DYNAMIC ANALYSIS OF A CLOSED LOOP MULTI INPUT ZETA CONVERTER TOPOLOGY FOR MODULAR HYBRID MICROGRID SYSTEM

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Abstract
This paper leads to the proposal of dynamic analysis of a closed loop multi input Zeta converter topology for modular hybrid microgrid system. In continuation to this the modelling is performed by using dynamic model of single input, dual input and closed loop dual input converter. The above mentioned models are designed, implemented and simulated using Matlab and simulation software. The inputs are fed from hybrid system to the converter topologies discussed and thus the output obtained are compared and studied that showcases the advantages of closed loop multi input zeta converter topology. The results so obtained are presented so as to verify the accuracy of the designedmodel.
Keywords— Power Converters, Zeta Converter, Photovoltaic Array, Photovoltaic System, WTGS, Renewable Energy, Microgrids, pi controller, PWM.

I. INTRODUCTION

In the present scenario conventional energy sources are moving towards depletion at a faster rate this has resulted in research and development of non-conventional sources of energy like solar, wind, hydel, bioenergy etc. The main one is the solar energy which is extracted using the PV cells. In order to improve these systems power electronics are augmented and interfaced with them. With the irregular nature of harvesting systems of renewable energy hybrid systems such as photovoltaic arrays (PV arrays) and wind turbine generation systems (WTGS) there has been rise in the development of a number of different topologies of DC/DC converters that can help maintain the output voltage of these systems at a constant level. Nowadays, multiple-input converters (MIC) that can integrate various types of renewable energy hybrid systems using a single converter power stage are becoming popular. PV arrays and WTGS are complementary to each other when it comes to continuous provision of energy to the load. That is it can be stated that the absence of light energy harvestedby the PV arrays can be replaced by the presence of wind energy harvested by wind turbine generation systems. Multiple-input converters topologies had been analyzed, synthesized, and evaluated in a many literatures. However, there have not been any light on a multiple-input Zeta converter topology. A multi input Zeta topology takes over the advantages of a single-input Zeta topology which includes the wide range of input voltage that it can handle because it can both step up and step down the input voltage. Also a Zeta converter is capable of providing output voltage with positive polarity. This acts as an added advantage as most types of load require this voltage polarity. A Zeta converter also helps in power factor correction and this characteristic is typically a boon for highly reactive systems. In this work, a closed loop dual input Zeta converter that can integrate a PV array system and wind turbine generation system into a single power stage is studied. Although here we are discussing only unto dual input zeta converter but higher order zeta converters can also be designed. This topology showcases potential modularity i.e. its design can provide scalable architecture and more flexibility. Apart from this by using this topology the replacement of multiple inputs of the converter can be done in a much simpler way. Dynamic behavior and a basis for the converter feedback control design are implemented with the study of dynamic model of converter. State-space averaging method is chosen because of the acceded advantages pointed out in the dynamic modelling conducted for a single-input Zeta converter. In order to verify the validity of the resultant model, a closed loop dual input Zeta converter is designed, implemented and simulated with the help of Sim Power System Toolbox of Matlab &Simulink.

II. OVERVIEW OF POWER CONVERTER

In the field of electrical engineering and the related field of electric power industry, power conversion is a method of converting electric energy from one form to another like converting from AC to DC, AC to AC, DC to AC ,DC to DC or changing the frequency or voltage etc. Hence we can say that a power converter is an electrical or electro-mechanical device for converting electrical energy. This could be a very basic transformer to change the voltage of AC power along with some combinations of more complex systems. The converter can also be referred as a class ofelectrical

Machinery that is used to convert one frequency of alternatingcurrent into another frequency. Power conversion systems usually incorporate redundancy and voltage regulation.

III. OVERVIEW OF ZETA CONVERTER

In present scenario DC/DC converters are widely used as power supply in electronic systems. Zeta converter forms a major source of this part. It is a fourth order DC/DC converter that is capable of amplifying as well as reducing the input voltage levels without inverting the polarities. The main reason for this is the presence of capacitors and inductors that act as a dynamic storage elements. It is also a non linear system which can be seen as a buck-boost-buck converter with respect to output and boost-buck-boost converter with respect to the input.

