Florida Energy Systems Consortium

Thrust Area 4: Solar (PV Integration)

PV Energy Conversion and System Integration

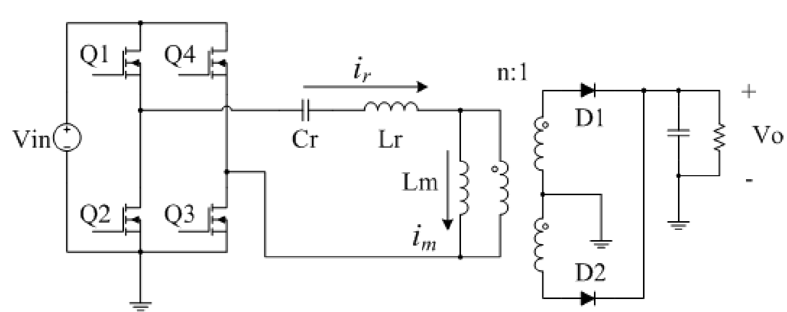
PI: I. Batarseh **Co-PIs:** J. Shen, Z. Qu, X. Wu, W. Mikhael, L. Chow
Post Docs: H. Hu (PhD)
Students: Kejiu Zhang (PhD), Souhaib Harb (PhD), Lin Chen (PhD)
Karthik Padmanabhan (PhD), Xiang Fang (PhD), Ala Alsaeed (PhD)

Description: The objective of this project is to develop a system-driven Plug'N'Gen solar power system demonstrating architecture of decentralized, low-cost, mass-produced, PV panel-mounted micro-inverters. This system will be able to compete with today's centralized multi-kW PV inverters that require cost prohibitive professional installation. The project tasks are: 1) novel inverter topology and control concepts; 2) advanced digital control algorithms; 3) SmartTie interface with the utility grid; and 4) low cost and ultra-compact PV inverter in package.

Budget: $1,267,000
Universities: UCF
External Collaborators: U. S. Department of Energy awarded the UCF PIs a two year $1,400,000 project (DE-EE003176) called "Photovoltaic Power Electronics Initiative (PERI)"

Progress Summary

The focus of this period was on developing very high efficiency LLC resonant DC/DC converter stage for the PV inverters.



LLC is a 3-resonant-component converter topology with high efficiency and high power density. It has advantages of achieving ZVS for wide input voltage and load range, which makes it ideal candidate for PV applications. LLC's operation is complicated. A systematic analysis and modeling based on its operating modes are proposed and verified by experiments. The model provides high accuracy in DC gain prediction comparing to traditional approaches (FHA method). And the model is used to optimize LLC design. A modified LLC topology with dual transformers is proposed. The modified topology has better efficiency than traditional one. A prototype board was built to perform comparative tests.

LLC optimal design is to find the circuit parameters that minimize the power loss while maintaining a desired DC gain level to adapt the wide input range. An optimal design procedure is developed based on the mode model. The experiments validate our LLC model study and show promising results of the dual-T LLC topology. A power loss model will be built to further improve the converter efficiency. Based on these results, the circuit for its implementation in the mico-inverter prototype will be finalized.

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Title: Photovoltaic Power Electronics Initiative (PERI)	Agency DOE	Period of Performance 24 months	Funding awarded $1,400,000

2011 Annual Report

Research on high step-up front-end DC/DC converter

Description

Based on extensive literature survey on the high step-up DC/DC converter, achieving high conversion efficiency with a high voltage gain presents the greatest challenge for non-isolated DC/DC topologies, which either operate with an extreme duty-ratio or result in high cost or low efficiency. Isolated topologies offer a more attractive solution. Another benefit of the isolated topologies is that it is easier to implement dual grounding for PV applications. To date, numerous isolated DC/DC converter topologies have been proposed in the literature, which can be categorized into six families: full bridge, half bridge, push-pull, resonant, forward and flyback. We have selected typical designs from each topology family to compare their efficiency with modeling approaches. Table 2 shows the peak efficiency numbers for different topologies.

Table 2: Comparison on High step-up DC/DC converters

DC/DC topologies	***Power rating(W)***	***Input voltage(V)***	***Output voltage(V)***	***Peak efficiency(%)***
Full bridge phase-shift	1kW	48	380	96%
Current fed half -bridge	200W	24	200	95.8
Push-pull	1.5kW	35V	350	96.5
Forward	1.0kW	36	380	97.3
Flyback	260W	36V	350	97

Approach

LLC converter offers soft switching and high switching frequency, and has the potential to achieve both high efficiency and high power density. LLC converter could be a very promising candidate for this project due to these favorable features. However, there are still several shortcomings to be overcome:

(1) There is no accurate LLC converter analytical model to guide design optimization. Fundamental harmonic approximation (FHA) is a widely used method in LLC analysis and design, which simply considers all current/voltage as single frequency sinusoidal waveforms. However, it's inaccurate when frequency varies in a wide range;

(2) There are conflicting requirements between efficiency and wide input voltage range.

