A Preview on Simulation of Super-Lift Converter for Grid Connected Solar Installation

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***Abstract*—Solar energy source is an "indigenous" environmental option, economically competitive with conventional power generation. This paper can serve as a compendium of the tremendous amount of new technology being developed in this field. Photovoltaic (PV) arrays are generally the bulkiest and most expensive parts of solar-powered electrical generation systems. Optimum utilization of available power from these arrays is therefore essential and can considerably reduce the size, weight and cost of such power systems. Again the photo-voltaic energy system requires storage to meet the energy demand during period of low solar irradiation and night time. The controller incorporates a DC-DC converter and is used as a controlled energy-transfer-equipment between the main energy source (PV arrays) and an auxiliary energy system. This paper deals the design of DC to DC converter which makes voltage at a specified value. This voltage is converted to AC by using inverter for successfully connecting to the grid.**

***Index Terms*—Super-Lift converters, solar cells, PV cells.**

I. Introduction

With the shortage of the energy and ever growing of the oil price, research on the renewable and green energy sources, especially the solar arrays and the fuel cells, becomes more and more important. To achieve high step-up and high efficiency, DC/DC converters are the major consideration in the renewable power applications due to the low voltage of PV arrays and fuel cells. The upper atmosphere of the earth receives solar energy at a rate of 442.4 Btu per sq ft-hr +2 percent [1]. The energy on the earth surface depends on transmission efficiency from atmosphere which depends on air mass, the sun's attitude, cloud and haze and diffuse radiation. Solar energy consists of electromagnetic radiations. Wave length varies from 0.3μ to 20μ [1]. About 99 percent of the energy lies in the range from 0.3μ to 3μ, with a pick at about 0.5μ. Photovoltaic cells convert solar rays to electrical currents. The task of a maximum power point tracker (MPPT) in a photovoltaic (PV) energy conversion system is continuously tuning the system so that it draws maximum power from the solar array regardless of weather or load conditions. Since the solar array has a nonideal voltage-current characteristic, and the conditions such as isolation, ambient temperature, and wind that affect the output of the solar array unpredictable, the tracker must contend with a nonlinear and time-varying system. Many tracking algorithms and techniques have been developed. The Perturb and Observe method [3] and the Incremental Conductance method [3], as well as variants of those techniques [4], [5], are the most widely used .PV array systems should be designed to operate at their maximum output power as well as voltage with minimum harmonic distortion under all operating conditions [2]. A DC/DC converter based circuit model for a solar photovoltaic array is given by [6] - [7].

In this paper, section III and IV are presented for basic principle of super lift converter and simulation result by using matlab respectively.

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II. PV Cell System

Photovoltaic's offer consumers the ability to generate electricity in a clean, quiet and reliable way. Photovoltaic systems are comprised of photovoltaic cells, devices that convert light energy directly into electricity. Because the source of light is usually the sun, they are often called solar cells. The word photovoltaic comes from "photo," meaning light, and "voltaic," which refers to producing electricity. Therefore, the photovoltaic process is "producing electricity directly from sunlight." Photovoltaics are often referred to as PV. PV cells convert sunlight directly into electricity without creating any air or water pollution. PV cells are made of at least two layers of semi-conductor material. One layer has a positive charge, the other negative. When light enters the cell, some of the photons from the light are absorbed by the semiconductor atoms, freeing electrons from the cell's negative layer to flow through an external circuit and back into the positive layer. This flow of electrons produces electric current. The stand-alone photo-voltaic energy system requires storage to meet the energy demand during period of low solar irradiation and night time. Battery storage in a solar system should be properly controlled to avoid catastrophic operating condition like overcharging or frequent deep discharging. Storage batteries account for the most PV system failures and contribute significantly to both initial and the eventual replacement cost. Charge controllers regulate the charge transfer and prevent the battery from being excessively charged and discharged. Switch mode DC to DC converters are used to match the output of a PV generator to a variable load. DC to DC converters allow the charge current to be reduced continuously in such a way that the resulting battery voltage is maintained at a specified value. A practical photovoltaic energy conversion system is shown in Fig 1. and it's block diagram fig 2. and Fig 3.