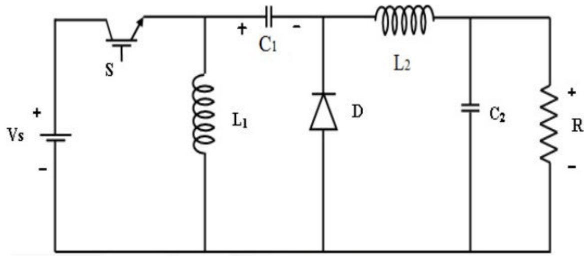


Fig. 1: Basic Zeta converter circuit

The above figure depicts the basic non isolated zeta converter. Based on the value of inductance, capacitance, load resistance and operating frequency there can be different operating modes. We can make use of state space analysis method for continuous inductor current. Following assumptions are made for this method:-

1. Converter operates in continuous inductor current mode
2. switching devices are considered to beideal
3. Frequency ripples in DC voltages areneglected

A. MODES OF OPERATION OF ZETA CONVERTER

The following are the two modes in which a Zeta converter works.

MODE 1 : CHARGINGMODE

- switch isON
- Diode D isoff
- the inductors L_1 and L_2 draws current from voltage sourceV_s

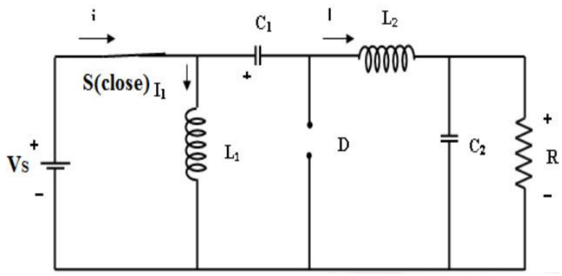


Fig. 2: Mode 1 equivalent circuit

MODE 2 : DISCHARGING MODE

- Switch isOFF
- Diode D isON
- The energy stored in inductor L_2 is transferred to R(load)

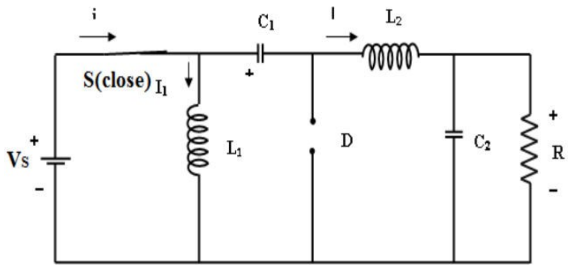


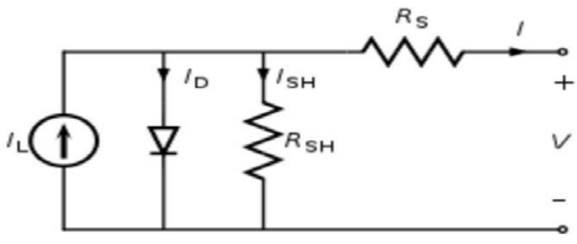
Fig. 3: Equivalent circuit of mode 2

3.1OVERVIEWOFPVARRAYSOR PHOTOVOLTAICSYSTEMS

In the present scenario there is an increased discussion regarding high oil prices, low reserves of fossil fuels, global warming, ecosystem and environmental damage etc. and this has lead to develop alternate energy resources with low emissions and high efficiency. The energy from sun or the photovoltaic effect is considered as the most essential and sustainable resource due to its availability, abundance and free cost. A photovoltaic cell is the basic building block of a solar panel and their series and parallel arrangement form a PV module or an array.

Now a days they are widely used in many applications as it can generate electricity directly without any environmental impact. Since its a semiconductor device it is not dependent on moving parts, is quite & static and makes its operation and maintenance cost lower. The output characteristics of PV system mainly depends on solar insolation cell temperature, output voltage etc. The equivalent models are implemented on the simulationsoftware.

Fig.4: Equivalent circuit of a photovoltaic cell



In the above figure I and V represents current and voltage of the PV cell, R_s and R_{sh} are series and shunt resistors, I_L is the photo current, I_D is the diode current. The IV characteristic of PV cell is depicted by the following equation:-

$$I = [\ I_L - I_0 exp\ \{\ q\ (\ V + IR_s\ )\ /\ AkT\ \} - 1\ ] - (\ V + IR_s\ /\ R_{sh}\ )$$

