International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 7 (2015) pp. 17751-17761

http://www.ripublication.com

CUK Converter Based PWM Inverter For Micro Grid Applications

P. Priyadharshini[1]
[1]PG Scholar, school of EEE, Sastra University, Thanjavur,
Priyahasini14@gmail.com

Abstract

This paper describesCuk converter based Pulse width modulation (PWM) inverter for micro-grid network. The Cuk converter regulates the dc bus voltage irrespective of voltage variations at input side. This dc bus voltage is injected to the utility microgrid through a transformer by single phase PWM voltage source inverter. The dcoutput voltage of Cuk converter is controlled by PI controller or Fuzzy logic controllerin order to sustain the grid voltage within the range. The comparative analysis of the Total Harmonic Distortion (THD) for PI as well as Fuzzy Logic Controller has been done. Thus, the Cuk converter fed PWM inverter for microgrid system has been simulated using MATLAB SIMULINK.

Keywords: Cuk converter, PWM inverter, microgrid network.

Introduction

Renewable Energy based micro-grid is being considered to provide electricity for the expanding energy demand in the grid distribution network and grid isolated areas.Thetechnical challenges associated with the operation and controls are immense.The expanding demand for the grid isolated areas and grid distribution network is supplied by the renewable energy based micro-grid. In order to satisfy the standard losses of the electricity generated by renewable energy sources, it is essential to regulate the output voltage [1].

A major advantage of a micro-grid is its ability, during utility grid disturbances to separate and isolate itself from the utility seamlessly with little or no disruption to the loads within the micro-grid. Significant environmental benefits made possible by the use of zero emission generator. Micro grid is a combination of many distributed generators such as renewable energy sources, traditional generators with energy storage units forms a power supply network. Generally micro grid operates in disconnected or islanded mode. Injection of power generated from renewable energy sources to the utility grid can be done at the transmission level or the distribution level depending on the scale of generation [2].

In Cuk converter, a capacitor separates the source from the load and thus the energy transfer from the source side to load side occurs through this capacitor. This energy transfer through a capacitor leads to low current ripples at both source as well as load side compared to other non-isolated converters. Hence quality of power can be maintained [3]. The Cuk converter will produce either high or low output voltage with respect to the input voltage and it has L-C type filter so that peak to peak ripple current of inductance are less compared with the buck-boost converter. It transfers energy when switch opens and closes. The Cuk converter is preferred to overcome the disadvantages in buck-boost such as discontinues input current and poor transient response. To remove the steady state error in Cuk converter, PI controller or fuzzy logic controller is used as closed system. The Closed loop of the Cuk converter output voltage is given as an input for the PWM inerter. The pulse width modulated outputs along with filter reduce harmonics at the output of the inverter. Then the inverter output is fed to the linear transformer which is then connected to grid.

Proposed Block Diagram

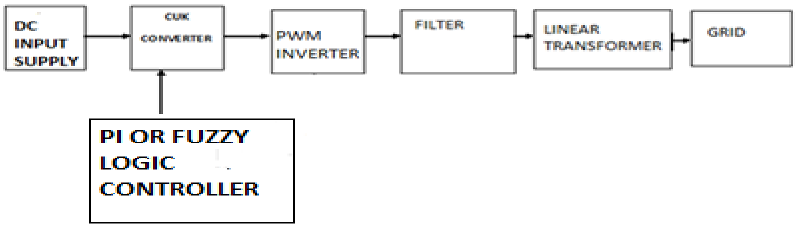

Figure 1: Proposed Block Diagram

The proposed block diagram is shown in fig.1.The above system consists of a Cuk converter (AC-DC), PWM inverter, LC output filter and grid. The output from the Cuk converter is given to the PWM inverter which is coupled with a filter. The PWM inverterwill convert the dc voltage into an ac voltage with respect to the switching signals which will reduce the harmonics in the output voltage.

Dc-Dc Converter

The circuit diagram of the Cuk converter is presented in Fig.2. Where V_{in} is input voltage source; input inductorL_1, V_o is output voltage, controllable switch S, diode D_1 energy transfer capacitorC_1, filter inductorL_2, filter capacitor C_2, and load resistance R. An important advantage of this topology is a continuous current at both the input and the output of the converter. The main Disadvantages of the Cuk converter are a high number of reactive components and high current stresses on the switch and the capacitorC_1.

