https://doi.org/10.1051/e3sconf/202454003010

Isolated Power Conditioning unit for Applications Involving Micro Wind Turbines

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Abstract: Renewable Energy sources have become one of the most desired modes of energy sources due to increasing pollution and declining fossil fuels. Wind energy sources is among the major contributors of renewable energy sources with much untapped potential and capable of installation even in remote areas. For larger scale wind power plants, Power Conditioning Unit plays a key-role as it deals with protection, voltage regulation and efficiency. Many power conditioning Units which are presently in application do not provide electrical isolation which may lead to adverse effects in case of fault conditions. The proposed model in this paper provides electrical isolation with the help of Quasi Z Source DC-DC converter with galvanic isolation.

1 INTRODUCTION

The utilisation of miniature wind turbines for distributed power generation in diverse applications has attracted increasing attention in recent years. Micro wind turbines provide a practical option for producing electricity in rural areas, homes, and other off-grid sites. But because wind energy is inherently unstable, there are issues with power quality, voltage regulation, and grid integration. An isolated power conditioning unit designed specifically for applications utilising micro-wind turbines is needed to overcome these issues.

The creation and analysis of an isolated power conditioning unit devised to improve the functionality and grid integration of miniature wind turbines are the main topics of this research. The isolated quasi-Z-source (q-ZS) converter concept, which combines the advantages of voltage boosting, bucking, and electrical power isolation, is incorporated into the power conditioning unit.

Multiple-pole low-speed Permanent Magnet Synchronous Generators (PMSGs) are one of the demanding technologies utilised in adjustable speed micro-WTs despite its relatively high cost because of their smaller-volume, exceptional reliability and performance, self-starting capacity, and absence of brushes in its design. A compact PMSG is frequently powered directly by a Strong torque on a three- or multiple-blade wind rotor prevents wearing of mechanical elements like gearboxes. Residential adjustable speed PMSG

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based micro-WTs of the sub-kW level may generate output voltage as low as several tens of volts due to their variable speed operation. They are therefore suitable for charging batteries, but grid interface requires a different converter.

In order to avoid mechanical elements, such as gearboxes, that experience wear, a PMSG is often employed with a three- or by multiple-blade wind rotor with very high level of torque. Domestic variable speed due to variable speed operation, PMSG-utilising micro-WTs of the sub-kW level are capable of producing output voltage as low as among tens of volts. They are therefore appropriate for battery charging, but grid interfacing calls for a separate converter.

There are numerable ideas regarding power conditioning units proposed by researchers but they tend to micro wind turbines but they are mostly to operate at a power level that is higher than that of tiny wind turbines. The nano wind turbines are frequently constrained to the average domestic electric applications, which has a limit of 11.75 kW for a three-phase power connection to a 400 V grid of distribution and a maximum of 5.85 kW for the connection of mono-phase to a 230 V grid of distribution. A Power Conditioning Unit that uses back-to-back converters is frequently non-isolated and used with small PMSG-based adjustable speed WTs. on the grid side, a conventional voltage source inverter, and on the generator side, a diode bridge rectifier and dc-dc converter. a system having the capability of controlling voltage without the use of a dc-dc converter by combining a rectifier of type diode bridge and an inverter of impedance-source.

Electrical circuits are kept apart by galvanic isolation, which creates a wall to stop current from flowing directly between input and output. This isolation reduces the possibility of electric shock and guards against potential dangers for both the staff and the equipment. It is especially crucial in high-voltage applications, such renewable energy systems or industrial power systems. Galvanic isolation provides defence against voltage transients, ground loops, and other electrical disturbances for delicate parts and circuits. It inhibits the transmission of fault situations, like overvoltage or short circuits, which might harm the power conditioning unit and the attached devices, by isolating the input and output sides. The system's overall dependability and longevity are improved by this safeguard.

