# CURRENT SHARING USING COMPENSATOR IN POSITIVE SUPER LIFT LUO CONVERTER WITH VOLTAGE LIFT FOR STANDALONE PHOTOVOLTAIC SYSTEM

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## Abstract

The photovoltaic(PV) power generation systems become a convenient and promising solution for electric power production by directly transforming solar radiations into electricity. This paper proposes current sharing in paralleled connected positive super lift luo converters (PSLLCs) for standalone photovoltaic system. Paralleled connected converters results in generation of higher output current. But the problem associated with such types of converter is that no equal sharing of output current takes place between individual converter modules in presence of parameter mismatches. Hence to ensure equal sharing of output current a new current sharing scheme without a dedicated current sharing controller is proposed. To regulate output voltage lag-lead compensator is used. The performance of lag-lead compensator is compared with lead and lag compensator through MATLAB/ Simulink.

***Keywords: PV cell, positive super lift Luo converter, Current sharing scheme, Compensator.***

## I. INTRODUCTION

Among various renewable energy sources, solar energy gives better solution, because they produce electric power without producing environmental pollution.

Photovoltaic (PV) systems can be divided into two categories, stand-alone and grid-connection systems. In stand-alone systems PV array feeds the loads directly without connecting to the utility system and have the advantages of simple system configuration and control schemes.

In this paper a PV panel (BPSX150 ) is used. The output voltage from PV panel is given as input to Step up DC-DC converter. DC-DC converter proposed in this paper is PSLLC.

An output current sharing for paralleled connected PSLLCs is proposed in Continous conduction mode (CCM) [1-2]. The mathematical model is first derived and then the compensators are designed. The performance of compensators is evaluated in terms of current distribution capability.

PV and VI characteristics of PV cell are presented in section II. Section III presents block diagram of proposed system. Section IV presents the operation and mathematical model of positive super lift LUO converter (PSLLC).Design of compensators for PSLLC are presented in section V. Section VI gives the simulation results. The conclusion is discussed in section VII.

## II . MODELLING OF PV CELL

The equivalent circuit of a PV cell is shown in Fig. 1. It includes a current source, a diode, a series resistance and a shunt resistance [3-4].The photocurrent $I_{ph}$ generated in the PV cell is proportional to level of solar illumination. I is the output current of PV cell. The current $I_D$ through the bypass diode varies with the junction voltage and the cell reverse saturation current $I_o$.

The mathematical equation use to express the current to load of a PV cell is given as

$$I = I_{ph} - I_s\left(exp\frac{q(V+R_sI)}{NKT} - 1\right) - (\frac{V+R_sI}{R_{sh}}) \quad (1)$$

In this equation, *Iph* is the photocurrent, *Is* is the reverse saturation current of the diode, *q* is the electron charge, *V* is the voltage across the diode, *K* is the Boltzmann's constant, *T* is the junction temperature, *N* is the ideality factor of the diode, and *Rs* and *Rsh* are the series and shunt resistors of the cell, respectively.

Fig.2(a),(b) and (c) shows the P-V,V-I and I-V characteristics of PV array for solar illumination of 1000 W/m$^2$.

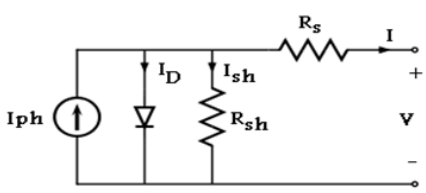



Fig. 1. Equivalent circuit of a PV Cell

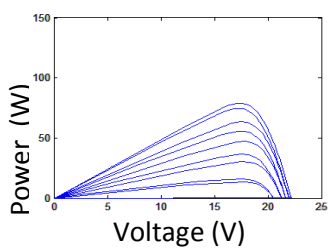



Fig. 2(a) .P-V Characteristics Curve

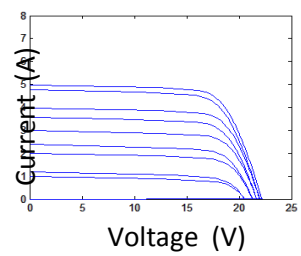



Fig. 2(b) .I-V Characteristics Curve

## III . CIRCUIT CONFIGURATION AND CONTROL SCHEME

### A . *Circuit Configuration*

A main trend in switch mode power supplies is the requirement of very low output voltages with very high currents. Fig. 3 shows how output current can be shared equally in the presence of parameter mismatches in paralleled connected PSLLCs. In fig inputs and outputs of two converters are connected in parallel [5-7].