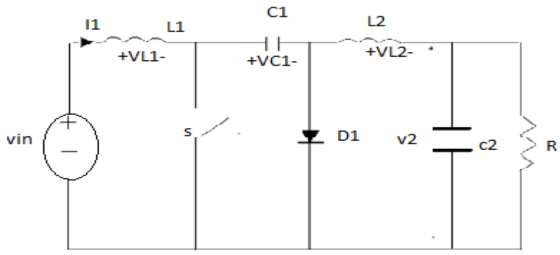

Figure 2: Circuit diagram of Cuk Converter

Mode I:
When the switch S is ON during **0 < t < DT**, the input inductor L_1 gets charged and stores its energy from the source whereas the capacitor C_1transfers the stored energy to the load R, L_2andC_2. The inappropriate voltage polarity of capacitor C_1 reverse biases the diode D_1 when the switch S is turned ON.

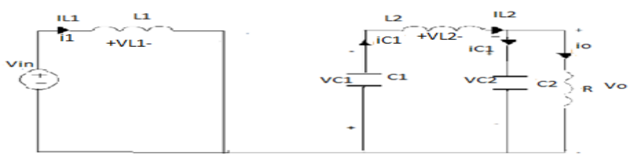

Figure 3: Equivalent Circuit of Cuk Converter When S is on

In the left hand mesh,

$$V_{L1} = V_{in}$$

$$\frac{dI_{L1}}{dt} = V_{in}$$

$$L_1\frac{dI_{L1}}{dt} = V_{in}$$

In the right hand mesh,

$$i_{c1} = i_{L2}$$

$$\frac{dV_{C1}}{dt} = \frac{iL_2}{C_1}$$

$$V_{L2} = -V_{C1} - V_O$$

$$L_2\frac{dI_{L2}}{dt} = -V_{C1} - V_O$$

$$\frac{dI_{L2}}{dt} = \frac{-V_{C1} - V_O}{L_2}$$

Current through capacitor c_2,

$$i_{C2} = i_{L2} - i_o$$

$$\frac{dV_{C2}}{dt} = \frac{iL_2}{L_2} - \frac{V_O}{R_{C2}}$$

Current will pass through the switch,s and the sum of inductor input and output current is calculated as,

$$i_s = i_{L1} + i_{L2}$$

Mode II

When the switch , S is OFF during **DT < t < T,** the energy storage capacitor C_1 is charged from source through $L_1$and D_1whereas the stored charges in $L_2$and$C_2$is transfer to the load R. Due to the voltage polarity of capacitorC_1, the diode D_1gets forward biased when the switch S is OFF.

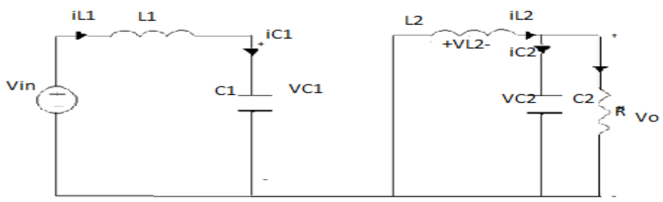

Figure 4: Equivalent Circuit of Cuk Converter When S is OFF

In the left hand mesh, applying KVL;

$$V_{in} = V_{L1} + V_{C1}$$

$$V_{L1} = V_{in} - V_{C1}$$

$$L_2\frac{dI_{L1}}{dt} = V_{in} - V_{C1}$$

$$\frac{dI_{L1}}{dt} = \frac{1}{L_1}(V_{in} - V_{C1})$$

The current through capacitorC_1,

$$i_{c1} = i_{l1}$$

$$\frac{dV_{C1}}{dt} = \frac{iL_1}{C_1}$$

In the right hand mesh, applying KVL;

$$V_{L2} = -V_O$$

$$L_2\frac{dI_{L2}}{dt} = -V_O$$

$$\frac{dI_{L2}}{dt} = \frac{-V_O}{L_2}$$

The current through capacitor c2,

$$i_{C2} = i_{L2} - i_o$$

$$\frac{dV_{C2}}{dt} = \frac{iL_2}{L_2} - \frac{V_O}{R_{C2}}$$

Current will pass through the diode D1, and the sum of input and output inductor current is calculated as,

$$i_{D1} = i_{L1} + i_{L2}$$

In steady state condition, the transfer function can be calculated by the average current across the capacitor in one period of cycle is zero.Therefore,by solving the linear equation during ON and OFF period, the average output voltage will be determined as follows:

$$\frac{iL_1}{iL_2} = \frac{D}{1-D}$$

$$\frac{iL_1}{iL_2} = \frac{-V_O}{V_{in}}$$

The CUK converter output voltage can be determined as;

$$V_o = \frac{-D}{1-D} V_{in}$$

C. Pulse Width Modulation Inverter

Inverter in Power-Electronics refers to a category of power conversion circuits that operate from a dc voltage supply or a dc current supply and convert it into ac voltage or current. The input to the electrical convertermay be a direct dc supply or dc supplyderived from associate degree ac supply. The advantages of PWM inverter is given below:

- Output voltage control can be obtained without any additional components.
- Lower order harmonics is eliminated or reducedalong side its output voltage management.
- Higher order harmonics is filtered simply.