3.2 OVERVIEW OFWTGS

Wind turbine generation system (WTGS) mainly deals with the utilization of wind energy for various scale of power generation. Here we mainly discuss the type of generator used for the energy conversion, like DC machines, synchronous Machine, squirrel cage machine, double fed induction generator, High temperature superconducting generator, etc. The utilization of wind energy is dated back to 5000 BC. The use of wind energy gained momentum with the rise in oil prices, deficit of fossil fuels, industrial initiatives etc. wind energy can be developed both onshore and offshore

3.3 OVERVIEW OF RENEWABLE ENERGY

Those sources of energy that do not deplete or can be replenished within human beings life time is termed as renewable energy. Wind, solar, geothermal, biomass etc form the major examples of these sources. Most of this energy is derived directly or indirectly from the sun. For example solar energy is derived from direct tapping of sun energy using solar technologies. The wind energy is derived from winds via wind mills, winds flow as a result of sun's heat. Another source bioenergy that is related to plants is also derived from sun's energy as plats use sunlight to grow.

But all renewable energy sources does not rely on sun like the geothermal energy uses the earth's internal heat whereas the tidal energy uses the moons gravitational pull and hydropower uses the energy of water flow.

The renewable energy makes up to 13-14% of world's energy supply and 22% of world's electricity.

The renewable energy sources are the major source of discussion in the present scenario due to two main reasons:

- The energy sources would notdeplete
- The green house gas emission is comparatively less with that of fossilfuels

Though these are termed as the globes energy future but still they face difficulties while deployment at a large scale, technological barriers, intermittent challenges, high initial capital etc.

3.4 OVERVIEW OFMICROGRIDS

Microgrids can be defined as a group of interconnected loads and energy resources distributed within a clearly defined electrical boundary that works together as a single controllable unit with respect to the grid. It can work in both grid connected mode or island mode by connecting or disconnecting from the grid. Microgrids are majorly of two types, the one that is near to a traditional utility customer and wholly on one site are termed as customer microgrids, True microgrids (µ grids) and the other one involves a segment of regulated grid called milligrids (mgrids).Microgrids offer various advantages to customers and utilities like reduced environmental impact, improved energy efficiency, reduced energy consumption, reliability of power supply, reduction in loss, better voltage control, congestion relief, economical infrastructure replacement etc. Microgrids have an ability to coordinate all these assets together and present them to the mega grid in such a manner that it is consistent with current grid operations and also avoiding any new investments which may be needed to integrate the emerging decentralized resources.

3.5 OVERVIEW OF HYBRIDSYSTEMS

Hybrid power systems can be termed as a combinationof different energy generation systems that are complementary as well like renewable sources of energies , there combination along with other sources such as LPG, diesel, gasoline genset. These hybrid systems make use of the best features of the energy resources and provide grid quality electricity (1KW to several 100 KW). Another important feature is that they can be developed to integrated designs within mini grids and village electrification. They also make an effective source of backup solution to main power grids during the time of blackouts and weak grids etc due to their high efficiency, long term performance andreliability.

3.6 PICONTROLLER

Discrete PI controllers are used mainly in digital electronics where they are implemented with the help of discrete sample period and discrete PI equation form that is required to approximate the integral of error. It is usually used for non integrating processes i.e. such process where we reach same output for the given set of inputs anddisturbances. The PI controller works in such a way that inherent offsets are eliminated with the help of proportional mode as well as integral mode. Mathematically it is represented as:-

$$P = K_p e_p(t) + K_p K_i \int e_p(T)dT + P_i(0)$$

- P =PI controlleroutput
- K_i = Integralgain
- K_p= Proportionalgain
- $P_i(0)$= Initial value of integralterm
- $e_p(t)$ = Controlled variable's desired value - measuredvalue

IV SIMULATION RESULT AND DISCUSSION

The complete design related to the project is created in Matlab & Simulation using Sim Power System Toolbox and thereby proves the validity of the dynamic analysis conducted. This designing is conducted in three stages:-

1. Single input zetaconverter
2. Dual input zetaconverter
3. Closed loop dual input zetaconverter

4.1 SINGLE INPUT ZETA CONVERTER

4.1.1SYSTEM PARAMETERS

PARAMETERS	VALUES
Discrete Sample Time	1µsec
Input DC Voltage V_{dc}	100V
Pulse Generator Amplitude (Q_1)	1.01
Pulse Generator Period (Q_1)	1/45 msec
Fet Resistance Q_1	0.1?
Inductance L_i	2.463mH
Capacitance C_1	330nF
Diode Resistance D_5	0.001 ?
Input DC Voltage V_{dc1}	100V
Pulse Generator Amplitude(Q_2)	1
Pulse Generator Period (Q_2)	1/45 msec

