

1. Objectives

Design a novel non-isolated DC/DC converter for a stand-alone PV-battery powered pump system which achieves the aims of:

- Use only one active switch, i.e. MOSFET
- Maximum power point tracking (MPPT) of the PV panel
- Charge/discharge of the battery
- Drive the pump within in a certain voltage range
- Implement reduced repeated power processing to improve the overall efficiency
- Steady DC-link voltage

2. Introduction

PV-pump application

- **Renewable Energy.** Due to the drastic increase of global energy demand and rapid consumption of conventional fossil fuel resource, solar energy has become one of the more popular renewable energies.
- **PV-pump.** Among the various applications of photovoltaic technology, a PV-battery powered pump system can be utilized in many areas such as
 - ❖ urban street watering
 - ❖ rural farm irrigation
 - ❖ Fish Farm



Fig.1 PV-pump system [1]

Converter Characteristics.

- ❖ For Most of these applications the motor does not need to run at a precise speed. Maintaining the output voltage within a certain range still guarantees the normal operation.
- ❖ A rechargeable battery is usually used in the system to balance the energy discrepancy between generated energy of PV module and load demand during different insolation conditions.
- ❖ Conventional design uses cascaded converters, as shown in Fig. 2. A high number of power switches usually indicates high converter cost and physical size.

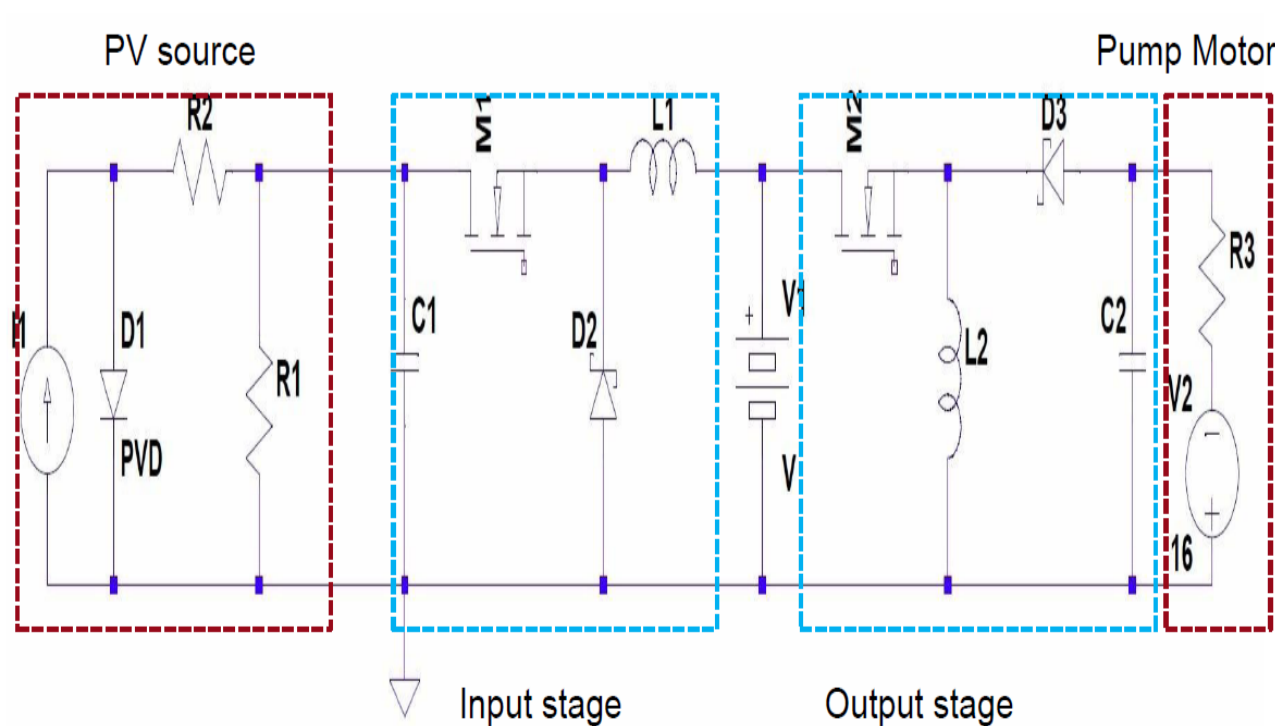


Fig.2 Conventional two-stage converter

3. Methodology

Single-stage single-switch converter

- The proposed single-switch converter, shown in Fig. 3 is derived through integration of a buck converter into a buck-boost converter which is connected in series.