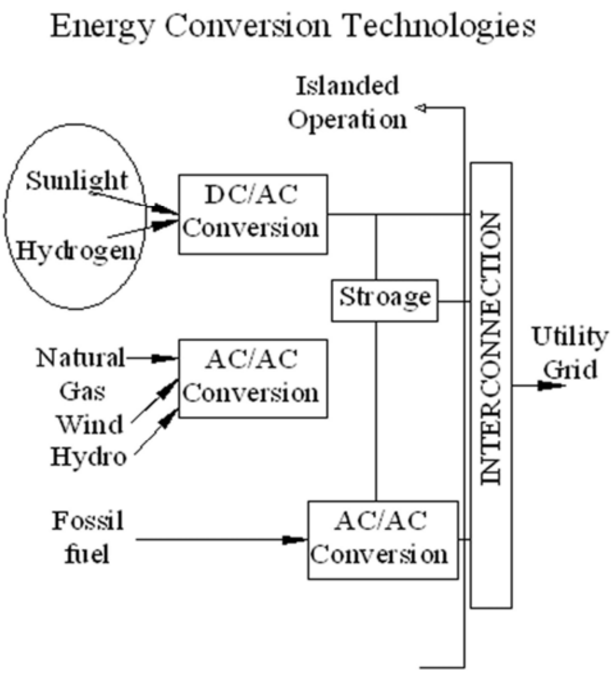

Fig. 1. Energy conversion technologies for injection of alternative energy power into the grid.

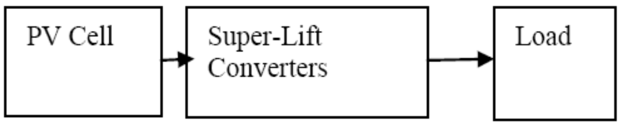

Fig. 2. Block diagram.

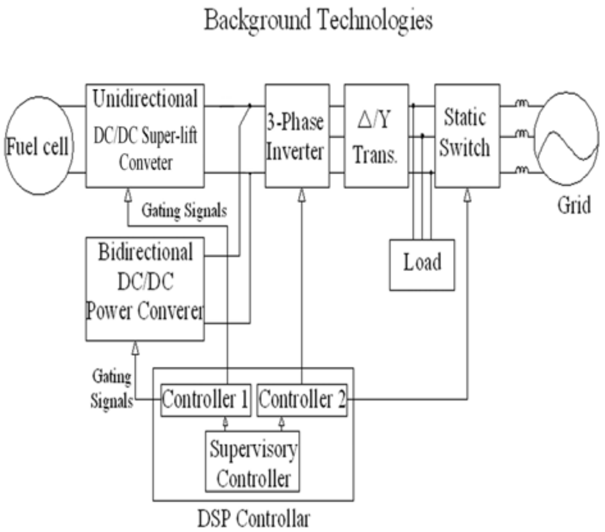

Fig. 3. Typical diagram of micro-source generation system.

III. Operation and Maintenance of Super-Lift Converter

Super lift Luo converter significantly increases the voltage transfer gain stage by stage in geometric progression [8]-[10] and can Positive output Super Lift Luo-Converters are sorted in several sub-series: Main series, addition series, enhanced series, re-enhanced series, multiple (j)-enhanced series. This section only introduces the main series. Each circuit of the main series has only one switch S, n inductors, 2n capacitors and (3n-1) diodes for n^{th} stage circuit.

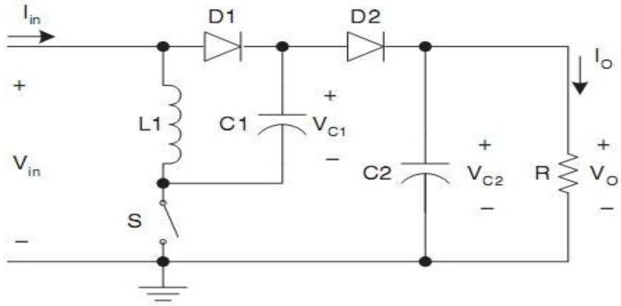

Fig. 4. Elementary circuit diagram.

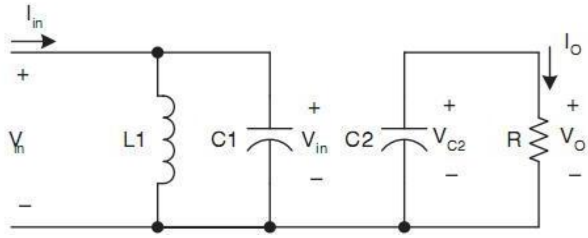

Fig. 5. Equivalent circuit during switching-on.