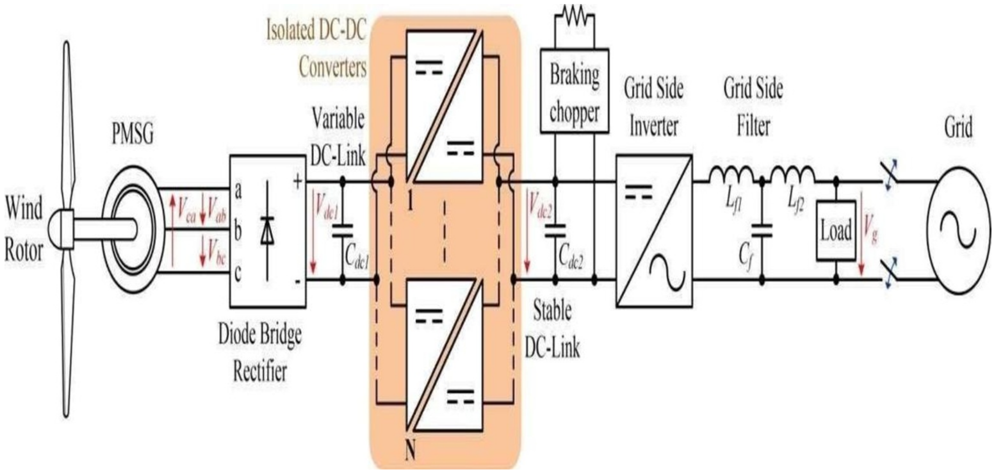

Figure 1. A Multi-stage PCU based upon the dc-dc converter (isolated) and based on a PMSG applied wind energy conversion block.

2 PROPOSED CONVERTER

The linked-inductor based impedance-source conversion class, in which the proposed galvanically separated single-switch q-ZS converter belongs, uses coupled inductors at the input side to combine the storage of energy and energy transfer from the supply to the output side functionalities.
The linked inductor combines two tasks: it transports energy from the input side to the output side and stores energy as a component of the q-ZS network. The study of steady state under the assumption of Continuous Conduction Mode (CCM) is shown below. The following was made prior to the circuit analysis.
(1) All the components are in ideal condition, with MOSFET acting as the switch S.
(2) The converter is running in conduction mode (CCM).
3) The switch S Modulation (PWM) control scheme.

A. Generalized Operating Principle

Employing a modified impedance network, an isolated quasi-Z-source DC-DC converter may transform voltage while maintaining galvanic isolation. The quasi-Z-source stage and the isolation stage, which are achieved using transformers, are the two primary stages of the converter topology.
The converter has an impedance structure made up of inductors (L) and capacitors (C) in the quasi-Z-source stage. The voltage waveform across its terminals is shaped by this network, which also enables voltage boost and buck operations. The key elements in this phase include Inductor, Impedance Network, Capacitors, Diodes and Switches.
Operating principle consists of two operating modes, they are:
1)Off-state during: capacitor Cf1 is charging, capacitor Cf2 will discharge with the load current, diode Dr1 is conducting, and q-ZS inductors will be discharging while q-ZS capacitors are charging.
2)on-state: the diode D1 is reverse biased, the q-ZS inductors will be charging while the q-ZS capacitors will be discharging, the diode Dr2 is conducting, the diode Dr1 is reverse biased, and the capacitors Cf2 and Cf1 are charging and discharge with the load current.
If inductors are suitably sized, the suggested converter can run continuously under a variety of voltage and load conditions. The proposed architecture has twice the minimum operating frequency of the q-ZS structure and twice the bottom DC voltage gain when compared to a full-bridge q-ZS DC-DC converter. If the voltage and current ripple remain same, the values of the q-ZS components will increase by a factor of two as a result.

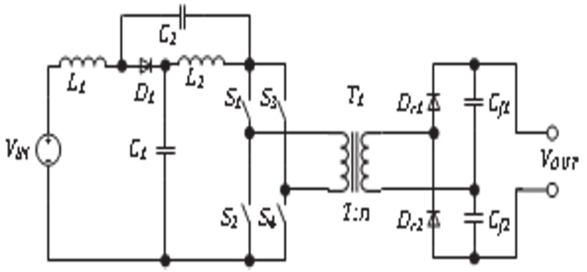

Fig. 2. Galvanically separated full-bridge DC-DC converter based on Q-ZS

B.Control Strategies

Regulating the voltage transformation, assuring stable operation, and obtaining the desired output voltage levels all depend on the control strategies used in an isolated quasi-Z-source DC-DC converter. To control the switching behaviour of the semiconductor switches in the converter, pulse-width modulation (PWM) techniques are employed.

