Power Conversion Improvement of Fuel Cell Based DG's with ANFIS Controller

Ieee Adda[1], Durgam Kumaraswamy[2] and B.V. Sanker Ram[3]

[1] SVS Institute Of Technology

Received: 11 December 2015 Accepted: 2 January 2016 Published: 15 January 2016

Abstract

This paper defines a novel ANFIS based controller is used for enhance power conversion efficiency of renewable energy source. Hear fuel cells are chosen among different types of renewable energy sources. Here a new converter topology is proposed to minimize conversion losses of devices used for power conversion. The input passive elements of rectifier reduce the circulating currents. The transformer and mutual inductors used to reduce stress on the power electronic conversion devices to improve conversion efficiency and voltage regulation. The ANFIS controller will enhance the power conversion efficiency by improving the switching speed and accuracy of in reference generation and it give extended stable operation.

Index terms— fuel cell (FC), renewable energy sources, conversion losses, adaptive nero fuzzy interface system (ANFIS).

1 Power Conversion Improvement of Fuel Cell based DG's with ANFIS Controller

Abstract-This paper defines a novel ANFIS based controller is used for enhance power conversion efficiency of renewable energy source. Hear fuel cells are chosen among different types of renewable energy sources.

Here a new converter topology is proposed to minimize conversion losses of devices used for power conversion. The input passive elements of rectifier reduce the circulating currents. The transformer and mutual inductors used to reduce stress on the power electronic conversion devices to improve conversion efficiency and voltage regulation. The ANFIS controller will enhance the power conversion efficiency by improving the switching speed and accuracy of in reference generation and it give extended stable operation.

2 I. Introduction

uel Cells (FC) are power sources that convert electrochemical energy into electrical energy with high efficiency, low emissions, and quiet operation. A basic proton exchange membrane (PEM) single-cell arrangement is capable of producing an unregulated voltage below 1V and consists of two electrodes (anode and cathode) linked by electrolyte [1]. The output current capability of a single cell depends on the electrode effective area, and several single cells are connected in series to form a FC stack. Due to the mechanical challenges associated with stacking several single cells, FC are typically lowvoltage, high current power sources and can continuously run while reactant is fed into the system [2].

Several approaches to realize DC-DC isolated power conversion for FC power sources have been proposed based on full bridge, push-pull, and currentfed topologies. Some of the key contributions in the area include the study outlined in the following. An FC power converter based on a controlled voltage doubler was introduced, which uses phase-shift modulation to control the power flow through the transformer leakage inductance [3]. This interesting topology proved to be less efficient than other traditional topologies [4], but presents the advantage of the low component count. An FC inverter based on a traditional push-pull DC-DC converter was presented featuring low cost, low component count, and DSP control [5]. Based on the push-pull topology, a modular architecture was presented to enhance scalability and reliability [6]. An innovative current-fed version of the push-pull topology has been reported as part of a grid connected inverter system [7]. A similar current-fed push-pull topology was employed in a step-up resonant converter, presenting a high voltage-conversion ratio [8]. A full-bridge forward DC-DC converter with a full-bridge rectifier was presented [9]. This is a very robust topology when operated with zero-voltage switching (ZVS) technique and represents an industry standard in many applications, such as telecom power supplies (high input voltage). A three-phase version of the full-bridge forward converter was recently proposed [10], based on Î?”-Y transformer connection and a clamp circuit to reduce the leakage inductance and circulating currents. A new family of phase-shift ZVS with adaptive energy storage was also proposed to increase soft switching operating range using auxiliary circuits [11]. As well, topologies based on current-fed full-bridge topologies were proposed featuring low-input ripple current and reduced stress on the input-side switches [12].