Table 1 System Parameters of single input zetaconverter

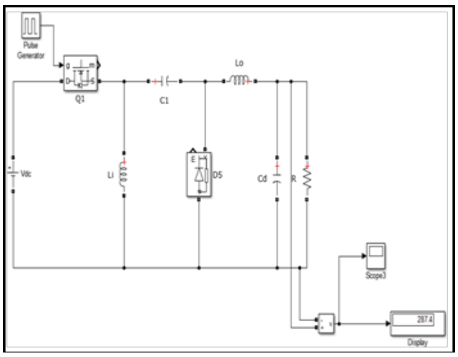


Fig 5 Simulation model of single input zeta converter

4.2 DUAL INPUT ZETACONVERTER

DUAL INPUT ZETACONVERTER

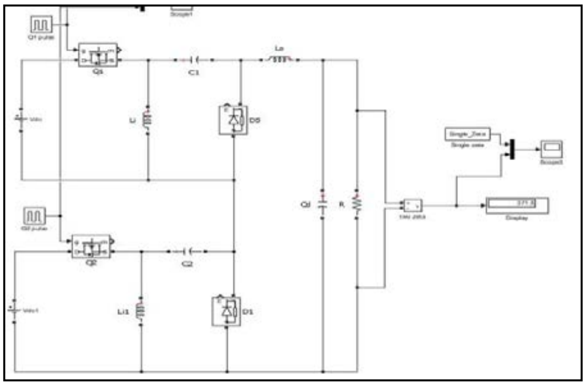


Fig.6 Simulation model of dual input zeta converter

4.3CLOSED LOOP DUAL INPUT ZETACONVERTER

SYSTEMPARAMETERS

PARAMETERS	VALUES
Input DC Voltage V_{dc}	100V
Inductance L_i	2.463Mh
Capacitance C_1	330Nf
Diode Resistance D_5	0.001 Ω
Input DC Voltage V_{dc1}	100V
Pulse Generator Period (Q_2)	1/45 msec
Inductance L_i	2.463mH
Capacitance C_1	330nF
Diode Resistance D_1	0.001 Ω
Inductance L_0	60µH
Capacitance C_d	250µF
Resistor R	100 Ω
PWM Switching Frequency	45000
Controller	PI
Propotional P	0.15
Integral	0.00023

Table 2 System Parameters of closed loop dual input zeta converter

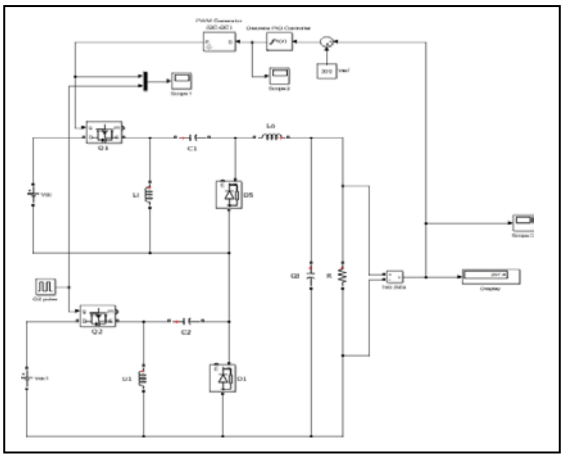


Fig.7 Simulation model of closed loop dual input zeta converter

4.4 SIMULATIONRESULTS

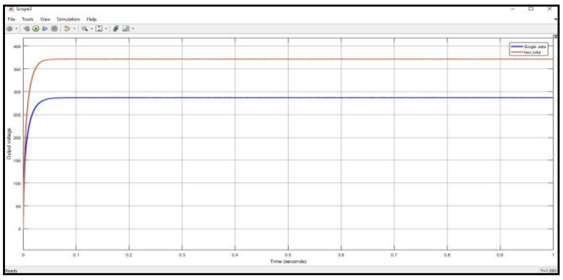


Fig.6 Simulation result of output DC voltage of single input and dual input zeta converter