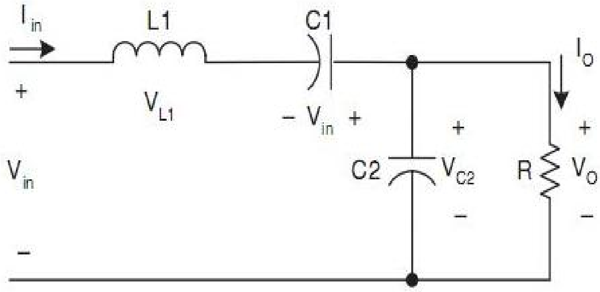

Fig. 6. Equivalent circuit during switching-off.

The Elementary circuit and its equivalent circuit during switching-on and off are shown in fig 4, 5, 6. The voltage across capacitor C_1 is charged to V_{in}. The current i_{L1} flowing through inductors L_1 increase with voltage V_{in} during switching-on period kT and decreases with voltage-(V_o-2V_{in}) during switching-off period (1-k) T. Therefore, the ripple of the inductor current i_{L1} is:

$$\Delta i_{L1} = \frac{V_{in}}{L_1} kT = \frac{V_o - 2V_{in}}{L_1}(1-k)T \quad (1)$$

$$V_o = \frac{2-K}{1-K} V_{in} \quad (2)$$

He voltage transfer gain is

$$G = \frac{V_o}{V_{in}} = \frac{2-k}{1-k} \quad (3)$$

The input current i_{in} is equal to (i_{L1} + i_{C1}) during switching-on and only equal to i_{L1} during switching-off. Capacitor current i_{C1} is equal to i_{L1} during switching-off. In steady-state, average charge across capacitor C should no charge. Following relations are obtained:

$$i_{LR-off} = i_{L1-off} = i_{C1-off}$$

$$i_{in-on} = i_{L1-on} + i_{C1-on}$$

$$kTi_{C1-on} = (1-k)Ti_{C1-off}$$

Inductance L_1 is large enough, i_{L1} is nearly equal to its average current.

Therefore,

$$i_{in-off} = i_{C1-off} = I_{L1}$$

$$i_{in-on} = i_{L1} + \frac{1-k}{k} I_{L1} = \frac{I_{L1}}{k}$$

$$i_{C1-on} = \frac{1-K}{K} = I_{L1}$$

And average input current

$$i_{in} = K i_{in-on} + (1-k) i_{in-off} = I_{L1} + (1-k) I_{L1} = (2-k) I_{L1} \quad (4)$$

Considering

$$\frac{V_{in}}{I_{in}} = \left(\frac{1-k}{2-k}\right)^2 \frac{V_o}{I_o} = \left(\frac{1-k}{2-k}\right)^2 R \quad (5)$$

The variation ratio of current i_{L1} through inductor L_1 is

$$\xi_1 = \frac{\Delta i_{L1}/2}{I_{L1}} = \frac{k(2-k)TV_{in}}{2L_1 I_{in}} = \frac{k(1-k)^2}{2(2-k)} \frac{R}{fL_1} \quad (6)$$

Usually €1 is small (much lower than unity); it means this converter normally works in the continuous mode.

The ripple voltage of output voltage V_O is

$$\Delta v_o = \frac{\Delta Q}{C_2} = \frac{I_o kT}{C_2} = \frac{k}{fC_2} \frac{V_o}{R} \quad (7)$$

Therefore, the variation ratio of output voltage Vo is

$$\varepsilon = \frac{\Delta v_o / 2}{V_o} = \frac{k}{2RfC_2} \quad (8)$$

Usually R is in kΩ, f in 10 kHz and C_2 in μF, this ripple is very smaller than 1%

IV. Simulation Result

The simulation is performed of superlift converter in matlab program for investigating Open loop Bode Diagram, Closed loop bode Closed loop impulse, Closed loop Nichol, Closed loop Nyquist, Closed loop pole zero, Step Closed loop, Open loop impulse, Open loop Nyquist, Open loop pole zero, Closed loop pole Zero map from fig 14. to 19. the fig7.

Input Voltage, MOSFET driving voltage, Output current of super lift converter, Output voltage of super lift converter, inverter, load and modulation index respectively. The output is presented in table and figures.

From the table, the output voltage of super lift converter is the three times of its input.

