Implementation And Study of PV Inverter with R and RL Loads

[1]Midhusha. S, [2]Ragubathi. ,[3]D ,Ashok Rangaswamy
[1,2]PG Scholar ,Sri Shakthi Institute of Engineering & Technology, Affiliated to Anna University of Chennai.

[3]Assistant professor/Department of EEE, Sri Shakthi Institute of Engineering & Technology ,Affiliated to Anna University of Chennai.

Abstract

The proposed PV inverter with inclusion of Quasi Z network has various advantages over present PV inverters, such as proper conversion of DC to AC power, reducing the harmonics content and also voltage doubling capability in a single conversion stage .The additional merits of proposed PV inverter with quasi Z network are Zero voltage turn on and Soft turn off, This in turn results in low voltage stress and switching losses. In this paper proposed PV inverter with different load such as R and RL is implemented and compared .This comparative study helps in understanding the operation of proposed network included in PV inverter. This network operates in high frequency which makes the system compact. As present system's bulky electrolytic capacitor removed and replaced by proposed network because electrolytic capacitor are prone to failure, particularly at high temperature. The efficiency and reliability of the system is compared. To obtain the satisfied result simulation is performed in MATLAB software.

1. Introduction

The PV system has very high reliability with least 20 years of servicing time, as there is no rotating or moving part involved. Thus the operating cost of PV systems is low. Due to the PV system's scalability and portability it also has good modulation. Utility , PV system located near the consumption side, the wire connection can be reduced and so as the construction and total cost .In past design, centralized converter based PV system was mostly used type .This modules were connected to three phase voltage source. The inverter's each output phase is connected to LC filter to reduce the harmonics . A three Phase transformer which is used to step up the voltage and provide galvanic isolation, connects the low frequency transformer in utility side are considered poor components, mainly because of its large size and low efficiency. To avoid this Frequency transformer, multiple –stage conversion systems are used widely in PV systems. Despite of high boosting capability multiple stage conversion has drawbacks such as reduces the power density and also the have low efficiency.

PV inverter or photovoltaic inverter are the type of inverter that includes various features to maximize the solar energy that is collected from PV panels. The basic function of PV inverter is to convert the direct current (DC) from a photovoltaic panel into alternating current (AC) with commercial or residential use and utility grid power. PV inverter has special feature that it maximize the energy available from the photovoltaic energy system. The power of a PV panel is dependent on the current and the voltage of the PV panel which can vary. The PV inverter uses a maximum power point tracking (MPPT) technique to fine the maximum power by adjusting the voltage and current supplied from the PV panel.

Photovoltaic panel power production is directly related to sunlight intensity which is affected daily by the sun cycle, clouds, shading from nearby objects (i.e. utility poles, trees, tall buildings).PV inverters are designed to operate over a wide range of voltage to capture power during lower light intensity. Providing electricity in the morning and then later in the afternoon increases the energy supply, Thus it shortens the payback period for a solar installations. The third major components is to maximize the power output of solar installation is to utilize high efficiency of PV inverters. Efficiency is termed as the measure of power out of the inverter as a percentage of the power into the inverter .High efficiency of PV inverters use less of power in the conversion process and supply more power for the ease of use.

2. Survey Of Existing Systems

Integral part of distribution system is power electronics, with help of which they convert the generated electricity into utility-compatible forms. However, the addition of power electronics usually adds reliability issues as well as costs.[1],[2]. Referring to the report by Sandia National Laboratories [3],that in Most of the PV system problems faced in the field is that they are complex and costly. The inverter failure lead to unreliable PV system which in turn lead to loss of hope in

renewable technology. Therefore, to achieve success for long term in PV system , new power converters with higher reliability and efficient long life time are required[3][4].

In past design used, centralized converter-based PV system was the most commonly used type of PV system. The system, PV modules are connected to 3phase voltage-source inverter. The output of each phase of the has an LC filter which is used to limit the harmonics. A 3phase transformer, which is used to step up the voltage and provides a galvanic isolation, that connects the inverter to the utility.

Actually low frequency transformer are considered poor equipment mainly due to their large size and low efficiency. To avoid this low frequency transformers PV system use multiple stage conversion system [1],[5],[6].The most common scheme, includes dc to ac voltage source inverter and dc to dc converter. Commonly, the dc to dc converter contain Offering a high boosting capability and galvanic isolation ,this converter produce low efficiency overall due to the presence of Multiple-stage conversion system. Moreover, bulky electrolytic capacitors are needed for dc link. Electrolytic capacitors, which are very sensitive to the temperature, may cause reliability problem to the overall system.