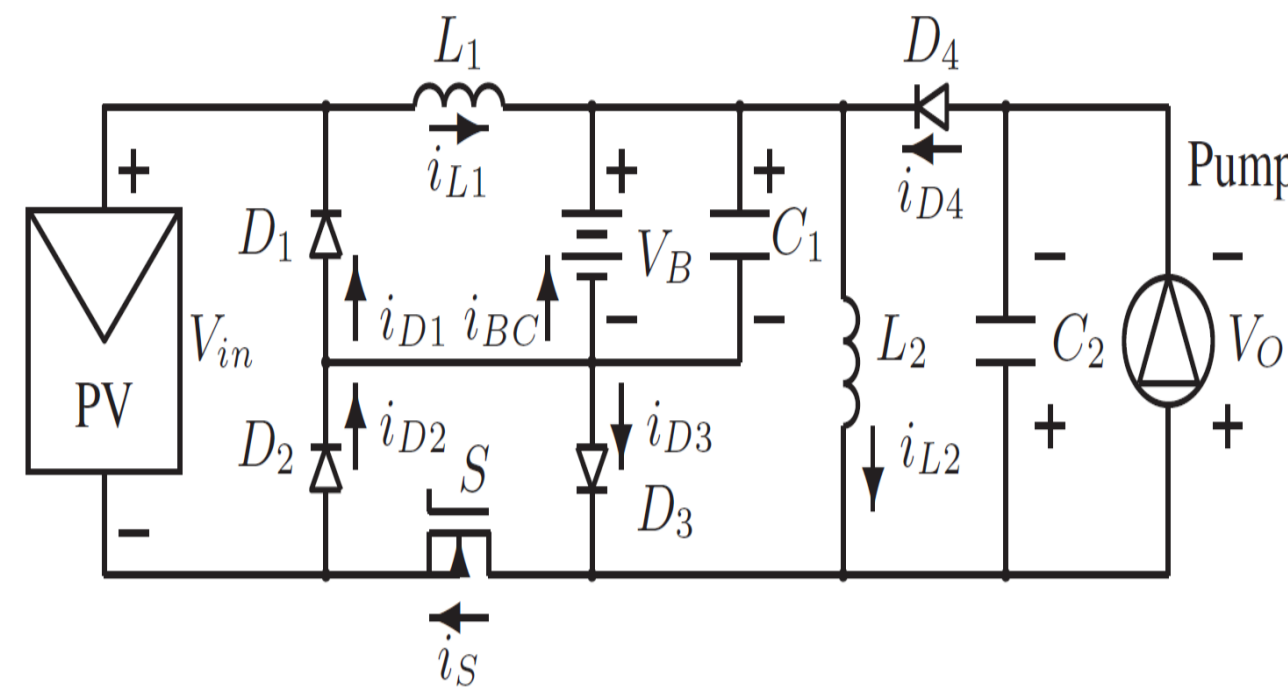


Fig. 3 Proposed single-switch DC-DC converter

- The input-stage buck converter and second-stage buck-boost share a single synchronous switch S. The control circuit and MOSFET gate drive circuit is simplified.
- The battery not only serves as a storage element but also provides a relatively constant DC-link voltage.
- A MOSFET of low turn-on resistance is used due the higher current stress of the single-switch converters.

$$IRFP4110PBF (R_{DS(on)} = 3.7m\Omega)$$

4. Operation Principle

Circuit operation for one switching cycle

There are 4 distinctive operation modes per switching cycle, as shown in Fig. 4.