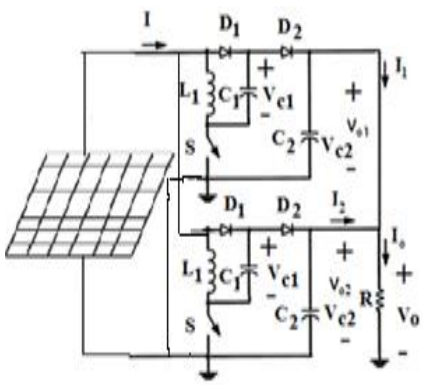



Fig. 3. Proposed Block Diagram

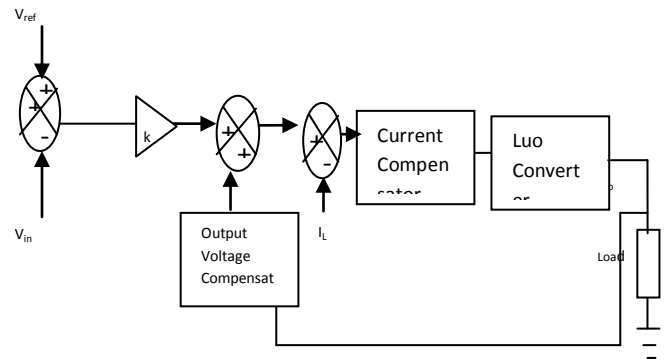



Fig. 4. Control Scheme for PPSLLCs.

***B . Control scheme***

The proposed control strategy is to ensure equal sharing of output current. Two loops are used, an individual inner current loop and a common output voltage loop. The output voltage loop generates the reference current based on the error in the output voltage. The difference between the reference current and currents from individual converter generate error signal . This error signal adjusts the duty ratio of respective converter modules for equal sharing of load current.

**IV. LUO CONVERTER AND MATHEMATICAL MODEL**

***A. Converter operation***

A power circuit diagram of the POESLLC is shown in Fig.5. In Fig. 5 (a), when the switch S is closed, the capacitor $C_1$ is charged to $V_{in}$ and the current $i_{L1}$ flows through the inductor $L_1$ which increases with the voltage $V_{in}$ [8-10].

In Fig. 5 (b) when the switch S is open, the inductor voltage decreases with the voltage, $-(V_o-2V_{in})$. Therefore, the ripple of the inductor current $i_{L1}$ may be written as:

$$\Delta_{iL1}=\frac{V_{in}}{L_1}dT=\frac{V_o-2V_{in}}{L_1}dT \tag{2}$$

$$V_o=\frac{2-d}{1-d}V_{in} \tag{3}$$

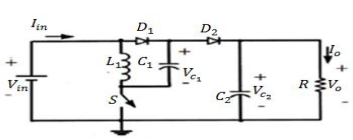


Fig. 5.Circuit of PSLLC

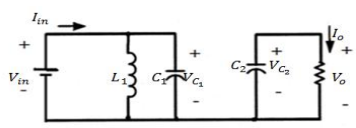


Fig. 5(a). Mode 1 Operation of PSLLC

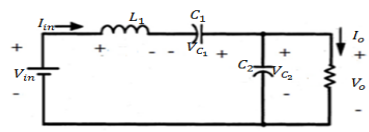


Fig. 5(a). Mode 2 Operation of PSLLC

The voltage transfer gain is:

$$G=\frac{V_o}{V_{in}}=\frac{2-d}{1-d} \tag{4}$$

The input current is equal to ($i_{L1}$+$i_{C1}$) during switching-ON and it is just equal to $i_{L1}$ during OFF. In the steady state, the average charges across the capacitor $C_1$ should not change.

$$i_{in-off} = i_{L1-off} = i_{C1-off}, \tag{5}$$

$$i_{in-on} = i_{L1-on} + i_{C1-on} \tag{6}$$

$$dTi_{C1-on} = (1-d)Ti_{C1-off} \tag{7}$$

If the inductance $L_1$ is large enough, $i_{L1}$ is nearly equal to its average current $i_{L1}$. Therefore:

$$i_{in-off} = i_{L1} = i_{C1-off}, \tag{8}$$

$$i_{in-on} = i_{L1} + \frac{1-d}{d}\frac{i_{L1}}{d} \tag{9}$$

$$i_{C1-on} = \frac{(1-d)}{d} i_{L1} \tag{10}$$

and the average input current is:

$$I_{in} = d_{i_{in-on}} + (1-d)i_{in-off} \tag{11}$$

$$I_{in} = i_{L1} + (1-d)i_{L1} = (2-d)i_{L1} \tag{12}$$

Considering T = 1/f

and:

$$\frac{V_{in}}{I_{in}} = \left(\frac{(1-d)}{(2-d)}\right)^2 \frac{V_o}{I_o} = \left(\frac{(1-d)}{(2-d)}\right)^2 R \tag{13}$$