The PV inverter which consists of electrolytic capacitor does not provide the same life time as PV modules. Consequently, the PV system requires frequent replacement of the inverter. In order to overcome all the above mentioned problem it is essential to take up a alternative inverter design topologies so as to make the inverter economical while also increasing their reliability[7].There are several solution proposed to overcome the problem partially. Reference [5] implemented a transformer-less scheme in which ground leakage current is minimized, but it had a drawback that voltage cannot be changed for wide range. Reference [9] introduced an integrated solution for PV/FC based hybrid distributed generation system to eliminate the requirement of high voltage buffer capacitor for inverters, this inverter does not provide isolation. In [10], small film capacitors replaced the large electrolytic capacitor. This proposed network is applicable for both low and medium power application.

3. Quasi Z-Network

The Quasi Z network is a suitable network for different renewable power application such as solar panels, wind power generator etc. Because of its unique characteristics of voltage boost and buck function in a single stage. If needed the Quasi Z network can boost the input voltage by introducing a special shoot –through switching state which means simultaneous conduction of both switches of same inverter's phase leg. The quasi z network shoot through states are used to boost and store the magnetic energy in both inductor L1 and L2 without short circuiting the capacitor C1 and C2 in figure1.The increase in magnetic energy provides the boosting of voltage on the inverter output during traditional operating states. When the input voltage is high enough then the shoot through state is eliminated, and the quasi Z-network begins to operate as traditional voltage source inverter.

This quasi Z network is similar to the normal Z-source network which uses a unique LC network with major advantages such as, reduced source stress, lower components rating , reduced component count and simplified control strategies for various adjustable motor drives(ASD) which require large range of gain. By controlling the Zero shoot-through duty cycle, the converter can generate any desired output voltage even more than the supply voltage.

PV inverter with high frequency ac link overcomes most of the problem associated with existing PV inverter. The switching losses are very minimum due to the soft switching and the frequency of the link is very high which results in compact link inductor. Moreover, the Zero voltage turn on and soft turn off results in low voltage stress on the switches.

4. Mode Of Operation

In this paper the figure.1 shows the complete PV system connected to a resistive load for simple analysis. The load can be any adjustable speed drives used in commercial or industrial application. The system results in efficient and reliable result in three phase application in renewable technology. The dc source can also be replaced by the irradiance term which is used for obtaining variable DC. This DC power is converted to AC. Through a single phase inverter which comprise of 4 bidirectional switches.

This AC single phase voltage is doubled with proper regulation, reducing the harmonic content to the matrix converter. In order to have proper conversion of single phase ac to three phase ac wave, matrix converter is used. The matrix converter used in this paper makes the complete system compact in structure and they directly convert the ac to ac power through a controlled bidirectional switches.

The output ac signal's magnitude and frequency is varied according to the application in single stage itself. Matrix converter topology volume is also compact when compared to the PWM-VSI. In addition to compact size and volume, the input current drawn has unity displacement factor as well as harmonic reduced sinusoidal output currents. This matrix converter operates in high surrounding temperature due to the lack of electrolytic

capacitor, which is very vulnerable to the temperature. They also have very long life span.
Operation of this system can be broadly divided as

- Charging mode and
- Discharging mode for the quasi-Z network.

4.1. Charging mode

This mode occurs when the DC supply is provided and the switches S1 and S2 are in On condition and S3 and S4 are naturally commutated from the previous state i.e. in Off state. At this state the inductor and capacitor are in charging condition. The figure.2 shows the current path flowing .The positive flow of current through S1 then to the inductor, which charges through diode and capacitor charging also takes place.
In the next state the inductors L1 and L2 with capacitor C1 and C2 starts discharging, and accordingly the matrix converter operates, i.e. The switch from top and bottom of different leg.

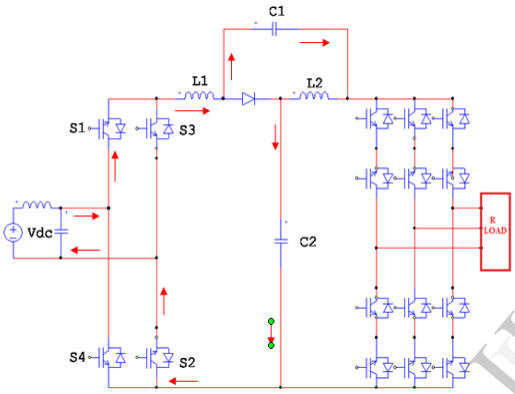

Figure 1.Charging operation of inductor and capacitor

4.2. Discharging mode

In this mode the voltage flows through the bidirectional switches, from to and bottom of different leg in order to produce proper amplified three phase output voltage and current.