Successful power conditioning for FC systems requires dealing with poor voltage regulation, high input current, and a wide range of output loading conditions while maintaining high efficiency and low switching stress. When exposed to these stringent requirements, full-bridge ZVS, push-pull, and current fed topologies are confronted with several technical challenges. For example, maintaining ZVS (full-bridge) is difficult due to the poor voltage regulation of the FC and the wide range of loading conditions, which creates excessive conduction losses due to circulating current in the primary. The push-pull topology reduces transformer utilization (primary center tap), compromises magnetizing balance as the power rating increases (winding asymmetry and excitation imbalance), as well as limiting the possibilities for soft-switching operation. Current-fed-based topologies need bulky input inductors (high current), present oscillations produced by the interaction between parasite (leakage inductance, intra winding capacitance, and the input inductor), and could present excessive degrading high-frequency ripple current in the output capacitors due to the absence of filter inductor. While the trend for high-input-voltage converters (e.g., connected to the line) has been to minimize switching losses and deal with relatively small line regulation, FC power conversion presents the opposite scenario with low input voltage, poor regulation, and very high input current. Unlike applications with high input voltage, achieving ZVS with low voltage does not lead to substantial efficiency gains, given the small energy stored in the MOSFETs output capacitance (Coss). The power dissipated in a MOSFET due to the output capacitance during turn on is a function of the square of the FC voltage ?? ð ??”ð ??”ð ??”ð ??” 2 . Since FC are low-voltage, high-current power sources, the relative importance of switching losses can be outweighed by conduction losses in the MOSFETs that are a function of?? ð ??”ð ??”ð ??”ð ??” 2 .

The ANFIS set theory is also used to solve uncertainty problems. The key benefit of ANFIS logic is that its knowledge representation is explicit, using simple ”IF-THEN” relations. All situations that are not characterized by a simple and well defined deterministic mathematical model, can be more easily handled in terms of the ANFIS-set theory, in which simple rules and a number of simple membership functions are used to derive the correct result.

In general, ANFIS sets are efficient at various aspects of uncertain knowledge representation and are subjective and heuristic, while neural networks are capable of learning from examples, but have the shortcoming of implicit knowledge representation.

The ANFIS-logic system is inflected in three basic elements: fuzzification, ANFIS inference, and de fuzzification. Degrees of membership in the fuzzifier layer are calculated according to IF-THEN rules. They base their decisions on inputs in the form of a linguistic variable derived from membership functions Which are formulas used to determine the ANFIS set to which a value belongs and the degree of membership in that set. The variables are then matched with the specific linguistic IF-THEN rules and the response of each rule is obtained through ANFIS implication. To perform compositional rule of inference, the response of each rule is weighted according to the impedance or degree of membership of its inputs and the centroid of the response is calculated to generate the appropriate output.

This paper addresses the challenges 1) to 5) by proposing a set of soft-switching techniques in a fullbridge forward topology. For this purpose, a special modulation sequence is developed to minimize conduction losses while maintaining soft switching characteristics in the MOSFETs and soft transitions in the output rectifiers. Auxiliary elements in the primary, such as series inductors and capacitors that are impractical to realize due the extreme input current are avoided by reflecting them to the secondary of the circuit to minimize circulating current and generate soft transitions in the switches. These variations are conceptually depicted in Fig. **??** indicating three major modifications suited for FC power conversion. The proposed combined techniques have the ability to maintain high efficiency in the entire operating range of the FC (wide input voltage) and under any loading condition. Detailed analysis of the techniques for efficiency gains is presented and a phase-shift ZVS topology is employed as a reference topology to highlight the mechanisms for performance enhancement and the advantages in the use of the special modulation. Experimental results of a 1-kW power converter are presented to validate the efficiency gains, illustrate the benefits of the special modulation, and demonstrate the soft-switching transitions.

3 II. Fc Voltage Regulation

This section briefly revisits the regulation characteristic of a polymer-electrolyte FC under different operating conditions, providing the basis for successful design of power conditioning stages. Both PEMFC and direct methanol FC (DMFC) belong to this category. The factors that mainly contribute to the output voltage behavior in a DMFC are fuel (methanol concentration), fuel flow rate (supplied to the anode), air/oxygen flow rate (supplied to the cathode), and operating temperature [1]. As well, the output current is a significant factor that affects the output voltage and, hence, its output power. It is interesting to note how the output voltage of this DMFC is greatly affected by its operating temperature and output current (fuel and oxygen flow rates are close to optimal in this case). This results in a significant change of the available output power, the area under the polarization curve. Therefore, in order to obtain a desired output power, it is first necessary to modify the operating conditions to increase the area under the polarization curve (for example, by increasing the operating temperature). It should be pointed out that the transition from a given polarization curve to another through variation in operating conditions is very slow. The main reasons for this behavior are the high heat capacity of the cell, and the slow mass transport processes in the flow fields and electrodes (fuel distribution in the flow channels and electrode assembly) [2], **??**23]. However, a fast dynamic response exists when the output current changes in fixed operating condition. As a result of this example, the poor voltage regulation, high current and low-voltage characteristics are highlighted. The same principle follows for larger electrode areas required to produce high currents, and a number of singles cells in series to conform a FC stack.

