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# Solar PV based LLC Half-Bridge Resonant Converter using BPWM Control Strategy

**Sreenivasa Rao Kalluri**
**M. Tech Student,**
**Department of PEED,**
**Malineni Lakshmaiah Engineering College.**

**I.Thulasiram**
**Assistant Professor,**
**Department of PEED,**
**Malineni Lakshmaiah Engineering College.**

## Abstract:

The input range of Boost pulse-width modulation (BPWM)- integrated resonant converters, such as the isolated boost resonant converter, while maintaining high conversion efficiency.One such topology is the LLC resonant converter. The LLC resonant topology allows for zero voltage switching of the main switches thereby dramatically lowering switching losses and boosting efficiency. Efficiencies of 93 to 96% can be achieved with LLC resonant converters. This paper will describe the operation of the LLC resonant topology by considering the PV input and illustrate how such high efficiencies can be attained. Resonant converters have been around for a long time. However, only now are they seeing increased acceptance as controllers become more available and there is an absolute need to improve efficiency. Perhaps this is excuted in MATLAB/SIMULATION.

## Index Terms:

Boost PWM control, Resonate converter, PV panel , LLC, ZVS.

## .I. INTRODUCTION:

Although in existence for many years, only recently has the LLC resonant converter, in particular in its half-bridge implementation, gained in the popularity it certainly deserves. In many applications, such as flat panel TVs, 85+ ATX PCs or small form factor PCs, where the requirements on efficiency and power density of their SMPS are getting tougher and tougher, the LLC resonant half-bridge with its many benefits and very few drawbacks is an excellent solution. One of the major difficulties that engineers are facing with this topology is the lack of information concerning the way it operates.

The purpose of this application note is to provide insight into the topology and help familiarize the reader with it, therefore, the approach is essentially descriptive. With the current global energy crisis, the focus is on efficiency and electronic products are facing the daunting challenge of delivering high performance, while consuming less power. As a result of this crisis, various governmental agencies around the world have or are looking to increase their efficiency standards for numerous products in their respective specifications. It will be difficult to meet these efficiency specifications with conventional hard switched converters. Power supply designers will need to consider soft switching topologies to improve the efficiency as well as to allow for higher frequency operation. An LLC resonant converter shows the maximum efficiency in the nominal condition, when the converter is operated at the resonant frequency. However, the switching frequency becomes reduced and growing apart from the resonant switching point as the input voltage decreases. This frequency change becomes a considerable issue under a wide input variation condition.

It makes LLC resonant converters have difficulty in magnetic design, and it also decreases nominal efficiency of the converters. Furthermore, output voltage in the converter is not well regulated using the conventional dc gain equation of LLC converters because the converter is affected by harmonics when it is operated out of the resonant point.A new half-bridge (HB) LLC resonant converter having wide gain variation characteristic is proposed. The proposed converter is operated at the resonant frequency, which is the maximum efficiency point of the HBLLC resonant converter, during nominal state and the converter shows boost PWM converter operation to increase the voltage gain with an auxiliary switch during hold-up state. The input energy is build up while the auxiliary switch is conducted and it is transferred to the secondary side for the last period.

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## II. RESONANT CONVERTER:

Resonant conversion is a topic that is at least thirty years old and where much effort hasbeen spent in research in universities and industry because of its attractive features: smoothwaveforms, high efficiency and high power density. Yet the use of this technique in off-linepowered equipment has been confined for a long time to niche applications: high-voltagepower supplies or audio systems, to name a few. Quite recently, emerging applications suchas flat panel TVs on one hand, and the introduction of new regulations, both voluntary andmandatory, concerning an efficient use of energy on the other hand, are pushing powerdesigners to find more and more efficient AC-DC conversion systems. This has revampedand broadened the interest in resonant conversion. Generally speaking, resonantconverters are switching converters that include a tank circuit actively participating indetermining input-to-output power flow. The family of resonant converters is extremely vastand it is not an easy task to provide a comprehensive picture.

To help find one's way, it ispossible to refer to a property shared by most, if not all, of the members of the family. Theyare based on a "resonant inverter", i.e. a system that converts a DC voltage into a sinusoidalvoltage (more generally, into a low harmonic content ac voltage), and provides ac power to aload. To do so, a switch network typically produces a square-wave voltage that is applied toa resonant tank tuned to the fundamental component of the square wave. In this way, thetank will respond primarily to this component and negligibly to the higher order harmonics,so that its voltage and/or current, as well as those of the load, will be essentially sinusoidal or piecewise sinusoidal. As shown in Figure 1, a resonant DC-DC converter able to provide DC power to a load can be obtained by rectifying and filtering the ac output of a resonantinverter.