The variation ratio of the inductor current $i_{L1}$ is:

$$\xi = \frac{\Delta_{iL1/2}}{i_{L1}} = \frac{d(2-d)TV_{in}}{2L_1 I_{in}} = \frac{d(1-d)^2}{2(2-d)}\frac{R}{fL_1} \tag{14}$$

The ripple voltage of the output voltage $V_o$ is:

$$\Delta_{vo} = \frac{\Delta Q}{C_2} = \frac{I_o(1-d)T}{C_2} = \frac{(1-d)}{fC_2}\frac{V_o}{R} \tag{15}$$

Therefore, the variation ratio of the output voltage, $V_o$ is:

$$\xi = \frac{\Delta_{vo}/2}{V_o} = \frac{(1-d)}{2RfC_2} \tag{16}$$

***B . Mathematical Model***

The state variables $V_1$, $V_2$ and $V_3$ are chosen as the current $i_{L1}$, the voltage $V_{C1}$ and voltage $V_{C2}$ respectively .

In Fig. 5(a) When the switch is closed, the state space equation of PSLLC is given as (17)

$$\dot{V}_1 = \frac{V_{in}}{L_1}$$

$$\dot{V}_2 = \frac{V_{in}}{C_1 R_{in}} - \frac{v_1}{C_1}$$

$$\dot{V}_3 = -\frac{V_3}{RC_2}$$

(17)

In Fig. 5(b) when the switch is open, the state space equation of PSLLC is given as (18)

$$\dot{V}_1 = \frac{V_{in}}{L_1} - \frac{V_2}{L_1} - \frac{V_3}{L_1}$$

$$\dot{V}_2 = \frac{v_1}{C_1}$$

$$\dot{V}_3 = \frac{V_1}{C_2} - \frac{V_3}{RC_2} \quad (18)$$

By using state-space averaging method, the state-space averaging model of the PSLLC is given as (19)

$$\begin{bmatrix} \frac{di_{L1}}{dt} \\ \frac{dV_{C1}}{dt} \\ \frac{dV_{C2}}{dt} \end{bmatrix} = \begin{bmatrix} \frac{1}{R_{in} L_1} & \frac{d-1}{L_1} & \frac{d-1}{L_1} \\ \frac{1-2d}{C_1} & \frac{-d}{R_{in} C_1} & 0 \\ \frac{1-d}{C_2} & 0 & \frac{-1}{RC_2} \end{bmatrix}$$

(19)

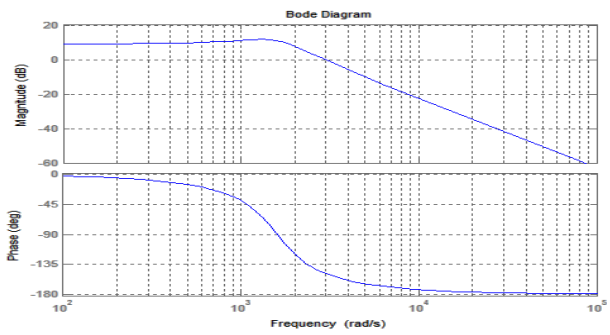
$$\dot{v} = Av + Bu \quad (20)$$

Its output equation is given as

$$V_o = v_4 \quad (21)$$

## V. DESIGN OF COMPENSATORS

In general compensator is used to modify system dynamics to satisfy the given



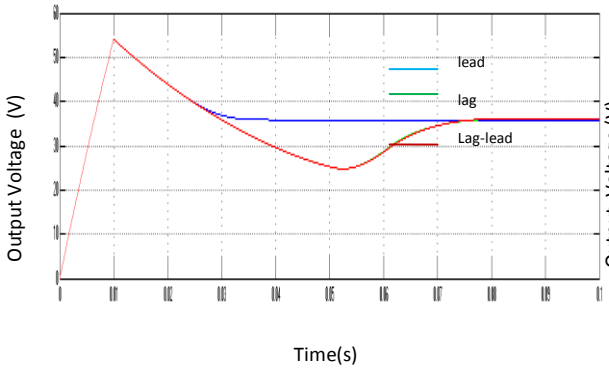

specifications. Lead compensator gives an improvement in transient response and small change in steady state accuracy. Lag compensator on the other hand gives an appreciable improvement in steady state accuracy at the expense of increasing the transient response time. Lag-lead Compensator combines the characteristics of both lead compensator and lag compensator. In the proposed system from the open loop response (Fig.6) of voltage transfer function, respective compensators are designed.

