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Research Paper

A NOVAL ANALYSIS AND DESIGN OF ANFIS CONTROLLER FOR RESONANT CONVERTER FED SERVO MOTOR

S Suganya[1]* and S Ragul[1]

**Corresponding Author: S Suganya* ✉ ssugansree@gmail.com*

This work deals with analysis and design of resonant converter fed servo motor using ANFIS Controller. The converter topology uses zero voltage switching control and also pulse width modulation control techniques. The inductor stores extra energy to extend the soft-switching range and reduce the reverse-recovery current of the secondary-side rectifier diodes, while the clamping circuit minimizes converter voltage ringing on both the primary and secondary sides of the transformer. The converter's two half-bridge inverters always operate at a 50% switching duty cycle when the output voltage is regulated above half of its maximum input voltage. To dynamically change the dead time of the bridge switch and turn ON or OFF one half-bridge for better efficiency under different load conditions, a digital controller is a better choice. Load independent and wide range ZVS with efficiency improvement at both a heavy and light loads. For low output voltage regulation and converter startup, the PWM technology used. This system can also optimally utilize magnetic components and reduces semiconductor stress. The digital controller uses for continues monitoring and controlling of the PWM pulses depend upon the load for minimizing the loss of current and voltage. With the simulation results using MATLAB/ Simulink, this topology is also a good candidate for high-power, high-density, and low-profile designs.

Keywords: Dual half-bridge, Phase-shifted control, Resonant converter, Zero voltage switching (ZVS), Servo motor, Pulse Width Modulation (PWM)

INTRODUCTION

To extend the soft-switching range and reduce switching loss at light loads, a resonant inductor is usually added to the converter's primary side. The inductor stores extra energy to extend the soft-switching range and reduce the reverse-recovery current of the secondary-side rectifier diodes. Favored because of its capability for Zero-Voltage Switching (ZVS) operation, which minimizes switching losses, this converter configuration is described in detail in Texas Instruments application note U-136A (Zhong, 2013). However, this extra energy can also cause a higher voltage spike across the rectifier diodes.

[1] Department of Electrical and Electronics Engineering, Annai Mathammal Sheela Engineering College, Namakkal, India.

A simple but effective clamping circuit can be used to mitigate this problem. The clamping circuit substantially minimizes the converter's voltage ringing on both the primary and secondary sides and captures most of the transient energy on the primary side, which is utilized for soft switching and recycled back to the DC input converter. Synchronous MOSFETs are often used to replace secondary rectifier diodes to minimize conduction loss (Zhang, 2009; Zhong, 2008). It becomes more challenging to extend the ZVS range when the output-rectification devices are diodes. Many circuits have been proposed to solve this problem.

The circuits can be categorized into two types: the first type is an active switch-controlled resonant network (Jang, 2003; Andreycak, xxxxx). Depending on the load, the converter's output-inductor current can be positive, zero, or negative at the end of a switching cycle. Both positive and negative currents actually help the primary switches to achieve soft switching. At a certain load point, the output inductor current returns to zero at the end of each switching cycle. For this case, the primary can only rely on its magnetizing current for soft switching. Properly sizing magnetizing inductance and keeping Sync FETs active are good ways to achieve ZVS over a wide load range. A good power conversion efficiency achievement has been demonstrated by this approach. However, unfortunately, the topologies proposed so far have not been able to minimize or eliminate the circulating current. A converter with the same ZVS merit but zero circulating current would make it possible to further improve the efficiency (Wu, 2006; Kim, 2002).

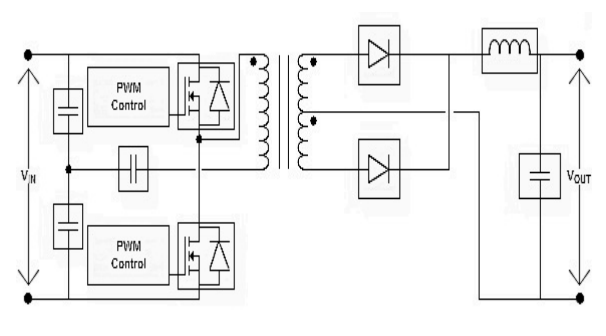
At a very light load (especially at zero load), however, the negative current may become so significant that too much energy is cycled back to the primary side, resulting in efficiency loss. This paper will introduce a new topology of phase-shifted dual half-bridge converters, which is able to achieve wide load-range ZVS, while the circulating current is fully eliminated. Detail operations of the new circuit and test results of a 385–48 V converter prototype will be provided as well.