Different types of DC-AC inverters can be built, depending on the type of switch network and on the characteristics of the resonant tank, i.e. the number of its reactive elements and their configuration.As to switch networks, we will limit our attention to those that drive the resonant tank symmetrically in both voltage and time, and act as a voltage source, namely the half-bridge and the full-bridge switch networks. Borrowing the terminology from power amplifiers switching inverters driven by this kind of switch network are considered part of the group called "class D resonant inverters".As to resonant tanks, with two reactive elements (one L and one C) there are a total of eight different possible configurations, but only four of them are practically usable with a voltagesource input. Two of them generate the well-known series resonant converter and parallel resonant converter considered and thoroughly treated in literature.

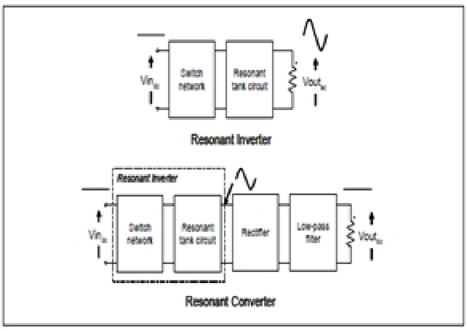


**Fig 1. General block diagram of a resonant inverter, the core of resonant converters.**

With three reactive elements the number of different tank circuit configurations is thirty-six,but only fifteen can be used in practice with a voltage source input. One of these, commonlycalled LCC because it uses one inductor and two capacitors, with the load connected inparallel to one C, generates the LCC resonant inverter commonly used in electronic lampballast for gas-discharge lamps. Its dual configuration, using two inductors and one capacitor, with the load connected in parallel to one L, generates the LLC inverter.As previously stated, for any resonant inverter there is one associated DC-DC resonant converter, obtained by rectification and filtering of the inverter output. Predictably, the above mentioned class of inverters will originate the "class D resonant converters". Considering off-line applications, in most cases the rectifier block will be coupled to the resonant inverter through a transformer to guarantee the isolation required by safety regulations.

To maximize the usage of the energy handled by the inverter, the rectifier block can be configured as either a full-wave rectifier, which needs a centre tap arrangement of transformer's secondary winding, or a bridge rectifier, in which case tapping is not needed. The first option is preferable with a low voltage / high current output; the second option with a high voltage /low current output. As to the low-pass filter, depending on the configuration of the tank circuit, it will be made by capacitors only or by an L-C type smoothing filter.

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The so-called" series-parallel" converter described typically used in high-voltage power supply, is derived from the previously mentioned LCC resonant inverter. Its dual configuration, the LLCinverter, generates the homonymous converter, addressed in that will be thesubject of the following discussion. In particular we will consider the half-bridgeimplementation, illustrated but the extension to the full-bridge version is quite straightforward.

## III. PROPOSED SYSTEM:

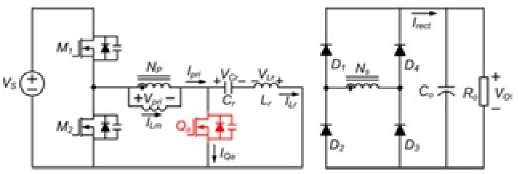

**Fig. 2. Schematic diagram of the proposed converter.**

The circuit diagram of the proposed converter is represented in Fig. 2. It is based on the conventional HB LLC resonant converter and an auxiliary switch is added to the primary side of the converter.

Fig. 8 shows the key operations of the proposed converter for the nominal state and for the holdup state. In nominal state, the proposed converter is operated just the same as the conventional LLC resonant converter operated at the resonant switching frequency.

The soft switching condition is naturally realized and no unnecessary conduction loss is appeared in this operation. Therefore, the maximum efficiency is showed with the proposed converter during nominal state.

When the converter enters into the hold-up state, the converter increases the voltage gain using the auxiliary switch Qa . The resonant inductor current is build up, while the auxiliary switch is conducted and it is transferred to load during off-state of the auxiliary switch.

Therefore, higher voltage gain is easily achieved in the proposed converter by increasing the duty ratio of Qa. The operational characteristic is similar to the boost PWM operation.Operations of the proposed converter are analyzed in this section.The operational principle for the nominal sate is the same with that of the conventional LLC resonant converter operated at resonant frequency. Thus, only the operation for holdup time is explained in this section.