4 III. Right-Aligned Modulation and

Primary Inductor Elimination in the Full-Bridge Topology

This section presents in a sequential and conceptual manner the steps taken to fulfill the requirements toward increasing the efficiency of the fullbridge forward converter in FC power conversion. A description of the power-loss mechanisms in the input stage is first presented, followed by the analysis of the output rectifier. Each design goal is addressed by the combined effects of the proposed soft-switching techniques.

5 a) Full-Bridge Input Stage

The conduction losses in the MOSFETs due to circulating current [design goal (a)] and the high-current bulky inductor in the primary are eliminated by removing the traditional Lzvs inductor in the primary and by forcing a right-aligned sequence of pulses in the upper switches as illustrated in Fig. **??** (modifications ? and ?). In order to illustrate the gains of the two changes with a practical example, Fig. 3 presents the conduction losses of a commercial MOSFET with low RdsON as a function of duty cycle for the voltage polarization curve of a commercial hydrogen FC. It can be seen that the total conduction losses un-der phase-shift ZVS (+ curve that includes circulating current) are considerably higher than losses only associated with power transferred to the secondary. The losses have been calculated using the rms value of the current through switchM1 and the MOSFET ON-resistance Rdson , which is a function of the device temperature?? ????????ð ??"ð ??"???? = ?? ???????? ?? ??1 2 (1)

For example, the IRFB4110 has 3.7 m? at 25 0 C and 6 m? at 100 0 C (typical), resulting in 35 W conduction losses under 75 A rms at 100 0 C. When the switching losses are analyzed, the same power device experiences less than 6.5 W during the turn-ON transition due to its output capacitance Coss when switching at 40 kHz with vfc = 22 V as given in the following:?? ????????ð ??"ð ??"?????? = 1 2 ?? ?????? ?? ???? ?? ð ??"ð ??"ð ??"ð ??" 2**(2)**

Therefore, it can be inferred that in this particular low-voltage high-current application, the efficiency gain resulting from reducing circulating current in four switches outweighs those of switching losses, especially under heavy loading conditions. When the lower switches are considered, the scenario is even more favorable, as M2 and M4 not only benefit from lower conduction losses, but also operate in ZVS due to the modification ?in the modulation (+50% duty cycle). In addition, the reduction in the conduction interval also helps to reduce copper losses in the transformer windings and favors the use of planar magnetic with their inherent low leakage inductance to increase power transfer.

6 b) Output Rectifier Stage

The output rectifiers contribute to conversion losses due to conduction and reverse recovery. Since the output voltage of the power converter is high (i.e., 220 V to supply a single-phase inverter), the conduction current is typically a few amperes per kilowatt of output power (i.e., 4.54 A), making the reverse-recovery losses the dominant factor. Reverse-recovery charge is a function of the forward conduction current (IF) and the rate of change of current (di/dt), as well as operating temperature of the device. The reverse-recovery losses can be estimated by using the recovery charge, switching frequency (Fsw), and reverse applied voltage (VR), including the peak ringing value as follows For this purpose, the Lzvs inductor is reflected to the secondary and placed at the output of each upper rectifier D5 and D7 (modification?). This technique limits the di/dt in the upper rectifiers, eliminates reverse recovery in the lower diodes D6 and D8, and reduces significantly the transformer oscillations by preventing a zero-voltage state at the secondary. As will be seen, the technique avoids simultaneous conduction of D5 , D6 , D7, and D8, thus reducing undesirable ringing that occurs when the primary current matches the inductor output current, which results in a severe voltage step in the secondary that creates ringing, and therefore, electromagnetic interference (EMI). In the following section, the operation of the full-bridge forward converter and the effect of the proposed modifications for efficiency improvements are presented in detail over the various switching intervals.

7 IV. Analysis of Anfis Controller

Proposed system consists of ANFIS to limit error in minimum range based on rules written and its membership functions. The proposed method is as shown in fig4. The simulation has been done on a DFIG system integrating the proposed FLCs for the vector control as shown in Fig. ??. The parameters of induction machine are influenced from Refs. [17] and are indexed in Tables ?? and 3.The vector control performance of proposed ANFIS controller is contrasted with a vector control utilizing fuzzy logic controllers. The wind speed is set at 6 m/s in accordance with a angular speed of 78 rad/s (Fig. ??(d)).