The simulation results show that the ANFIS controller based zero voltage switching controller fed servo motor drive systems which are easy to implement in industries and it has the advantages of Lower RMS current through the switches. So, minimize the stress for power semiconductor switching devices. The Load independent and wide ranges ZVS with efficiency improvement at both a heavy and light loads. It has no circulating current and reactive power. In section II the dual half bridge converter is discussed, in Section III the topology of resonant converter is explained, in section IV the implementation of Adaptive Neuro Fuzzy Inference System is discussed and in section V the simulation results has mentioned.

EXISTING DUAL HALF BRIDGE CONVERTER

A half-bridge converter is a type of DC to DC converter. These converters are like forward and fly-back converters. This type of converters can supply an output voltage either lower or higher than input voltage and it can also provide electrical isolation via a transformer. The half-bridge converter design can yield higher output power normally power potential up to 500 W even though more complex than forward or fly-back converter. The parts used in it are smaller and less expensive. Figure 1 shows the basic half bridge converter circuit diagram.

Figure 1: Half Bridge Converter Topology



To reverse the polarity or direction of the motor the dual half bridge arrangements are used. This type of dual arrangement also used to break the motor, where motor comes to sudden damage or stop. Usually the problems are the motor terminal shorted, or to let free run to stop, as it is effectively disconnected from the circuit. The objective of this system is to achieve zero-voltage switching over a widely varying load, but can also function in PWM mode for increased voltage range. Figure.2 shows the existing dual half bridge converter circuit diagram.

A Zero-Voltage Switching (ZVS) operation minimizes switching losses. A large circulating current in this topology causes significant conduction loss at heavy loads, while at light loads the circulating current becomes too little for switches to achieve ZVS. Both characteristics impact the ability to achieve maximum efficiency and a new approach to improve power-conversion efficiency. The leading half bridge initiates each output pulse and the lagging half bridge terminates it has two half bridge inverters. The two inverters are still operating in open-loop bus-converter mode.

IMPLEMENTATION OF RESONANT CONVERTER SOFT SWITCHING

In all Pulse Width Modulated DC to AC converter and DC to DC converter, in switching mode only the controllable switches are operated. In which they are required to turn on and turn off the entire load current in each switching time. The high switching stress and high switching power loss are subjected by the switches in this type of operation. The shortcomings can be minimized whenever the voltage across the converter switches is zero at switching time if each switch changes its status from on to off or vice versa. The converter topologies which result in zero voltage and zero current switching require some form of LC resonance so they are known as “resonant converters”. The simulation models of this Resonant Converters and servo motor are designed. Iin the simulation package aid menu has created to design the power electronics networks.

Figure 2: Dual Half Bridge Converter

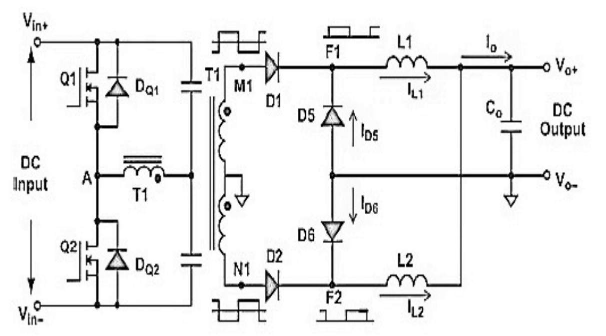
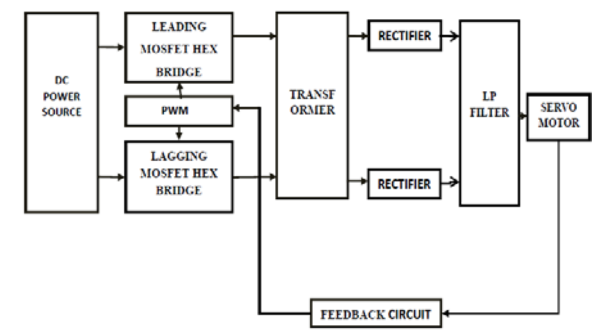


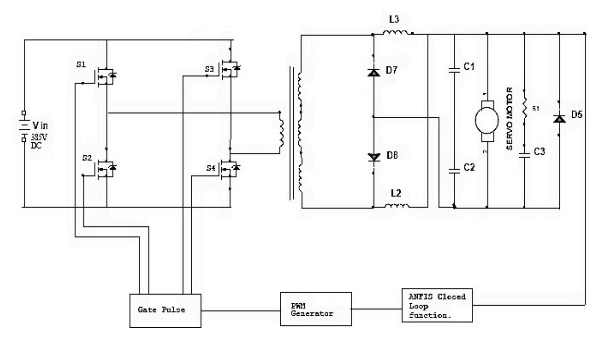
Figure 3: Block diagram of proposed system



Hence governing equations and functions of each power electronics network circuit are represented in blocks this method has been found versatile and simple.