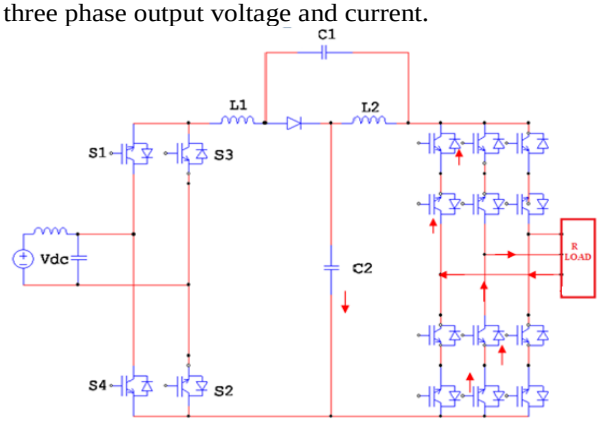

Figure 2.Discharging state of inductor and capacitor

The average current through the inductors in both configuration have same value, which is give by,

$$I_l=P/Vin \quad (1)$$

In the above equation the P is the system power rating and Vin is the input voltage. Here the current is maximum on shoot through state.
The capacitance of the Quasi Z network C1 and C2 is represented as,
C1=C2=(2.P.Ds)/(0.03.Vin.Vdc.f)

$$= P/(0.015.Vin2.f).Ds.(1-2Ds) \quad (2)$$

5. Simulation Result And Discussion

In this paper simulation is carried out for PV system with different loads .i.e. R load and RL load and the performance is compared .The system has front end which is termed as PV energy harvesting .Here the PV panel is represented by irradiance, which produce variable dc voltage. And the MPPT is used to extract maximum power and then provide to the quasi Z network. This is made as subsystem in as shown in Figure.4.

5.2. Front end-PV harvesting

This section consist of DC source with 30 V and then obtained 60V maximum extraction through MPPT algorithm .This maximum power point tracking is essential in all the PV inverters. In this proposed PV inverter can perform MPPT as it follows any references within it range i.e. In this for simulation purpose 100V varying value in order to represent PV panel. For example if the irradiance drops within a referred limit The temperature will be assumed as standard value and is vice versa when irradiance increases.
The power electronic switches are chosen according to their maximum current and voltage they have to withstand. As the voltage on each individual switch does not exceed twice the peak of line to neutral voltage. Each switch has to be rated so as to carry least four times the RMS of input or output currents. firstly .charging or discharging takes place only one half of the link cycle.Secondly, average of triangular wave is half of its peak The waveform is analyzed which shows the distortion level or the harmonic content in ac power obtained from the conversion system. It is proved that without the quasi Z network, the ac power obtained is distorted due to the harmonic content present.

5.3. Back end-Matrix converter

The simulation set up for the back end section matrix converter, circuits are designed and are represented in subsystem for the convenience and are simulated with feedback loop provided. Current feedback is provided so as to obtain error free output. The matrix converter comprises of

bidirectional switches structured in compact form. They are connected with the controller in order to have better switching sequence so as to provide amplified proper alternating three phase power. Proposed PV inverter has a significant advantage that without filter present in load side this matrix converter has an capability to reduce the harmonic content in the output.

Table 1.Design parameters for matrix converter

S.no	Back end		
	Parameter	***Values***	***unit***
1	The output voltage	400	V
2	The output current	145	A
3	The operating frequency	10	kH

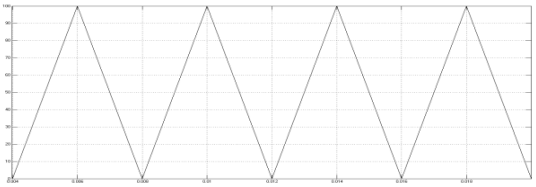

Figure 3. Input -PV panel varying voltage

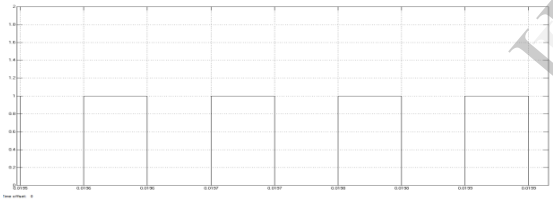

Figure 4. Output voltage of MPPT

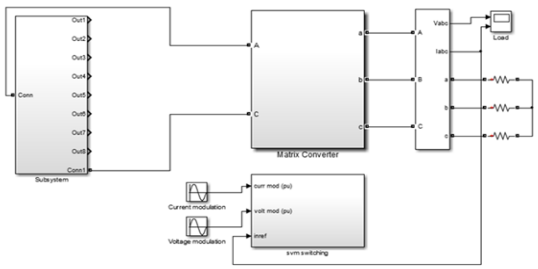

Figure 5. MATLAB setup of PV inverter connected to R load

The PV panel in MATLAB software is represented by the irradiance, the peak voltage is provided as 100V i.e. the dc voltage is varying between form minimum value to 100V as solar radiance is varying throughout the day. When the PV inverter is connected to the R load, operating in high frequency it is found that the voltage level is doubled and the current is in phase with the voltage, and when the PV inverter connected to the RL load the voltage level is doubled as in the R load and the current is lagging with respect to the voltage.