8 V. Operation Intervals and Loss-Reduction Effects

The combination of the proposed techniques, Lzvs inductor reflection to the output of the rectifier (?), right-aligned gate signals for the upper switches (?), and +50% duty cycle in the lower switches (?) are investigated in detail in this section. Fig. ?? shows the switching sequence for MOSFETs M1, M2, M3, and M4 along with the main waveforms for the techniques under study. Transition intervals have been exaggerated for clarity.

9 a) Detailed Analysis of the MOSFETs Waveforms

The waveforms for MOSFETs M1 and M4 and their respective body diodes D1 and D4 are shown in Fig. 7 during a full-cycle period, including the gate signals G1 and G4, drain to-source voltages vM1 and vM4 , currents for the MOSFETs n-channel iM1 and iM4 , and the body diodes iD1 and iD4.

As can be seen, unlike phase-shift ZVS or resonant converters, the proposed techniques prevent unnecessary circulating current in the transformer and through the MOSFETs, and allows power transfer during the conduction interval. This is a key requirement in lowvoltage, high-current applications, where the conduction losses are substantial and outweigh switching losses at moderate switching frequencies. As well, the +50% duty-cycle modulation sequence ensures zero-voltage transitions in MOSFETs M2 and M4. The gains described in this section are further enhanced in the output rectifier as described in the following section.

10 b) Output Rectifier Waveforms

In order to complete the analysis of the waveforms and efficiency gains, the output rectifier should be investigated. The current and voltage waveforms for D7 (upper) and D8 (lower) diodes are presented in Fig. ??, where both conduction losses and reverse-recovery instants can be identified.

In summary, the waveforms for the proposed soft-switching techniques reveal the following improvements. 1. The auxiliary inductors La and Lb shape the current waveforms of D5 and D7 during reverse recovery. Therefore, the inductor values can be selected to achieve a desired Qrr in the upper diodes and, hence, control the total reverse recovery conversion losses. 2. Diodes D6 and D8 experience negligible reverserecovery losses, unlike the phase-shift ZVS topology, which is ex plained by near-zero forward current when the reduced reverse voltage is applied. 3. The presence of La and Lb reduce oscillations and the peak reverse voltage applied to D6 and D8 that result from transformer ringing. Transformer oscillation results in undesirable effect, such as high maximum reverse voltage rating for the diodes, EMI, over voltage between windings, and conversion losses in auxiliary snubber circuits. The concept of avoiding a zero-voltage condition on the transformer secondary is addressed by preventing simultaneous conduction of D5 , D6 , D7 , and D8 . As a result, the turn-ON pulse is partially reflected to the secondary of the transformer as if the converter were operating in discontinuous conduction mode. Hence, the oscillations are reduced under any loading condition.

11 c) Frequency Response and Dynamic Behavior

The frequency response of the control-to-output characteristic of the full-bridge topology, which is a buck-derived topology, is dominated by the transfer function of the output filter (L and When the converter is operated in phase-shift ZVS, a series inductance is required to limit the current rate of change in the primary to generate soft transitions in the switches ??24]. This limitation, reduces the effective duty cycle reflected to the secondary, therefore, affecting the control-to-output characteristic. As a result, an artificial dumping effect is created in the frequency response by the series inductance, which softens the control-to-output characteristic peak at the resonant frequency of the filter ??25]. In closed-loop operation using traditional compensation (small signal), the artificial dumping does not have any noticeable effect in phase and gain margins. A similar behavior is experienced when the proposed techniques are employed using traditional compensators, therefore, showing a dynamic response similar to that of a phase-shift ZVS.

In this study, in order to facilitate the efficiency evaluation process, multiple measurements were performed with a closed loop controller (small-signal) in steady-state operation. The controller was realized with an inner current loop (inductor current) and an outer voltage loop. Validation of the waveforms and comparative efficiency measurements are presented in the following section.