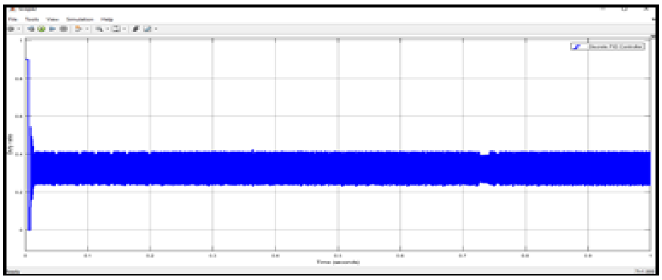


Fig.7 Simulation result of variable duty ratio with respect to time for closed loop dual input zeta converter

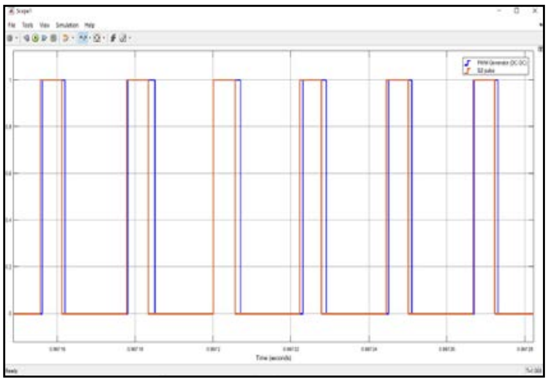


Fig.8 Simulation result of two MOSFET pulses for closed loop dual input zeta converter

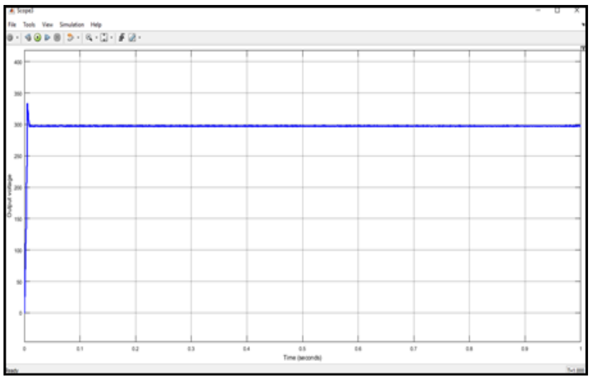


Fig.9 Simulation result of output DC voltage of closed loop dual input zeta converter

3.5 OUTPUT DATA

CONVERTER TYPE	OUTPUT VALUES
Single Input Zeta Converter	287.4V
Dual Input Zeta Converter	371.5V
Closed Loop Dual Input Zeta Converter	Constant 300V(value variable with respect to duty ratio)

Table3. Output voltage values

CONCLUSION:

This paper represents the study of dynamic analysis of closed loop multi input zeta converter for modular hybrid micro grid systems. It has been carried out in three steps as shown above from which we infer the following:-

Single input zeta converter: here we see that when we provide 100V DC input with a duty ratio of 50%, we obtain three times the input as our output i.e.287.4V

Dual input zeta converter: here we see that when we provide 100V DC as the two inputs each with a duty ratio of 50%, the output so obtained is 371.5V which is much greater than the single input zeta converter.

Closed loop dual input zeta converter: In this scheme we attach a feedback loop to the above dual input zeta converter system. With same set of inputs and duty ratio when we run the system we get an output that is taken as feedback by the feedback system and compared to a reference voltage generating required duty ratio for the MOSFET Q_1. The variable duty ratio maintains the output voltage at desired amplitude. Here we have set the duty ratio with the help of a PI controller with K_p and K_i as 0.15 and 0.00023 respectively.

Hence we can infer that a multi input zeta converter is much more feasible and reliable when compared with other converter topologies such as cuk, sepic, buck, boost and even the single input zeta converter. Apart from this the multi input zeta converter has a wide range of scope to be utilized in the coming scenario in consideration with research and development in the field of renewable energy resources.

The main advantages that have been inferred are that this fourth order converter topology is capable of operating in both step up and step down mode i.e. it can perform individually the activity of buck converter and boost converter. Apart from this due to presence of capacitors and inductors there is automatic insulation between input and output, lower ripples are there, better load transient response and easy compensation. Another added advantage is that we can replace the inductors with transformers; diode etc and can work with high ranges of power from low input sources.

The feedback technology is very easy to design and implement. The outputs so obtained are usually constant for wide range of uneven inputs i.e. this feature makes it a favourite for renewable energy utilizations which are mainly uneven sources of supply. The presence of feedback loop also reduces noise, distortions, precise control of frequency, system response, gain and bandwidth, independent working parameters etc. There gird connections are also easier as compared to other topologies.

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