This simulation software enables the simulator to design and change the parameters or the modulation methods of the various circuits. The current and voltage waveform for both input and output of this system can be seen for different number of operation in momentary form. To obtaining the waveforms for numerous power electronics circuits and to more complex power electronic systems this study would be useful. Generally three types of resonant converters are present; they are series and parallel resonant converters and series parallel type.

Figure 2: Circuit Diagram

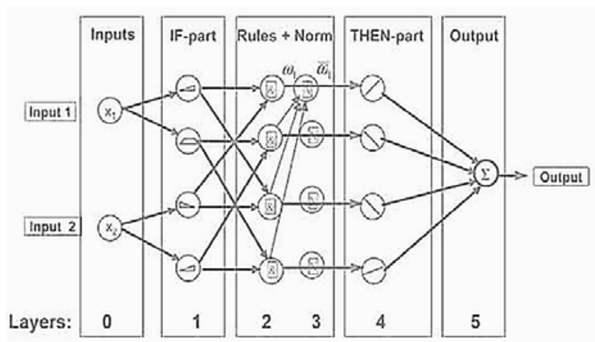


Apart from this now a days, resonant converters are most commonly used in power electronic circuits because it is inexpensive and robust. Among the many advantages that resonant power conversion has over conventionally adopted pulse-width modulation include a low electromagnetic interference, switching losses low, less volume, and low weight of components due to a heavy switching frequency, high efficiency, and less reverse recovery losses in diodes owing to a low di/dt at switching instant (Zhang, 2005; Kim, 2005), resonant converter is widely used for applications of power electronic productions such as battery chargers, switching power supplies, renewable energy generation system, telecom power systems, and interruptible power supplies. The servo motor is controlled by the resonant converter; where the switching pulse to the inverter is given according to the ANFIS controller output.

ADAPTIVE NEURO FUZZY INFERENCE SYSTEM

Adaptive Neuro Fuzzy Inference System (ANFIS) is a kind of neural network that is based on Takagi–Sugeno fuzzy inference system. Hence it induces both principles of neural networks and fuzzy logic control; it is capable of capturing the advantages of both in a single framework. Its inference system corresponds to a set of fuzzy IF–THEN rules that have learning capability to approximate nonlinear functions. Hence, ANFIS is considered to be a universal estimator.

Figure 4: Structure of ANFIS



We have only considered membership functions that have been fixed, and somewhat arbitrarily chosen. Also, we have only applied fuzzy inference to modeling systems whose rule structure is essentially Pre determined by the user's interpretation of the characteristics of the variables in the model. In general the shape of the membership functions depends on parameters that can be adjusted to change the shape of the membership function. The parameters can be automatically adjusted depending on the data that we try to model.

Structure of ANFIS speed controller is shown in Figure 4. It is a five-layer feed forward fuzzy neural network. Every layer has its definite meaning.

Layer 1: (Input Layer) Input layer represents input variables of controller, they are speed error and its variance ratio referred as x1, x2 respectively. This layer just supplies the input values xi to the next layer, where i= 1 to n.

Layer 2: (Fuzzification Layer) this layer (membership layer) checks for the weights of each membership functions (MFs). It receives the input values from the 1st layer and act as MFs to represent the fuzzy sets of the respective input variables. Further, it computes the membership values which specify the degree to which the input value xi belongs to the fuzzy set, which acts as the inputs to the next layer.

Layer 3: (Rule layer) each node (each neuron) in this layer performs the pre-condition matching of the fuzzy rules, i.e., they compute the activation level of each rule, the number of layers being equal to the number of fuzzy rules. Each node of these layers calculates the weights which are normalized.