12 VI. Simulation Results

13 a) Validation of the Waveforms

A complete switching cycle in M1, M4, D7, and D8 was measured under medium loading condition to validate the waveforms. In order to facilitate the visualization, the switching frequency was set to 40 kHz. Fig. ?? shows the waveforms of MOSFET M1, including gate and drain-to-source voltages, and the secondary transformer current. It can be seen that the MOSFET current starts at zero (ZCS) at the beginning of T1 and slowly ramps up until it reaches the current level of the output-filter inductor at the beginning of T2. The MOSFET turns off during T3, limiting the conduction interval to T1-T2. The body diode D1 conduction interval can be seen in T11, which returns the energy of the leakage inductance to the input dc bus and avoids circulating current in the primary. The small energy in the leakage is absorbed and clamped by the input capacitors of the converter. The lowerMOSFETM4 waveforms are shown in Fig. ??0, where the zero-voltage transition during turn-ON can be seen at the beginning of T11. Thereafter, at the beginning of T4, M4 turns off. As well, D4 has a soft-switching transition during T5. The conduction interval in M4 is similar to that of M1, showing reduced conduction losses.

In order to evaluate the converter operation under phase shift ZVS, the inductor Lzvt was included and La and Lb were removed. Fig. ??1 shows MOSFET M1 drain-to-source voltage (Ch1) and gate-to-source (Ch2) signals along with the secondary current waveform is (Ch4). It can be seen that the turn-ON transition occurs during (T1) interval and the conduction is extended until the end of (T6). As described by the analysis of conduction losses, the conduction interval presents unnecessary circulating current. MOSFET M4 (lower side switch) presents a similar behavior with circulating current.

Focusing on the rectifier stage, the upper output-rectifier D7 waveforms with the proposed techniques are shown in Fig. ??2. The turn-OFF transition from forward-biased to blocking is illustrated in interval T1. The effect of Lb and Llk can be seen in the current transition, resulting in moderate reverse-recovery losses at the beginning of T2. The end of the interval T7 corresponds to the instant when the current in Lb matches the current in the output-filter inductor L. During T8 , the slope of iD7 is mainly due to L. The conduction interval is defined from T7 to T1 of the next switching cycle. As can be seen, the transformer oscillation are small and experience a fast damping beginning at T2 (no snubber have been included in the prototype). Only an initial peak is experienced due to the effect of the stray inductance in the current path (hall effect sensor measurement path) and Lb. This provides a clear indication that the proposed arrangement only requires a small local snubber connected from D7 cathode to L input terminal, as opposed to the well-known bulky snubber circuit in ZVS circuits.

Upper side diode Voltage Medium Loading.

14 Fig. 8: Upper diode voltage under proposed controller

The improvement that results from the proposed modifications is better appreciated in the experimental waveforms for D8 depicted in Fig. 13. Due to the interleaving effect of La and Lb during T3-T5 interval, diodeD8 experiences a fast transition from high conduction current to near-zero current. At the beginning of T7, the converter input voltage is partially reflected to the secondary and blocks D8 immediately with a transition that produces negligible reverserecovery losses in D8. As well, the blocking transition presents moderate ringing at the beginning of T7 while the upper diode current iD7 ramps up.

When this is compared to the behavior under phase-shift ZVS, which is presented in Fig. ??4, diode D8 presents undesirable reverse-recovery losses at the beginning of interval T8, where a small negative-current peak can be seen due to the effect of Qrr . As predicted by the analysis, the ringing peak voltage in D8 is high, increasing the reverse-recovery losses and requiring a bulky snubber.

