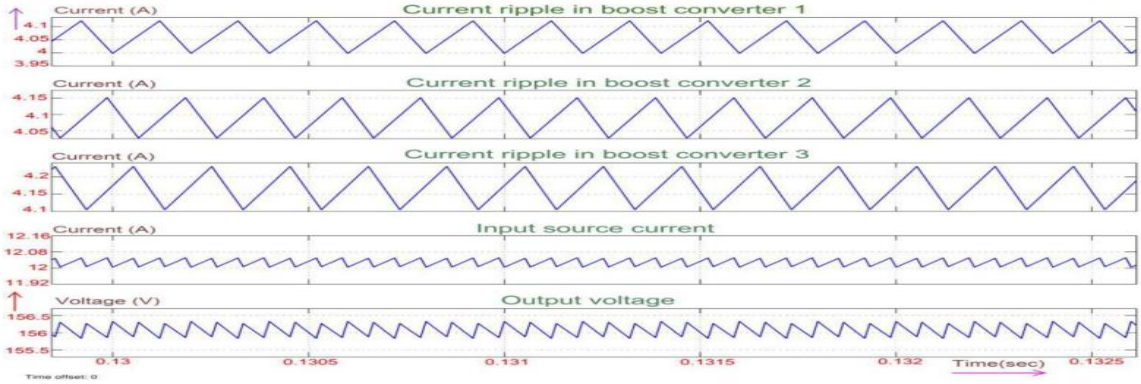

Fig.3. Ripple waveforms of 3-phase IBC

effectively [74][77].The battery is connected to the three-phase interleaved dc-dc converter in order to reduce the ripple current from 32.5% to 8%,increase of battery lifetime and reduction of total size of inductors. The ripple current [79] is further reduced to 2%from 8% by connecting a filter capacitor and design rule of filter capacitor is analyzed [75].

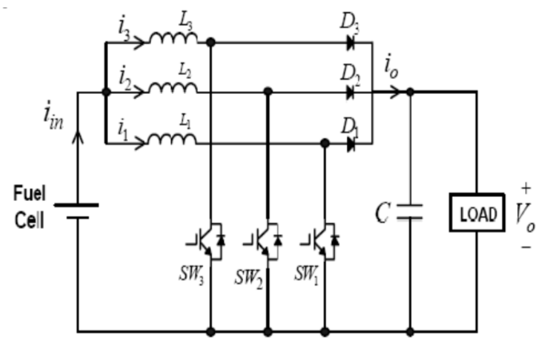

Fig. 4. Circuit diagram of 3-phase IBC

TABLE II

Parameter N=3	I_{min}	I_{max}	I
Ripple in Inductor 1	3.99	4.1	0.11
Ripple in Inductor 2	4.03	4.14	0.11
Ripple in Inductor 3	4.01	4.13	0.12
Input Source Current Ripple	11.94	11.98	0.04

III CONCLUSION

On detailed investigation carried out on literature on 2-Phase & 3-Phase Interleaved Boost Converters with various parameters of input current ripple , output voltage ripple it is understood that with increase in number of phases the ripple can be reduced [Tab III].

TABLE III Comparison of Input Current Ripple & Output Voltage Ripple

No. of Phase	Input Source Current Ripple	Output Voltage Ripple
2	0.04	0.63
3	0.022	0.54

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