TABLE I. Input and Output of Superlift Convertor

Parameter	Value
Inductance	0.5mH
Capacitance C1	125μF
Capacitance C2	250 μF
Resistance of the load	10Ω
Lose of inductor	0.125 Ω
Inductor current	8.115942A
Output current	3.246377A
Source current	11.362319A
Stored energy in inductor	0.0302Jouls
Stored energy capacitors	0.1380Jouls
Dc voltage of the dc source	11.362319V
Output voltage of converter(volts)	32.463768V
Switching frequency(hertz's)	100KHz
Duty ratio of the switch	0.6
Output power	105.3896W
Power loss	658.68515W
Energy loss	0.0066Jouls
Energy factor	22.0184
Pumping energy	0.007641Jouls
Storage energy	0.168237Jouls
Efficiency	0.137931
Damping ratio	0.037977
time constant	0.002337
damping time constant	0.000089

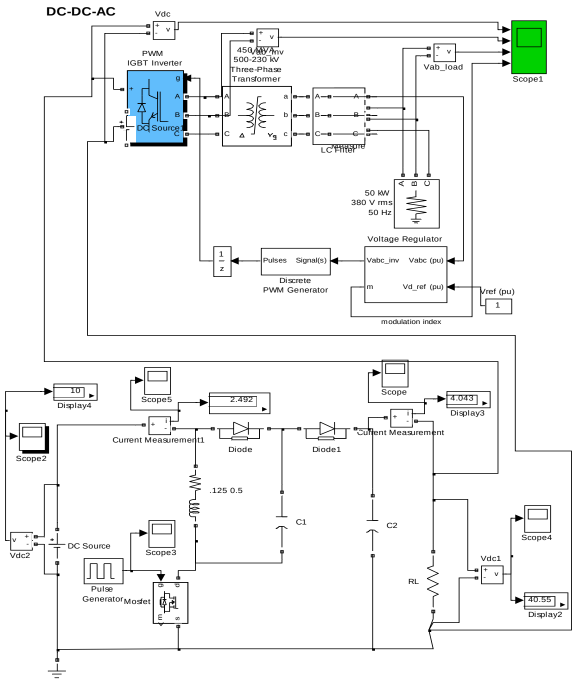

Fig. 7. Simulink Circuit for solar installation.

From the simulink, its figure out that due to the input voltage 10V, output voltage of Super-lift converter is 40.55V. This output is feed to the IGBT inverter to converter dc to ac voltage and this ac voltage is step up by using *Δ-γ* transformer to feed the load or grid.

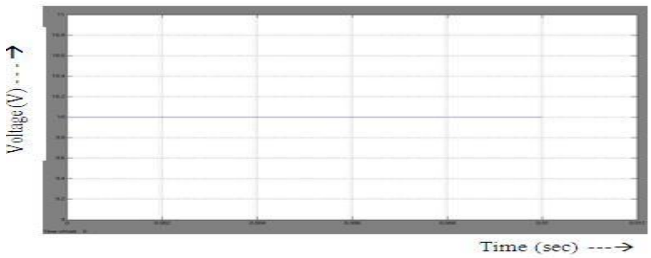

Fig. 8. Input Voltage.

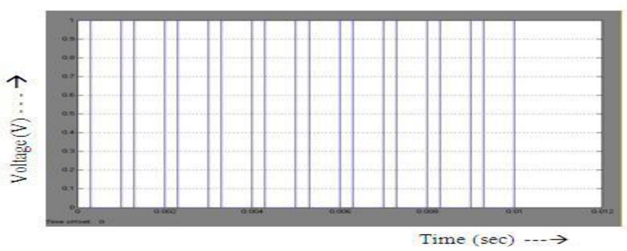

Fig. 9. MOSFET driving voltage.

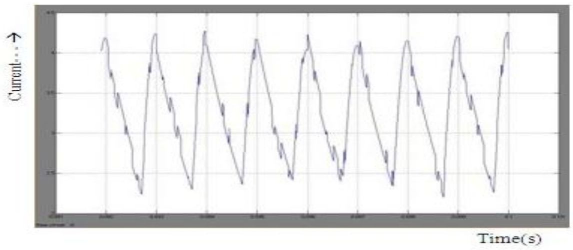

Fig. 10. Output current of super lift converter.