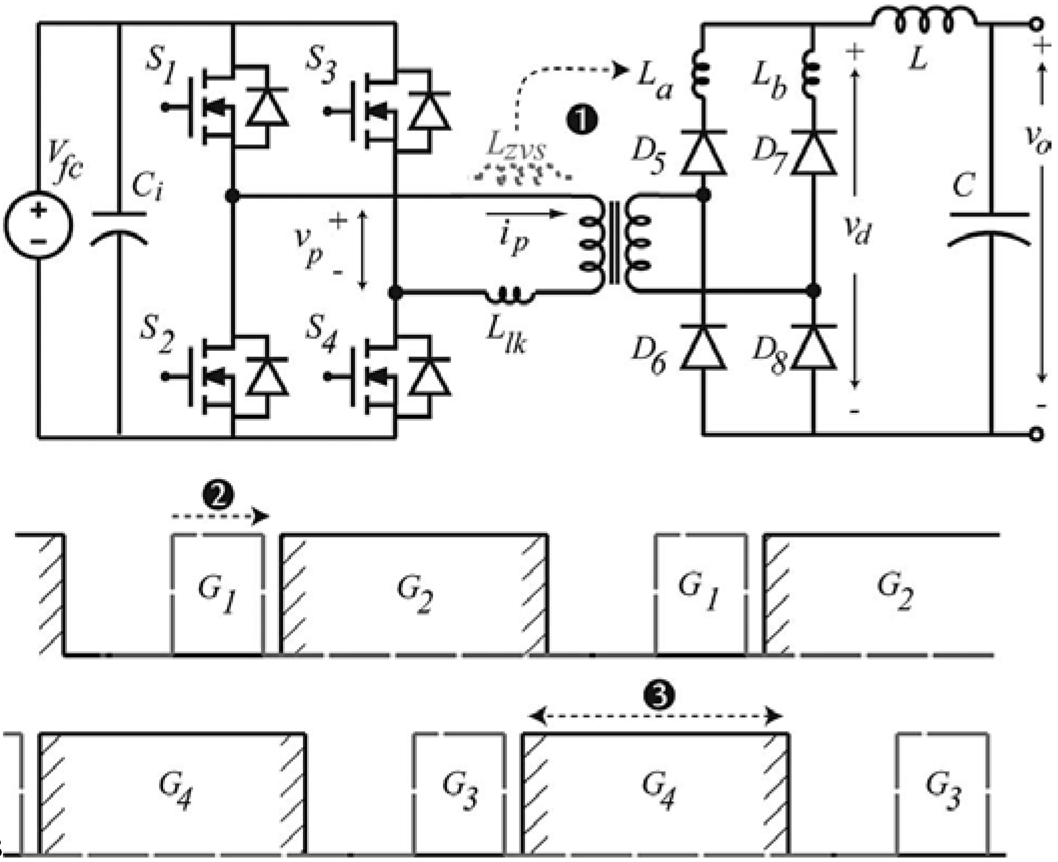
Finally, in order to verify that the input current is positive, a fundamental requirement in FC power conversion, Fig. ??5 presents the input current of the converter and the transformer input voltage operating under medium loading condition. As predicted by the analysis, the current remains positive during all the switching intervals.

15 b) Comparative Efficiency Measurements

The combined switching and conduction losses for the proposed soft-switching techniques are presented in this section. A phase-shift ZVS is employed as a reference topology for comparative evaluation. The same power devices, power transformer, drivers, deadtime insertion, heat sink and fan, and output filter were employed in both cases to ensure a fair comparison (see Table ??). Note that the objective of the experimental efficiency measurements is to illustrate the efficiency gains with the proposed modifications rather than performing an absolute measurement of the converter efficiency. The efficiency measurement accounts for the power switches, printed circuit board, connections, and magnetic parts and does not include losses in the controller and drivers. For ZVS operation, the auxiliary Lzvt inductor and snubbers were included, while removing La and Lb. Several tests were performed for various input voltages vfc = 18, 25, and 30 V under variable loading conditions (50-1000 W range) for both power converters. The results are shown in Fig. ??6, illustrating the efficiency as a function of output power and input voltage in a 3-D plot. It is important to highlight that even though efficiency characterization in power converters is traditionally performed using fixed input voltage, FC power conversion requires the use of a polarization curve (variable input) to account for the lax voltage regulation that is characteristic in these power sources. Therefore, a surface efficiency measurement provides a better means for comparison, as presented in Fig. ??6. The efficiency profile achieved with the proposed soft-switching techniques, referred to as Modified in the figure is depicted with circle markers, while the phase-shift ZVS is illustrated with star markers. It can be seen that the proposed modifications present a significant efficiency gain under any operating condition. For example, an efficiency gain of 3%-4% in a power converter with an overall efficiency of 90% provides an improvement close to 30%-40% in the thermal management of the power stage and allows the use of lower cost power semiconductors/ Heat sinks. This can be considered as an excellent improvement toward power density and cost of the power conversion stage, while maintaining the simplicity of a full-bridge topology. As well, the efficiency gains result in cumulative fuel savings (i.e., hydrogen or methanol) under any operating condition (light, medium, and heavy) by employing the proposed soft-switching techniques.