Fuzzy Logic Controller

FLC will process the parameters and takes decision regarding the control action and it will convert the linguistic control using knowledge base into an automatic control strategy [13].

Block Diagram of Fuzzy

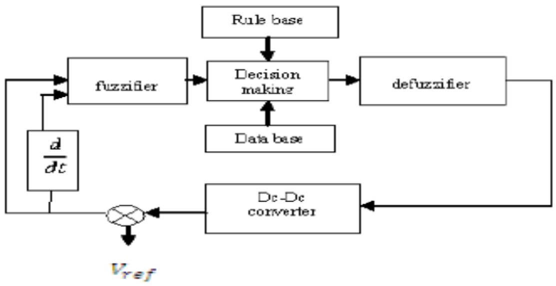

Figure 5: Block diagram of fuzzy logic controller

Fuzzification
- Measure the input variables (error, change in error).
- Convert the input variables into suitable linguistics values.
- Convert the input variables into corresponding universe of discourse using membership function.

Decision Making Logic
- Capability of simulating human decision making process.
- Infers a system of rules through fuzzy operators namely ‘AND’ and ‘OR’
- Generates a single truth values using Max-Min Criteria.

Defuzzification
- Mean of the maximum.
- Centre of the area method.
  $z_o = \mu_j$.X jμ^i
- N is Yields a Crisp, non fuzzy control action.

Table 1: Rule Base Table

E / ΔE	NB	NM	NS	ZE	PS	PM	PB
PB	ZE	PS	PM	PB	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PS	NM	NS	ZE	PS	PM	PB	PB
ZE	NB	NB	NS	ZE	PS	PM	PB
NS	NB	NB	NM	NS	ZE	PS	PM
NM	NB	NB	NB	NM	NS	ZE	PS
NB	NB	NB	NB	NB	NM	NS	ZE

Simulations Results

CUK converter simulation using PI controller is shown in Fig.9.The output voltage of the CUK converter varies with load which changes after a few seconds in open loop. So closed loop simulation which is independent of load variation is obtained by using PI and Fuzzy logic controller. The PI and fuzzy controller are properly tuned to achieve well regulated dc output voltage for input voltage disturbances. The PWM inverter will convert the dc voltage into ac voltagewhich is being coupled with the LC filter and there will be a reduction of harmonics in the output voltage. The sinusoidal output voltage of the inverter is properly connected to the grid through transformer. In the control circuit of inverter, the actual inverter output voltage is sensed and compared with sinusoidal reference signal and the resulting error is processed in the PI controller. The output of this controller is given to the pulse width modulation circuit which generates suitable pulses to the various switches in the inverter circuit.

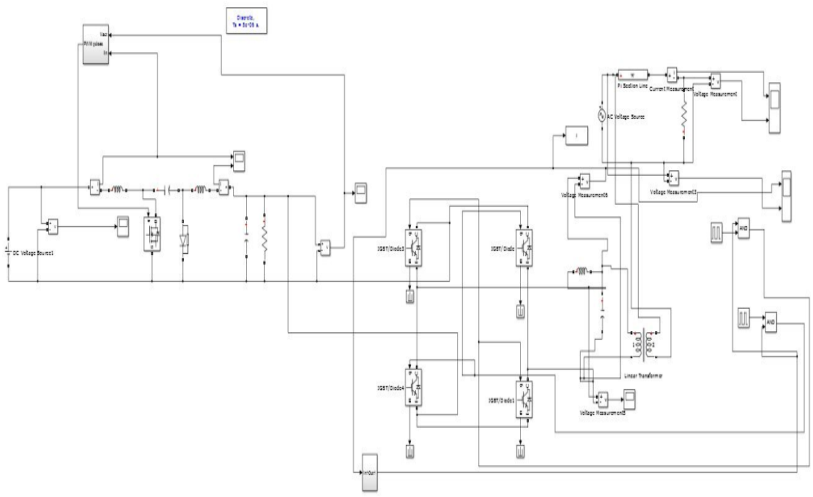

Figure 6: Simulink Model of Cuk converter and PWM Inverter with Filter in Closed Loop