Layer 4: (Defuzzification Layer) It provides the output values "y" resulting from the inference of rules. Connections between the layers l 3 and l 4 are weighted by the fuzzy singletons that represent another set of parameters for the Neuro Fuzzy Network.

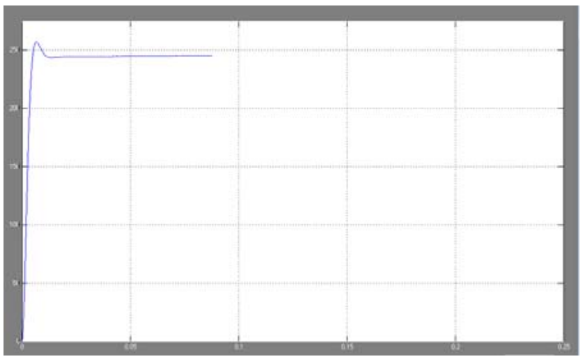
Layer 5: (Output Layer) It sums up all the inputs coming from the layer 4 and transforms the fuzzy classification results into a crisp values. The ANFIS structure is tuned automatically by least-square-estimation and back propagation algorithm.

The above mentioned optimization procedures are repeated by using sample data until proper error index or the maximum number of training is achieved. After learning and training, the test data can be used to check the controller to ensure effectiveness of the controller. It is observed that the ANFIS controller gives much better dynamic response for the system. From the results of proposed inverter topology, it is observed that all the switches work under soft switching condition and freewheeling diodes are turned off under zero current condition which greatly reduces the reverse recovery problem of the diodes. Further, voltage stress on all the switches is very low and it is not greater than the dc supply voltage.

SIMULATION RESULTS

The topology of high power and high-density switching converter designs is a phase shifted, full-bridge DC/DC converter the switching between phase shift mode and PWM mode. The

Figure 5: Output voltage waveforms



magnetizing currents of the power transformers reach a constant and stable peak value at the end of each half switching cycle, assuming that there is no magnetic flux walking and that the circuit operates in continuous conduction mode. To dynamically change the dead time of the bridge switch and turn ON or OFF one half–bridge for better efficiency under different load conditions, a digital controller is a better choice. The simulation results using MATLAB/Simulink are shown below in Figure. By using PWM control, the converter can regulate its output down to zero volts, but the two inverters will lose soft switching.

All switches work in zero voltage switching condition. The performance of this intelligent Adaptive Neuro Fuzzy Inference System controller is compared with other type of controllers. The simulation results using MATLAB show that the ANFIS controller renders a better transient response compared to the one obtained using phase shifting. Due to common characteristic of resonant converter and because of high circulating energy lots of conduction losses occur. The ZVT and zero current transition methods are proposed to overcome the drawbacks of the resonant converter. Using resonance the ZVT and ZCT methods are that switches turning ON and turning OFF under zero voltage and zero current. By adding auxiliary circuit, the conventional bidirectional dc-dc converter to the converters applied by the ZVT and ZCT.

The auxiliary circuit is operated under hard switching condition, the losses occur. The simulation of the DC-DC converter with ANFIS controller is shown in Figure 6.

A combination of neural networks and fuzzy logic offers the possibility of solving tuning problems and design difficulties of fuzzy logic. The resulting network will be more transparent and can be easily recognized in the form of fuzzy logic control rules. This proposed approach combines the well established the well advanced method of both the methods and avoids the drawbacks of both. In this paper, Neuro-fuzzy controller architecture is proposed, which is an improvement over the existing Neuro fuzzy controllers. It overcomes the major drawbacks of the existing Neuro-fuzzy approaches; of either keeping neural networks and fuzzy logic as separate entities (co-operative models) working towards a common goal or in most of the existing Neuro fuzzy approaches, the trained controller no longer can be interpreted as fuzzy logic controller.

CONCLUSION

The converter’s two half-bridge inverters achieved at a 50% switching duty cycle when the output voltage is regulated above half of its maximum input voltage. The rms current through the switches are lower. Therefore the power semiconductor switching devices are minimized. A zero-voltage switching ZVS) operation minimizes switching losses. A large circulating current in this topology causes significant conduction loss at heavy loads, while at light loads the circulating current becomes too little for switches to achieve ZVS. Both characteristics impact the ability to achieve maximum efficiency and a new approach to improve power-conversion efficiency. The leading half bridge initiates each output pulse and the lagging half bridge terminates it has two half bridge inverters. The two inverters are still operating in open-loop bus-converter mode.

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