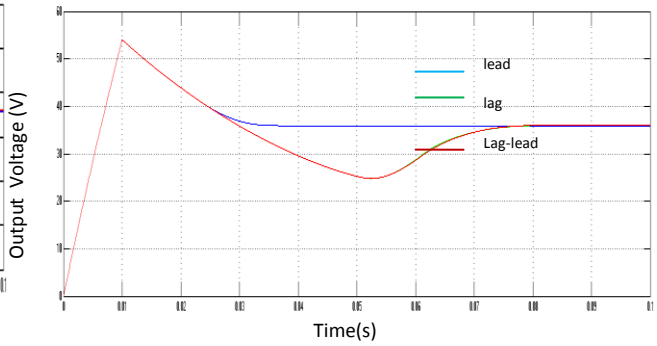
## VI . RESULTS AND DISCUSSIONS

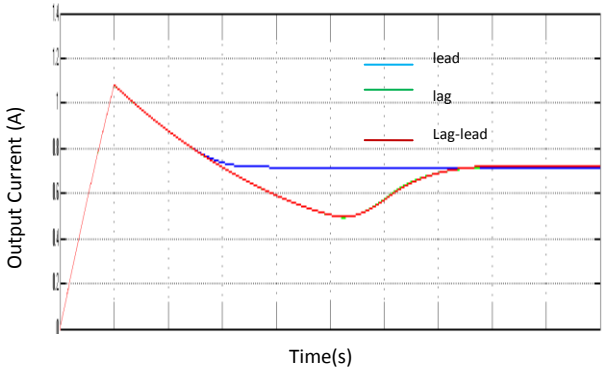
This section is to discuss the simulation studies of positive super lift LUO converters(PSLLCs) with compensators for standalone photovoltaic system. Simulations are

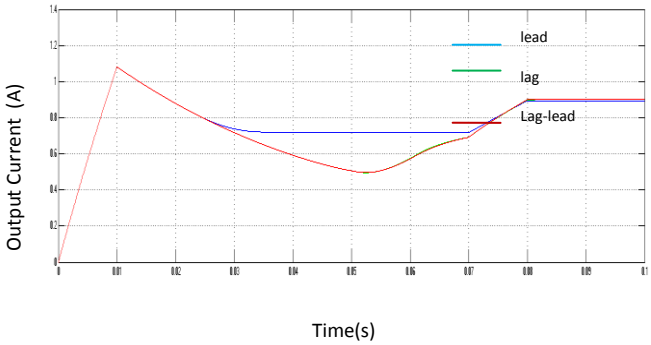
performed on PV array and PSLLCs circuits with parameters listed in Table 1 and 2 using MATLAB/ Simulink.

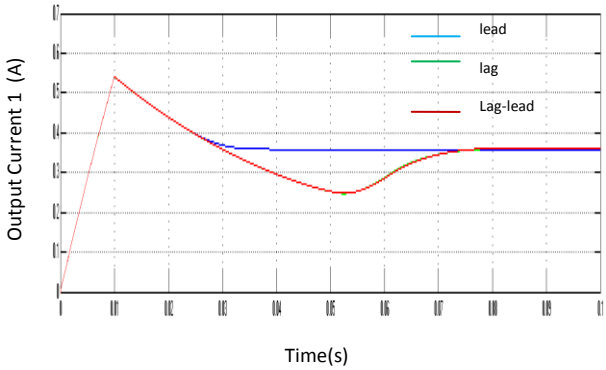
Figure 7 shows simulation waveforms with $L_{11} = 100\mu H \ and \ L_{12} = 105\mu H$ . Figure 6(a) shows the dynamic behaviour at start-up of the output voltage of paralleled modules for load resistance 50 Ω. It can be seen that the output voltage of the paralleled modules has a slight overshoot and a settling time of 0.038s for lead compensator and 0.074s for lag and lag –lead compensator.