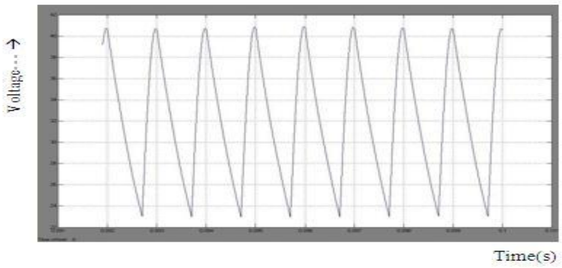

Fig. 11. Output voltage of super lift converter.

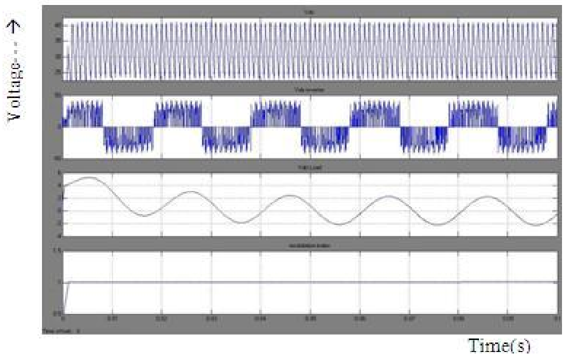

Fig. 12. Output voltage of super lift converter, inverter, load and modulation index.

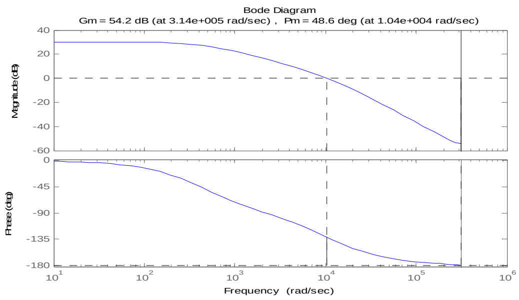

Fig. 13. Open loop bode diagram.

From the Bode diagram the gain margin is +54.2 dB (at 3.14×10^5 rad/sec) and phase margin +48.6 deg (at 3.14×10^4 rad/sec). Since the phase margin and gain margin are positive the system is stable.

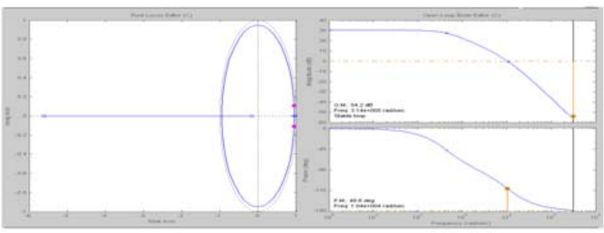

Fig. 14. Root locus and bode diagram.

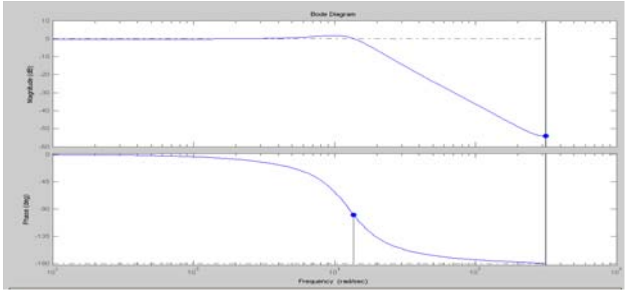

Fig. 15. Closed loop bode.

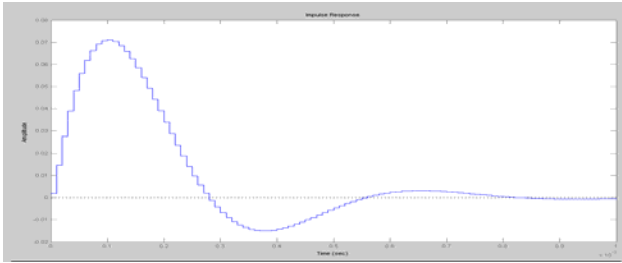

Fig. 16. Closed loop impulse.

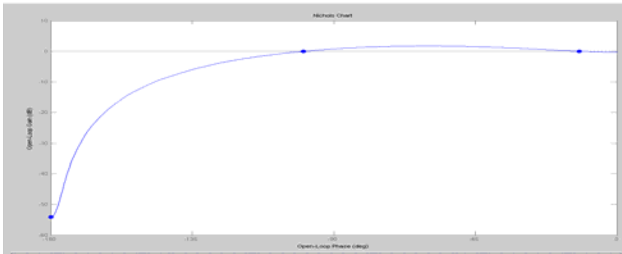

Fig. 17. Closed loop Nichol.