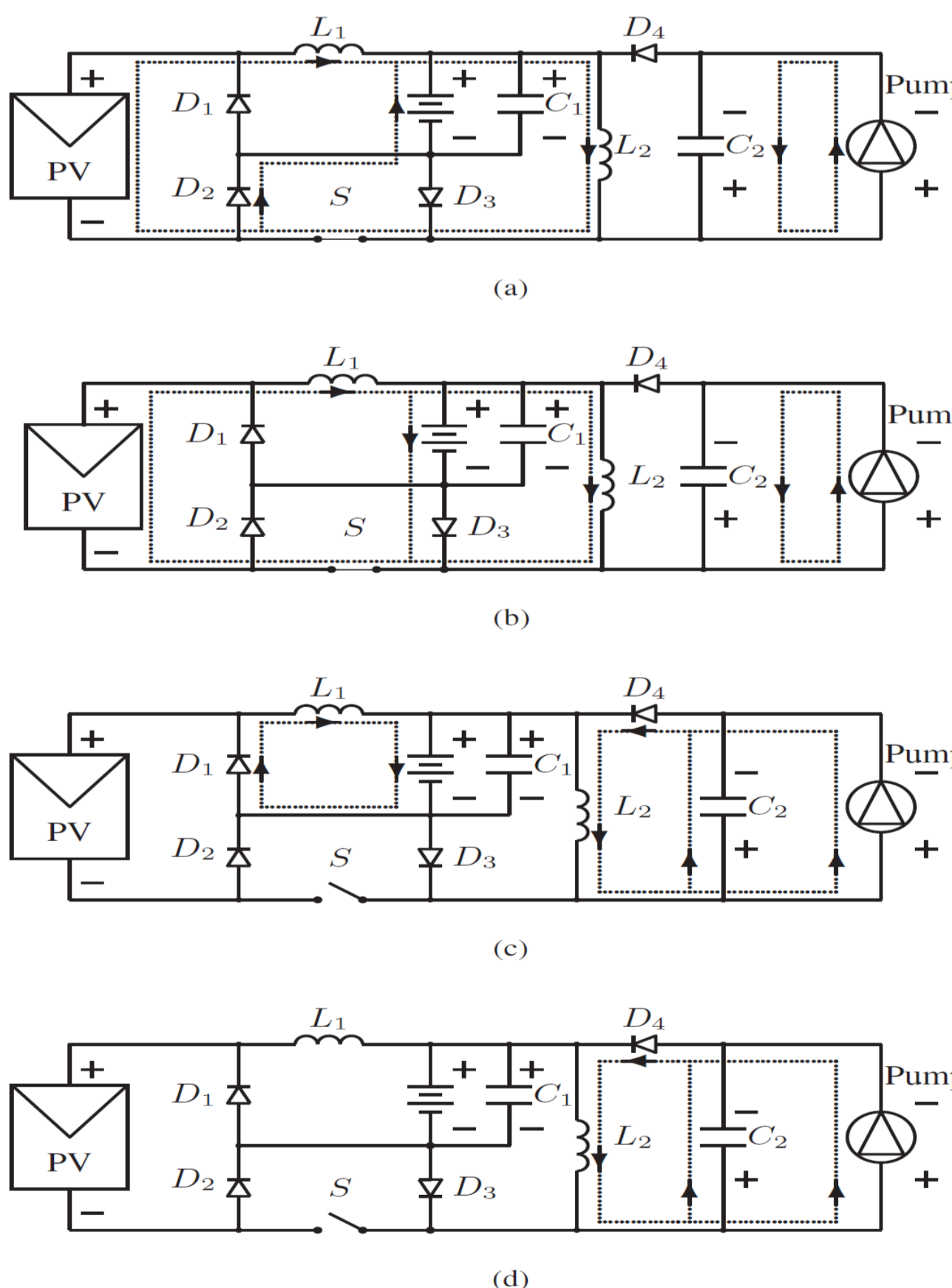


Fig. 4 Circuit operation modes

- **Mode a:** Switch S is closed. Two inductors are charged up.
- **Mode b:** This mode happens when the current of the first inductor is larger than that of the second inductor during the switch S is closed.
- **Mode c:** Switch S is turned off. Two inductors start to discharge.

- **Mode d:** The first inductor goes to DCM and the second inductor continues to discharge its energy to the pump.

Repeated power processing

- The power dissipated in individual component of the cascaded converters accumulates during energy transmitted from one stage to another since the power is repeatedly processed, as shown in Fig. 5.