PWM is a modulation technique that modifies the width of the pulses in a train of square-wave pulses with a constant frequency in order to alter the average voltage applied to a load. PWM is utilised to regulate the duty cycle of the switched signals applied to the switches in the isolated quasi-Z-source converter.

By employing PWM control strategy, Duty cycle needs to be varied depending on the voltage boost and buck operation of the system.

During voltage boost operation duty cycle needs to be adjusted such that the flow of power from the input supply to the impedance network, the voltage across the output load is essentially increased. During buck operation, the output voltage can be decreased by allowing more energy to flow from the impedance network to the output load.

There are many control strategies available to ensure effective PWM control such as Voltage-mode control, Current-mode control, Maximum – Power -Point - Tracking (MPPT), Proportional-Integral (PI) Control, Digital Control. Overall, the application-specific requirements, such as output voltage precision, transient response, and stability considerations, determine the best control technique. To achieve optimal performance, sophisticated control approaches can be integrated, and experimentation or simulation may be required to fine-tune the control settings.

The control schemes and operation of the isolated quasi-Z-source DC-DC converter is suitable to wind turbine applications. They make wind energy a dependable and lucrative source of renewable energy by enabling effective power conversion, optimal energy extraction, steady grid integration, and voltage regulation. To maintain optimal performance in wind turbine systems, proper implementation and control parameter tweaking are crucial.

C.Equations

DC voltage gain is mainly explained by the duty cycle D. It is comparable to the full-bridge q-ZS DC-DC converter's shoot-through state. The voltage pressure of the switch S1 and diode D1might be estimated as the peak value of the intermediate DC-link voltage, VDC,

$$VDC = VIN /1- 2.D = B.\ VIN\ B \qquad (1)$$

where VIN is the converter's input voltage,

D = Duty cycle of S1,

B = Boost factor of input voltage.

Operation of the circuit mainly depends on the voltages of the q-ZC converters which can be known by using the following equations:

$$Vc1= VIN(1- D)/1-2.D \qquad (2)$$

$$Vc2= VIN\ D/1- 2.\ D \qquad (3)$$

A non-symmetrical AC voltage containing a positive high regard to VC2 and a non-positive peak regard equal to -VC1 is sent into the transformer's primary winding. Similar to the q-ZS capacitors, unequal voltage leads in non-symmetrical voltage across the VDR-capacitors.

$$Vcf1= n1Vc2 = n1\ VIN\ D/1-2D \qquad (4)$$

$$Vcf2= n1Vc1 = n1\ VIN\ (1-D)/1-2D \qquad (5)$$

From the above equations 1 and 2, We get:

$$G = VIN / V\,out = V/1-2D \qquad (6)$$

If inductors are suitably sized, the suggested converter can run continuously under a variety of voltage and load conditions. The proposed topology has a two-fold minimum operating frequency of the q-ZS network and the two-fold lower DC voltage gain when compared to the full-bridge q-ZS DC-DC converter. If the voltage ripple and current-ripple are kept constant, the values of the q-ZS components will increase by a factor of two as a result.

3 SIMULATION REUSLTS

The topology is examined with respect to simulations using MAT- lab software. The circuit is simulated with respect to figure displayed above fig.1. The input is first given to the q-zs network consisting inductors (L1 & L2) and capacitors (C1 & C2) which will be further passed to transformer via capacitor called blocking capacitor connected in series. The capacitor Cb is mainly used to isolate the D component of the transformer input in order to avoid transformer saturation. A switch (MOSFET) is connected in parallel between capacitor C1 and transformer. The transformer which we take is an isolated transformer whose main task is to provide galvanic isolation between input and output terminals of the circuit. The secondary of the transformer is connected to the Voltage Diode Rectifier (VDR) which consists of two diodes and two capacitors namely Cf1, Cf2. d1 & d2. The voltage diode rectifier is a key component in enabling energy transfer between the impedance network and the output load during voltage boost and buck operations in an isolated quasi-Z-source DC-DC converter. To enable bidirectional energy transmission while retaining voltage transformation and galvanic separation, the diode rectifier is included into the converter.