## IV.CONTROL STRATEGY:

Boost power converters have been widely used for Power Factor Correction (PFC) in AC-DC conversions and for power management in battery powered DC-DC conversions. Moving beyond low-power applications, such as cellular phones, smart phones and other portable electronic products, boost converters are being used more and more in medium-power applications. For example, in computing and consumer electronics, boost converter-based LED drivers for notebook displays, LCD TVs and monitorshave been developed. In communications and industrial products, simple boost converters areused in satellite dish auxiliary power supplies and peripheral card supplies.A typical pulse-width-modulation (PWM) boost converter along with a simple controller is shown in Figure2. This diagram illustrates that there is a DC path from input VIN to output VOUT via the inductor L1 and the output rectify diode D1. Such topological properties define the normal operation range of the boost converter at VOUT≥VIN all the time. In the aforementioned applications, this property is fully utilized to achieve targeted high-efficiency power conversion.

## Simulation Circuit:

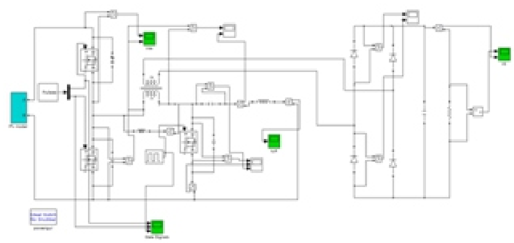

**Fig.3. Matlab Simulation Circuit**

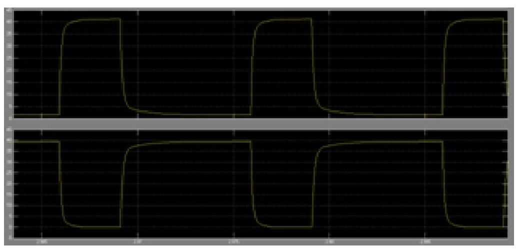

**Fig.4. Vds - M1,M2 switches**

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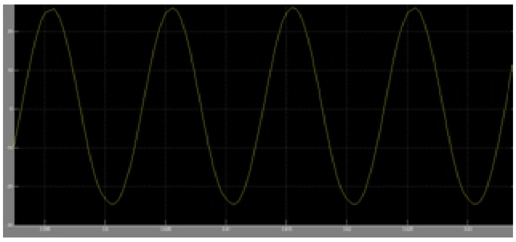

Fig.5. Inductor Current (ILr)

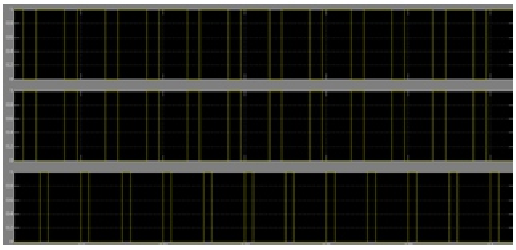

Fig.6. Gating Signals (Vgs) of M1,M2 &M3

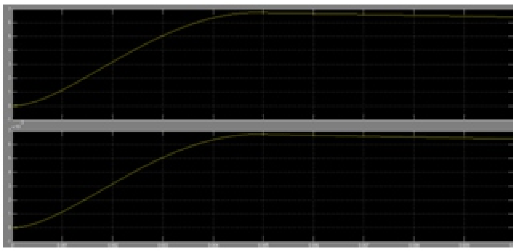

Fig.7. Output Voltage (V0) & Current (I0)

## V.CONCULSION:

The input range of Boost pulse-width modulation (BPWM)- integrated resonant converters, such as the isolated boost resonant converter, while maintaining high conversion efficiency has been achived. One such topology is the LLC resonant converter. The LLC resonant topology allows for zero voltage switching of the main switches thereby dramatically lowering switching losses and boosting efficiency. Efficiencies of 93 to 96% can be achieved with LLC resonant converters. We have been proved that high efficacy has achieved

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## Authors Details:

**Sreenivasa Rao Kalluri,** Currently pursuing M.Tech (PEED) in MALINENI LAKSHMAIAH ENGINEERING COLLEGE. His area of interests are power electronics & electrical drives.

**Thulasiram.I,** Obtained his B.TECH (EEE) degree from MALINENI LAKSHMAIAH ENGINEERING COLLEGE. M.Tech.(PEED) from VRS & YRN College of Engineering & Technology Currently he is working as Assist. Prof. (2yrs) in MALINENI LAKSHMAIAH ENGINEERING COLLEGE..