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

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Abstract: The use of renewable energy sources (RES) has increased dramatically during the last few years. As a result of its many advantages over the other RES, solar electricity is now the most practical option. In this study 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 designed model.

Keywords: Power Converters, Zeta Converter, Photovoltaic Array, Photovoltaic System, Renewable Energy, Microgrids, Hybrid Power Systems, Feedback System

I. INTRODUCTION

As non-renewable resources are depleted, renewable ones rise in importance. However, numerous studies have focused on the need for several kinds of power converters (buck, boost, and buck-boost) to increase the output voltage of renewables including solar, wind, and hydrogen fuel. In renewable energy systems, power converters that can raise or buck the voltage, respectively, are required.

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 harvested by 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.[1]

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.[2]

A. Power Converters

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 of electrical machinery that is used to convert one frequency of alternating current into another frequency. Power conversion systems usually incorporate redundancy and voltage regulation.[3]

B. DC-DC Converter

An electrical or electro- mechanical device to convert one level of DC to another level is termed as a DC/DC Converter in simple terms. The properties of the converters such as efficiency, ripple, load response, transient response etc can be changed with the help of their external parts and designs. These external parts are generally dependent on external conditions such as input and output specifications. The power supply circuits are often used as a part of commercially available circuitry products and are designed in order to satisfy the constraints such as electrical specifications, size, cost etc. Usually they are designed and selected according to the properties they emit and standard operating conditions.[4]

The following properties are considered very critical while designing DC/DC converters.

• Efficiency [high]

• Output Ripple [small]

• Operation [stable] - abnormal switching, over voltages or burnout should not lead to breakdown of stable operation

• Load - Transient Response [good]

These properties can be controlled to certain extent by proper selection of DC/DC converter IC's and specific external parts. Along with the individual applications the weight age given to these properties varies.[5]

II. 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.[6][7]

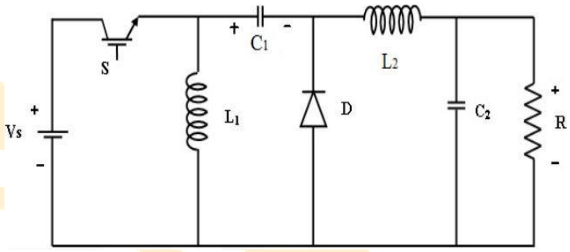

Figure 1: Basic Zeta converter circuit

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 be ideal

3. Frequency ripples in DC voltages are neglected

III. RESEARCH METHODOLOGY

A. THE PI CONTROLLER

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 and disturbances.[8][9]

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:-

$$P = Kpep(t) + KpKi\int ep(T)dT + Pi(0)$$

B. PULSE WIDTH MODULATION

It is a process of generating analog signal from a digital signal. It is mainly dependent on duty cycle and frequency. The duty cycle is the amount of time the signal remains on to the total time taken to complete one cycle whereas the frequency determines the speed of completion of one cycle of PWM.

When we cycle a digital signal at a faster rate and certain duty cycle the output so obtained behaves like constant analog signal that can be given to power devices. Pulse width modulation is widely used in control application such as hydraulics, pumps, control valves, electronics, mechanics etc.[10]

There are mainly three types of PWM:

1. The pulse centre may be fixed and other edges are either compressed or expanded

2. Lead edge is fixed and tail edge modulated

3. Tail edge fixed and lead edge modulated

C. FEEDBACK SYSTEMS

The system in which a sampled output is fed back to the input so as to form an error signal to drive the system is termed as feedback systems. They are also termed as closed loop systems.

With the help of this system we can modify the input in such a way to produce response that differs drastically as compared to that of non feedback or open systems. The basic circuit of a feedback system is shown below:

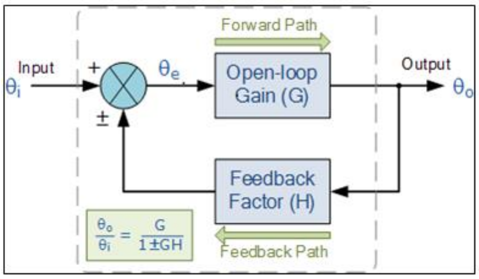

Figure 2: Feedback system

IV. SIMULATION RESULTS 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 zeta converter

2. Dual input zeta converter

3. Closed loop dual input zeta converter

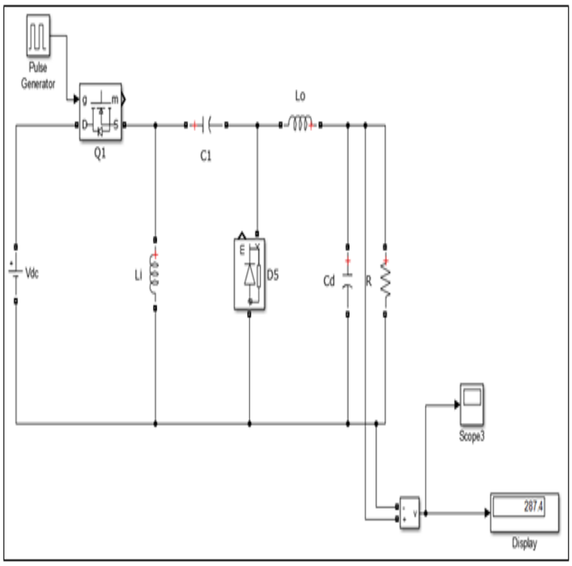

Figure 3: Single input zeta converter

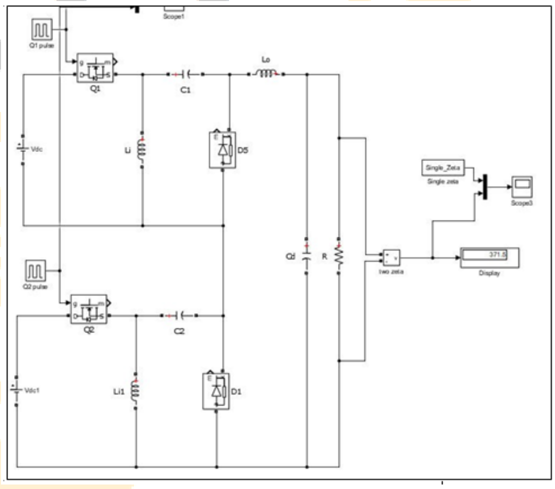

Figure 4: Dual input zeta converter

CLOSED LOOP DUAL INPUT ZETA CONVERTER

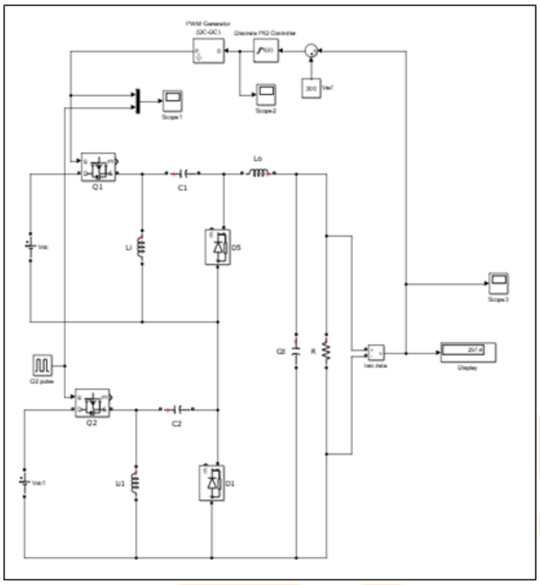

Figure 5: Simulation model of closed loop dual input zeta converter

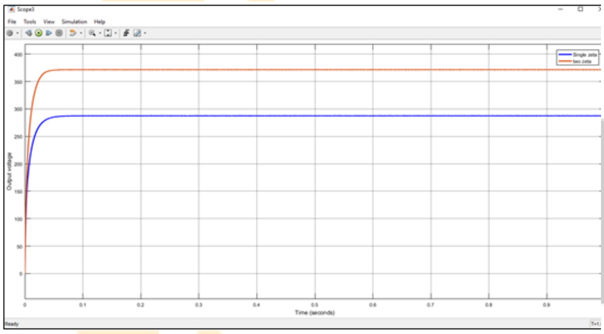

Figure 6: Simulation result of output DC voltage of single input and dual input zeta converter

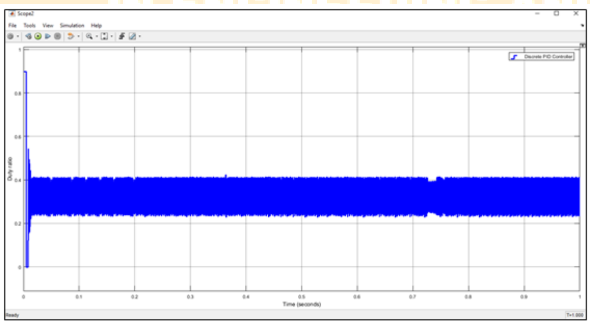

Figure 7: Simulation result of variable duty ratio with respect to time for closed loop dual input zeta converter

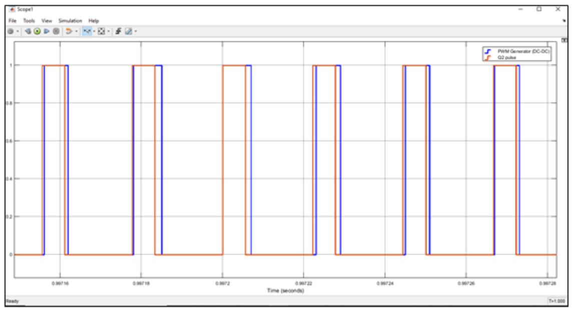

Figure 8: Simulation result of two MOSFET pulses for closed loop dual input zeta converter

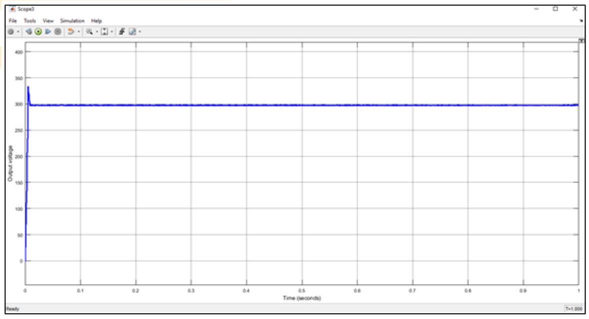

Figure 9: Simulation result of output DC voltage of closed loop dual input zeta converter

Output Voltage Value

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)

V. 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:

1. 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

2. 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.

3. 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 Q1. 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 Kp and Ki 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.

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