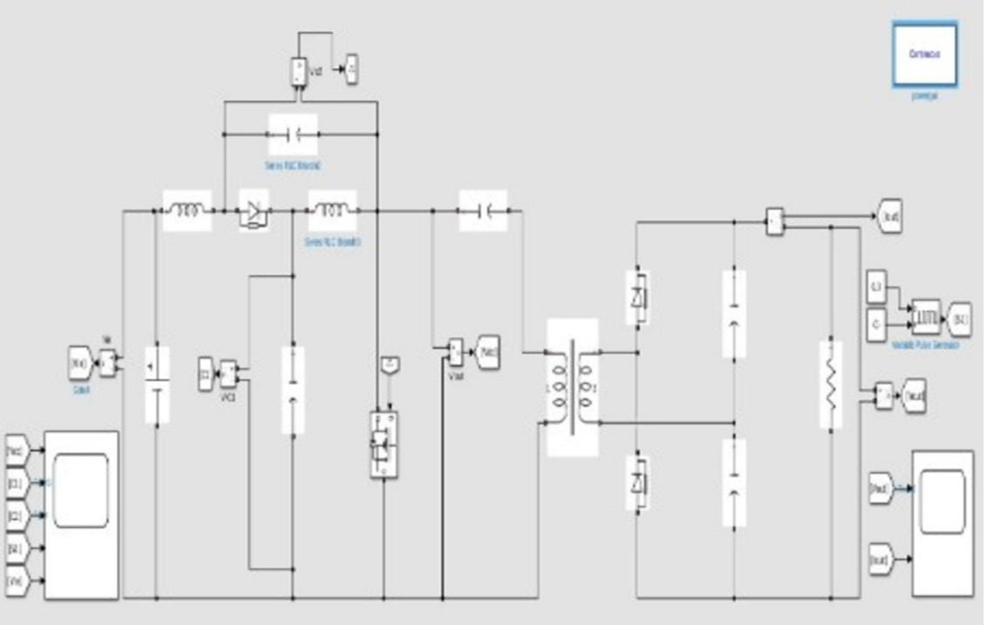

Fig 3. Simulation diagram of Isolated Q-Z-Source DC-DC Converter

Fig 4. Simulation Results of Isolated Quasi Z Source DC-DC Converter

Below table denotes, Details regarding the components taken and parameter values taken along with their symbols.

TABLE 1: SIMULATION- PARAMETERS OF ISOLATED QUASI Z SOURCE DC-DC CONVERTER

S.NO	**COMPONENTS**		
	Parameters	***Symbol***	***Value***
1	Voltage Input,V	V_{IN}	25
2	Average-Inputcurrent,A	I_{IN}	7
3	Voltage Output	V_{OUT}	240
4	Duty-CycleofS_1	D	0.3
5	Transition-Frequency,kHz	f_{sw}	100
6	Turnsratio of Transformer	n	4
7	Magnetic-inductance-of Transformer,μH	-	30.8
8	Leakinginductance of Transformer,μH	-	0.3
9	Capacitance of the qZScapacitors,μF	C_1,C_2	26.4
10	Inductance of the qZSinductors,μH	L_1, L_2	23
11	Capacitance-DCblockingcapacitor,μF	C_b	5.7
12	Capacitance-VDRcapacitors,μF	C_3,C_4	2.2
13	DC-output voltage	V_{DC}	62.5

4 Conclusion

This study discusses about a innovative isolated quasi- Z source DC-DC converter with additional protection with the help of galvanic isolation in the view of variable speed micro wind turbines. This device makes it possible to integrate smaller home wind generators into the distribution grid. Enhanced control methods are typically that focus on reports of miniature wind energy conversion stations. Although accurate studies of the efficiency and energy wastage in accordance with the operational capacity of the comparable wind turbines are frequently neglected, the operation aspect of the power electronic converter is occasionally neglected. The proposed technique can be implemented with minimal change to the existing control systems. The new modular quasi-Z-source dc-dc converter at the centre of the suggested galvanically separated power conditioning unit has just a handful of switching modules to minimise power losses in control schemes. The suggested design can reduce manufacturing costs when the needed number of modules is small and the required power levels range up to several kW. This model provides additional protection like electrical isolation, better voltage regulation, compatibility and interface flexibility.

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