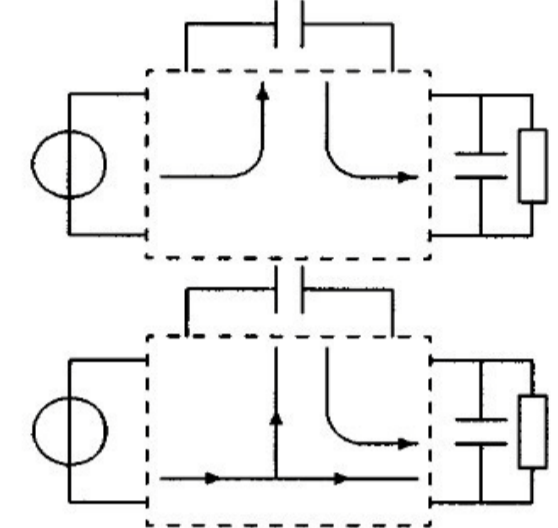


Fig.5 Power flow illustration [2]

- In **Mode a**, the current from the PV source directly flows into output stage inductor through the first inductor without passing the battery and capacitor, as shown in Fig. 6.

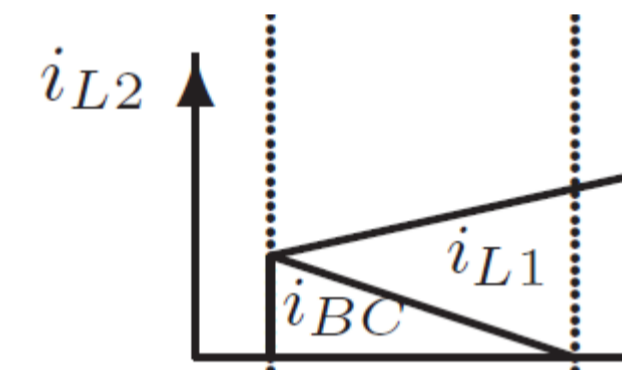


Fig. 6 Key current waveforms for **Mode a**

Experiment Results

A transient response shading half of the PV cell is demonstrated in Fig. 7. The PV input voltage is regulated to its original value after the shading. The average operating frequency of the converter is 85%.

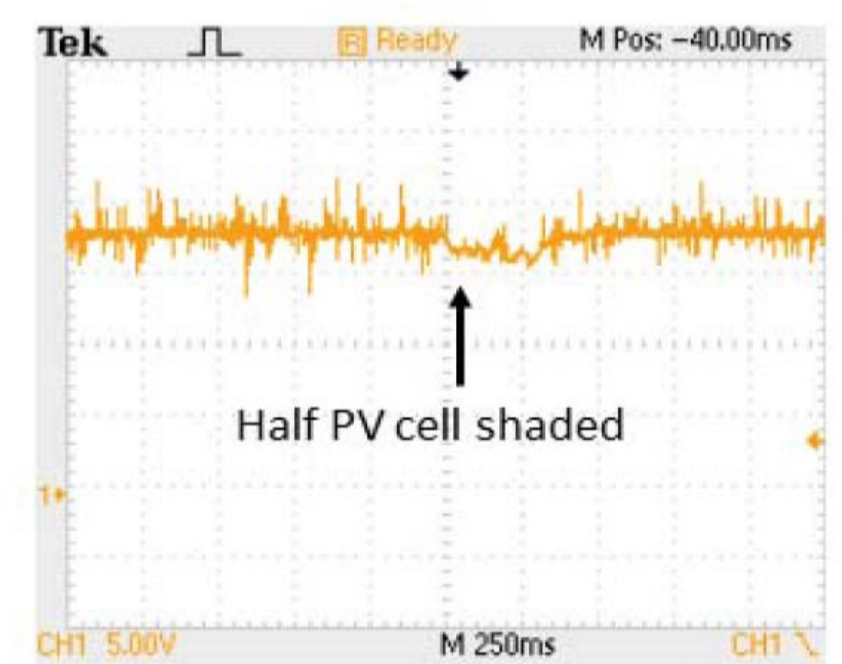


Fig. 7 Transient response of PV input voltage

Conclusion

A design of a single-switch DC-DC converter for the PV-battery powered water pump system is proposed with experimental verification. With reduced number of active switches and controls, the main functions such as MPPT and driving the motor within certain speed range can still be realised without sacrificing the overall efficiency as compared to conventional two-stage design. The voltage stress problem of the DC-link capacitor in conventional single-stage converters is eliminated when a battery is used. Reduced repeated power processing is achieved automatically during the operation.

References

- [1] MDM pumps, at website: <http://www.mdminc.com/blog/index.php/page/2/>
- [2] C. Tse and M.H.L. Chow, "Theoretical study of switching power converters with power factor correction and output regulation," *Circuits and Systems I: Fundamental Theory and Applications*, IEEE Transactions on, vol. 47, no. 7, pp. 1047-1055, 2000