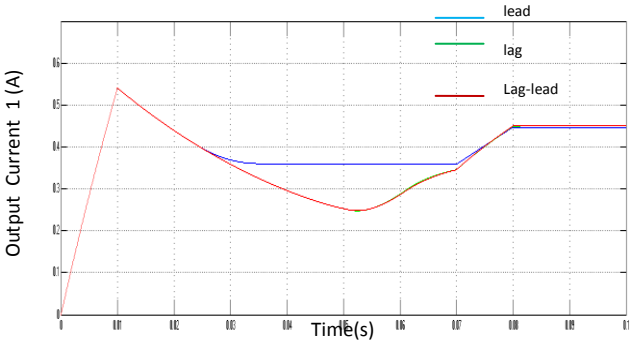

Output Voltage (V)
Time(s)
lead
lag
Lag-lead

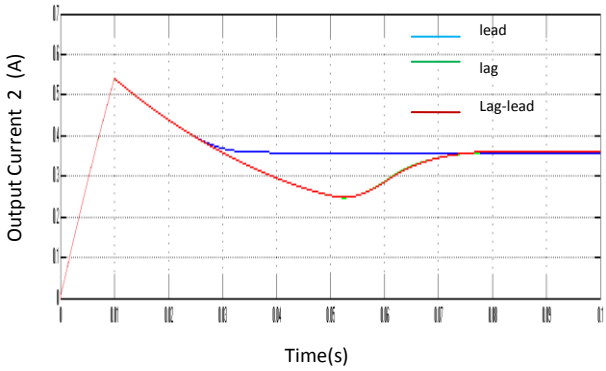

Output Voltage (V)
Time(s)
lead
lag
Lag-lead


Output Current (A)
Time(s)
lead
lag
Lag-lead


Output Current (A)
Time(s)
lead
lag
Lag-lead


Output Current 1 (A)
Time(s)
lead
lag
Lag-lead


Output Current 1 (A)
Time(s)
lead
lag
Lag-lead


Output Current 2 (A)
Time(s)
lead
lag
Lag-lead

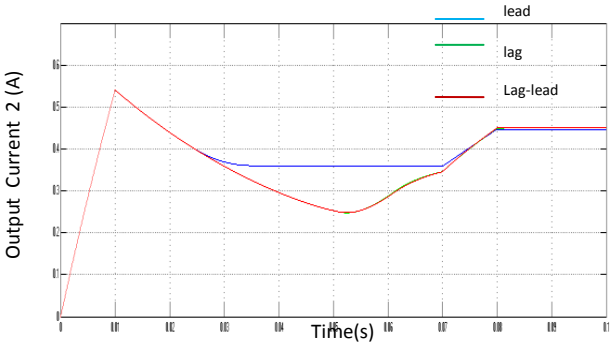

Output Current 2 (A)
Time(s)
lead
lag
Lag-lead

Figure 7.Simulation waveforms with $L_{11} = 100\mu H$ $and$ $L_{12} = 105\mu H$ in start-up for various solar radiations and R=50Ω

(a). Response of average output voltage of

Figure 8. Simulation waveforms for a step change of load from 50 Ω to 40 Ω.

(a). Response of average output voltage of PSLLCs

**Table 1.BPSX150 PV module**

| Parameter | Specification |
|---|---|
| Peak Power ($P_{PV}$) | 80 W |
| Peak power voltage($V_{PV}$) | 16V |
| Current at peak power($I_{PV}$) | 5 A |
| Open circuit voltage ($V_{OC}$) | 0.9 V |
| Short circuit current($I_{SC}$) | 5A |

**Table 2. Parameters of Paralleled connected PSLLCs**

| Parameter Name | Symbol | Value |
|---|---|---|
| Input Voltage | $V_{in}$ | 12V |
| Output Voltage | $V_O$ | 36V |
| Inductor | $L_{11}, L_{21}$ | 100uH |
| Capacitors | $C_{11}, C_{21}$, $C_{12}, C_{22}$ | 30uf |
| Nominal switching frequency | $f_s$ | 100KHz |
| Load resistance | $R$ | 50 |
| Range of duty ratio | $d$ | 0.3 to 0.9 |

All three different compensators works well for R=50Ω.

Fig. 8(a),(b),(c),(d) shows the response of the average output Voltage, output current , average output current of module1 and average output current of module2 of paralleled modules using three different types of compensator for a step change of load from 50 Ω to 40Ω at time = 0.06s .All three compensators work well for the given disturbance. Fig 7 and 8 shows that current sharing takes place well without a dedicated current sharing controller

**VII. Conclusion**

This paper has proposed a current sharing in PSLLCs using lead, lag and lag-lead compensators for standalone photovoltaic system. The control scheme for paralleled connected PSLLCs is designed using Lead, Lag and Lag-Lead compensators. The system has been proved to be effective in load voltage regulation and current sharing using compensators. Improvement in transient response is observed in lead compensator. In Lag and Lag-Lead compensators the steady state accuracy is better when compared to Lead compensator, but with increasing transients.

The proposed method is suitable for an efficient power supply for satellite communication, Uninterruptible power supplies etc.

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