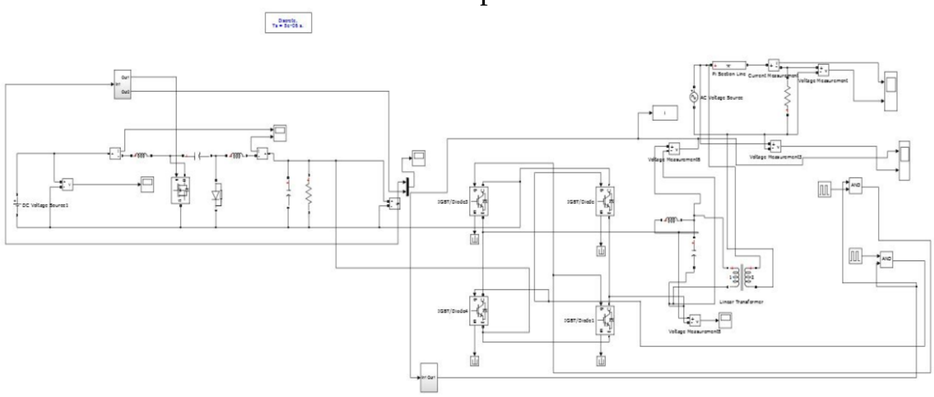

Figure 7: Simulink Model of Cuk Converter and PWM inverter using Fuzzy Logic Controller

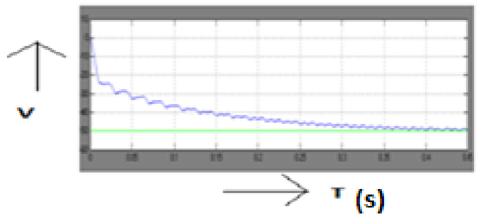

Figure 8: Output of Cuk Converter Using Fuzzy Logic controller

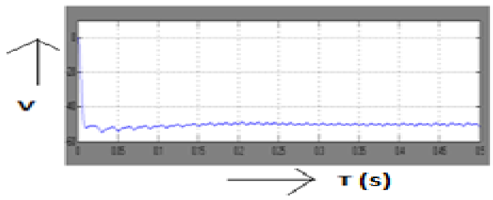

Figure 9: Simulation Result of Cuk converter Output Voltage using PI controller

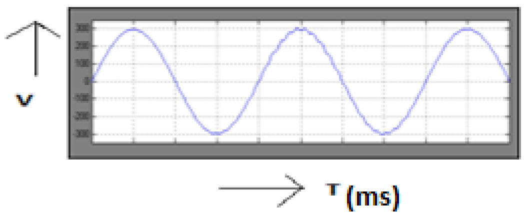

Figure 10: Simulation Result of Inverter Voltage with Filter using PI Controller

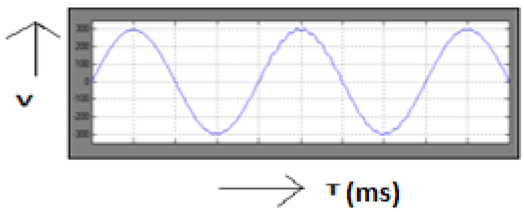

Figure 11: Simulation Result of Inverter Voltage with Filter using Fuzzy Controller

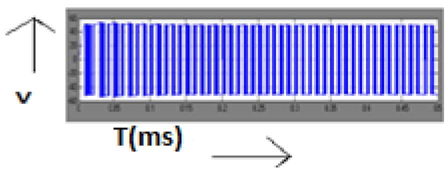

Figure 12: Simulation Result of Inverter Voltage without Filter using PI controller

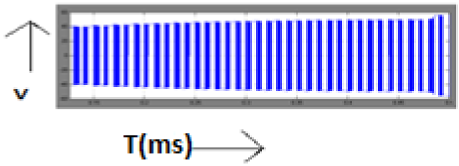

Figure 13: Simulation Result of Inverter Voltage without Filter using Fuzzy controller