An accurate LLC converter model is developed using numeric method and verified by experiment. Fig.2 shows the model verification and comparison results based on 250W design. It indicates that the developed model matches the experimental results very well.

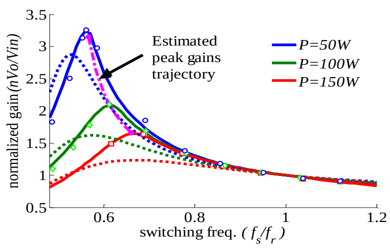


Fig.2: Comparison between mode model (solid lines), FHA (dash lines), estimated peak gains (dash-dot line) and experiment (markers)

LLC converter has 3 resonant components. It proved to be a significant challenge on how to optimize these three components. We devoted much of our effort to analyzing different LLC operation modes. From the LLC mode analysis, we learned that the resonant current level is related to the parameter Lm/n: the larger the Lm/n value (n stands for turn-ratio of transformer), the lower the resonant current is, which is preferable since it indicates smaller conduction loss. In this way, the optimization design is simplified as finding the maximum Lm/n while meeting the DC gain requirement.

A modified LLC converter, shown in Fig.3, is proposed to achieve the high efficiency, while maintaining wide DC gain range. A comparative study has been carried out between the proposed topology with the traditional design (conventional LLC converter shown in Fig.4). Two converters were optimally designed based on the aforementioned optimal design approach. Fig.5 shows the efficiency improvement by the proposed topology.

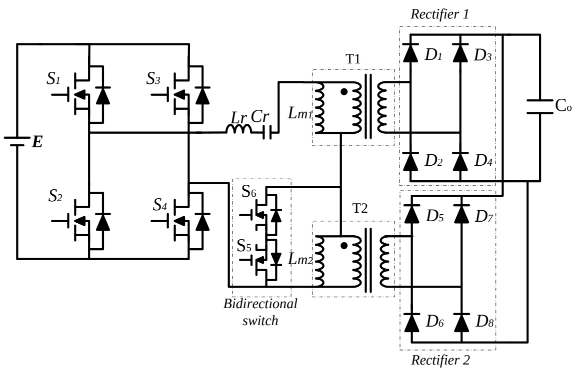


Fig.3: Modified LLC converter

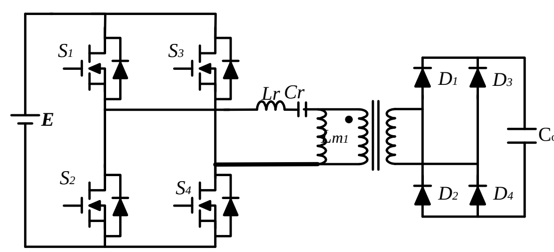
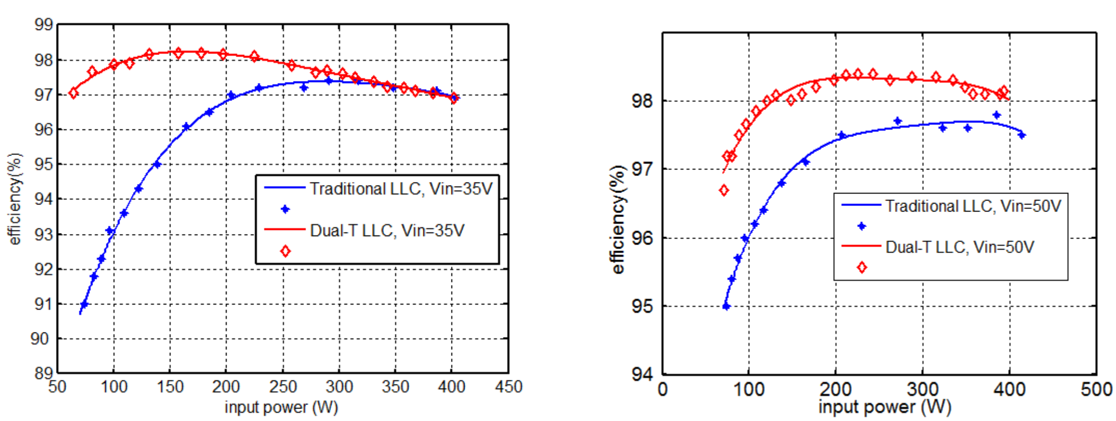


Fig.4: Traditional LLC converter



(a)Vin=35V (b) Vin=50V

Fig.5: Efficiency comparison between two LLC converters