16 VII. Conclusion

The ANFIS based new control topology will reduces the power conversion losses. The transformer utilized conversion network can minimizes stresses on power electronic devices used for conversion. stress less devices can give better performance gives to reduces the losses. The ANFIS based controller can works fast and accurately in pulse generation compared to conventional Fuzzy Logic controller. [1]



123

Figure 1: Fig. 1 , 2 & 3 :

1

Parameters	Value limits
v fc	18-40V
v o	220V
L	1.33mH
D a , L b	10uH
C	680uF
C i	4400Uf
F sw	40-100kHz
T/f primary turns N p	2
T/f secondary turns N s	26

Figure 2: Table 1 :

[Andersen and Barbi (2009)] ‘A three-phase currentfed push-pull DC-DC converter’. R L Andersen , I Barbi . *IEEE Trans. Power Electron* Feb.2009. 24 (2) p. .

[Sabate et al. ()] ‘Design considerations for highvoltage high-power full-bridge zero voltage switched PWM converter’. J A Sabate , V Vlatkovic , R B Ridley , F C Lee , B H Cho . *Proc. IEEE Appl*, (IEEE Appl) 1990. p. .

[Todorovic et al. (2008)] ‘Design of a wide input range DC-DC converter with a robust power control scheme suitable for fuel cell power conversion’. M H Todorovic , L Palma , P N Enjeti . *IEEE Trans. Ind. Electron* Mar. 2008. 55 (3) p. .

[Yorozu et al. ()] ‘Electron spectroscopy studies on magneto-optical media and plastic substrate interface’. Y Yorozu , M Hirano , K Oka , Y Tagawa . *Digests 9th Annual Conf. Magnetics Japan*, August 1987. 1982. 2 p. 301.

[Jacobs and Bean ()] ‘Fine particles, thin films and exchange anisotropy’. I S Jacobs , C P Bean . *Magnetism*, G T Iii, H Rado, Suhl (ed.) (New York) 1963. Academic. p. .

[Wang and Hashem Nehnir (2007)] ‘Fuel cells and load transients’. C Wang , M Hashem Nehnir . *IEEE Power Energy Mag* Jan./Feb. 2007. 5 (1) p. .

[Kwon and Kwon (2009)] ‘High step-up activeclamp converter with input-current doubler and output-voltage doubler for fuel cell power systems’. J.-M Kwon , B.-H Kwon . *IEEE Trans. Power Electron* Jan. 2009. 24 (1) p. .

[Kwon et al. (2009)] ‘High-efficiency fuel cell power conditioning system with input current ripple reduction’. J.-M Kwon , E.-H Kim , B.-H Kwon , K.-H Nam . *IEEE Trans. Ind. Electron* Mar. 2009. 56 (3) p. .

[Lembeye et al. (2009)] ‘Novel halfbridge inductive DC-DC isolated converters for fuel cell applications’. Y Lembeye , V D Bang , G Lefevre , J.-P Ferrieux . *IEEE Trans. Energy Convers* Mar. 2009. 24 (1) p. .

[Eason et al. (1955)] ‘On certain integrals of Lipschitz-Hankel type involving products of Bessel functions’. G Eason , B Noble , I N Sneddon . *Phil. Trans. Roy. Soc. London* April 1955. 247 p. . (references)

[Maxwell] ‘Oxford: Clarendon, 1892’. J. Clerk Maxwell . *A Treatise on Electricity and Magnetism*, 2 p. . (3rd ed.)

[Vlatkovic et al. (1992)] ‘Small signal analysis of the phaseshifted PWM converter’. V Vlatkovic , J A Sabate , R B Ridley , F C Lee , B H Cho . *IEEE Trans. Power Electron* Jan. 1992. 7 (1) p. .

[Young ()] *The Technical Writer’s Handbook. Mill Valley*, M Young . 1989. CA: University Science

[Krishna and Mohan (2009)] ‘Three-port seriesresonant DC-DC converter to interface renewable energy sources with bidirectional load and energy storage ports’. H Krishna , N Mohan . *IEEE Trans. Power Electron* Oct. 2009. 24 (10) p. .

[Tao et al. (2008)] ‘Threeport triple-half-bridge bidirectional converter with zero-voltage switching’. H Tao , J L Duarte , M A M Hendrix . *IEEE Trans. Power Electron* Mar. 2008. 23 (2) p. .

[Elissa] *Title of paper if known*, K Elissa . (unpublished)

[Nicole] ‘Title of paper with only first word capitalized’. R Nicole . *J. Name Stand. Abbrev* (in press)