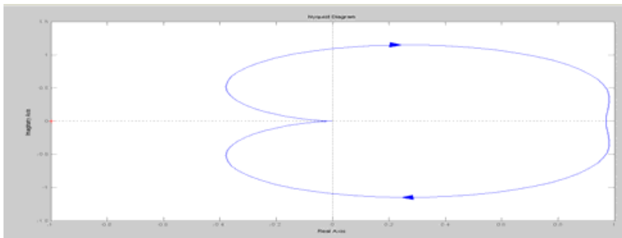

Fig. 18. Closed loop Nyquist.

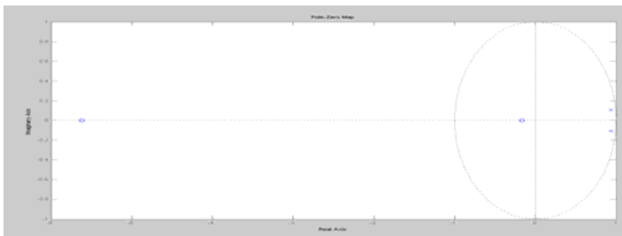

Fig. 19. Closed loop pole zero map.

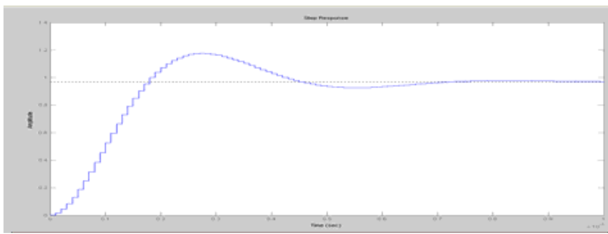

Fig. 20. Step closed loop.

From the above responses, we can summarize that the system operates at the stable region.

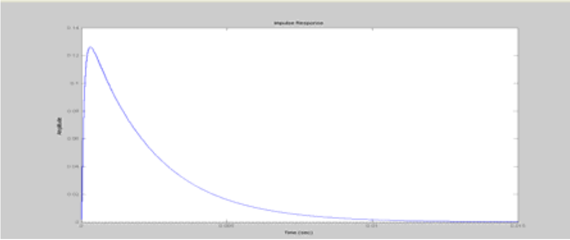

Fig. 21. Open loop impulse.

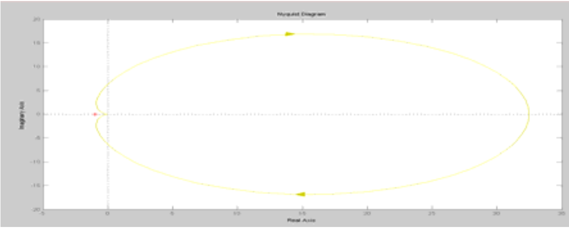

Fig. 22. Open loop Nyquist.

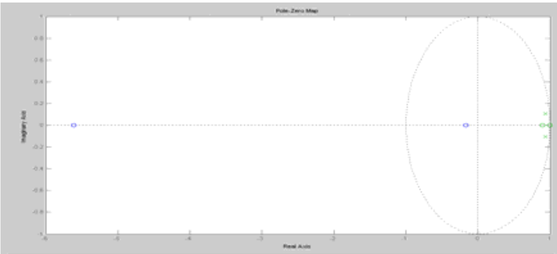

Fig. 23. Open loop pole zero.

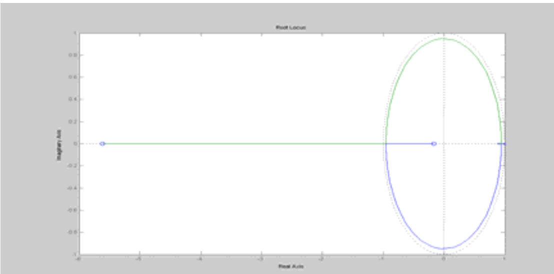

Fig. 24. Closed loop pole zero.

V. CONCLUSION

In this work, the importance of single-stage grid connected PV systems has been highlighted. A single-stage topology with improved features has been proposed. The positive output elementary super lift Luo converter (POESLLC) performs the voltage conversion from positive Source voltage to positive load voltage. Due to the time variations and switching nature of the power converters, their dynamic behavior becomes highly non-linear. This paper has successfully demonstrated the design, analysis, and suitability of the converter. This output voltage is successfully coupled to the ac load and grid.

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