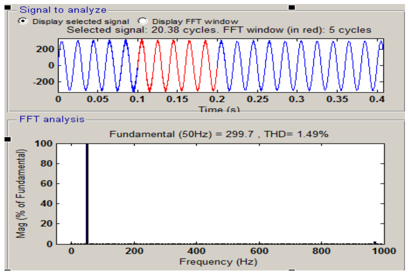

Figure 14: FFT Analysis of Inverter Output Voltage using PI controller

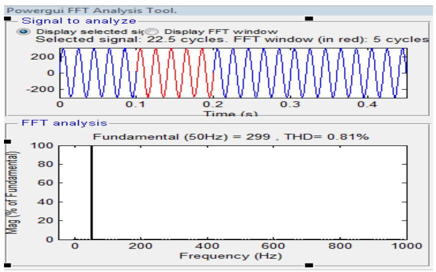

Figure 15: FFT Analysis of Inverter Output Voltage using Fuzzy

Table 2: Comparison of THD with PI Controller and Fuzzy Logic Controller

CONTROLLER	THD%
PI	1.49
FUZZY	0.81

Conclusion

The proposed scheme implies the Cuk converter based PWM inverter fed for microgrid network which is briefly discussed in this paper. The closed loop performance of Cuk converter has been analysed and a well regulated dc output voltage is produced by using PI or Fuzzy logic controller. The THD analysis of PI and Fuzzy logic controller is analysed and compared. The simulation results of PWM inverter along with the LC filter shows sinusoidal output voltage with the THD of 1.49% which makes it suitable for micro grid applications. The above proposed system can be further extended for high voltage applications or distributed generation by introducing a renewable input source.

References

[1] K. Doran, F. Barnes and P. Pasrich, "Smart Grid Deploy- ment in Colorado Challenges and Opportunities," 2010. http://www.cees. colorado.edu

[2] Z. H. Jiang and X. W. Yu, "Hybrid DC- and AC-Linked Microgrids: Towards Integration of Distributed Energy Re- sources," *Energy* 2030 *Conference*, Atlanta, 17-18 November 2008, pp. 1-8.

[3] A. Sabzali, E. H. Ismail, M. Al-Saffar, and A. Fardoun, "New bridgeless DCM sepic and Cuk PFC rectifiers with low conduction and switching losses," *IEEE Trans. Ind. Appl.*, vol. 47, no. 2, pp. 873–881,Mar./Apr.2011.

[4] Jung-Min K, Kwang-Hee N, Bong-Hwan K. Photovoltaic power conditioning system with line connection. *IEEE Transactions on Industrial Electronics* 2006; **53**(4):1048-1054.

[5] D.P.Hohm, M.E.Ropp, "Comparative Study of Maximum Power Point Tracking Algorithms using an experimental programmable, Maximum Power Point Tracking Test Bed", *IEEE, 2000.pp.1699-1702*

[6] Bangyin L, Shansu D, Tao C. Photovoltaic DC-building-module-based BIPV system-concept and design considerations. *IEEE Transactions on Power Electronics* 2011; (5):1418-1429.

[7] E.M. Fleming and I.A. Hiskens, "Dynamic of a microgrid supplied by solid oxide fuel cells".In Proc. IEEE, IREP Symp, Aug 2007, pp 1-10.

[8] E.Durán, M. Sidrach, J.Galán and J.M. Andújar,"Comparative Analysis of Buck-Boost Converters used to obtain I-V Characteristic Curves of Photovoltaic Modules", *IEEE,2008,pp. 2036-2042.*

[9] A. Sabzali, E. H. Ismail, M. Al-Saffar, and A. Fardoun, "New bridgeless DCM sepic and Cuk PFC rectifiers with low conduction and switching losses," *IEEE Trans. Ind. Appl.*, vol. 47, no. 2, pp. 873–881,Mar./Apr.2011.

[10] Riad Kadri, Jean-Paul Gaubert, and Gerard Champenois, "An Improved Maximum Power Point Tracking for Photovoltaic Grid-Connected Inverter Based on Voltage- Oriented Control," *IEEE Trans. Industrial Electronics, vol. 58,No. 1, pp. 66-75, Jan. 2011*.

[11] S. Daisons Stallon, K. Vinoth Kumar, S. Suresh Kumar, "High Efficient Module of Boost Converter in PV Module", International Journal of Electrical and Computer Engineering (IJECE), vol.2, no.6, pp. 758- 781, 2012. [11]Aldo Balestrino, Alberto Landi, and Luca Sani, "Cuk Converter Global.

[12] Z. H. Jiang and X. W. Yu, “Hybrid DC- and AC-Linked Microgrids: Towards Integration of Distributed Energy Re- sources,” *Energy* 2030 *Conference*, Atlanta, 17-18 November 2008, pp. 1-8.

[13] Liping Guo, J. Y. H. a. R. M. N., *comparative Evaluation of LinearPID and Fuzzy Control for a Boost Converter*.