As inductive load current is in lagging it can be used for particular application which require such specifications. This system including Quasi Z network will in turn improve the efficiency and reliability of complete system.

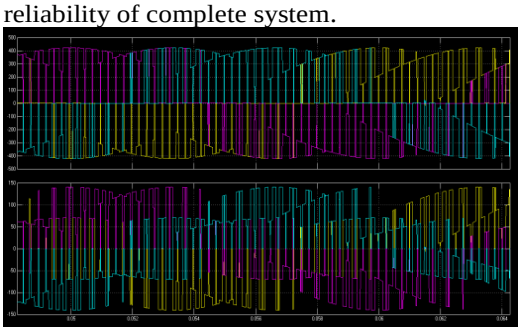

Figure 6. Voltage and Current waveform for R load connected PV inverter

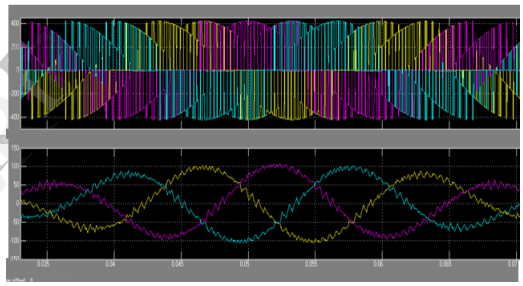

Figure 7. Voltage and Current waveform for RL load connected PV inverter

6. Conclusion

This paper presents a efficient, reliable and compact PV inverter. They can be utilized in various applications ranging from low and medium voltage variable speed motor drives. This proposed inverter has various merits such as transformer-less, single stage conversion system and various other advantages like boosting up the voltage with proper conversion of dc to ac power with reduced harmonic content. In this paper the PV inverter with R load and RL load are simulated and the waveform is studied. The Proposed PV inverter due to the inclusion of quasi Z network doubles the voltage level which in turn improves the efficiency approximately by 2.6 times the efficiency of existing PV inverter, leading to long life span.

10. References

[1] S. Atcitty , J.E. Granat ,M.A.Quinta and C. A. Tasca , *Utility-scale grid tied PV inverter reliability workshop* summary report ,Sandia National Labs.,

Albuquerque, NM,USA, SANDIA Rep. SAND2011-4778.[Online].Available:http://energy.sandia.gov/wp/wp content/gallery/uploads/Inverter_Workshop_FINAL_072811.pdf

[2]S.Chakraborty, B. Kramer, and B.Kroposki, "*A review of power electronics interfaces for distributed energy systems towards achieving low-cost modular design*," Renew.Sustain.Energy Rev.,Vol.13,no.9,pp.2323-2335,Dec.2009.

[3] Y.C. Qin , N. Mohan,R West and R. Bonn,*Status and needs of power electronics for Photovoltaic inverters*, Sandia National Labs., Albuquerque, NM,USA, SANDIA Rep.SAND2002-1535. [online]. Available:www.prod.sandia.gov/techlib/access control.cgi/2002/021535.pdf

[4]Y.Huang, F.Z. Pemg, J.Wang and D. W. Yoo, "*Survey of the power condition system for PV power generation*," in Proc.IEEE PESC, Jun.18-22,2006,PP.1-6.

[5] T. Kerekes, R. Teodorescu , P. Rodriguez , G. Vazquez and E . Aldabas , "*A new high –efficiency single-phase transformerless PV inverter topology*,"IEEE Trans. Ind Electron .,vol 58,no. 1,pp.184-191,jan.2011.

[6]G.Eason , B.Noble and I.N. Sneddon , "*On certain integrals of Lipschitz-Hankel type involving products of Beseel function*,"Phil.Trans.Roy.Soc.London,vol.A247,pp.529-551,April 1995.(references)

[7] J. Clerk Maxwell, *A Treatise on Electricity and Magnetism*, 3rd ed.,vol.2.Oxford Clarendon, 1892,pp.68-73

[8] I. S. Jacobs and C. P. Bean, "*Fine particles, thin films and exchange anisotropy*," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.

[9]Y.Yorozu,M.Hirano,K.oka, and Y.Tagawa, "*Electron spectroscopy studies on Magneto-optical media and plastic substrate interface*," IEEE Trans.J.Magn.Japan,vol.2, pp.740-741, August 1987 [Digest 9th Annual Conf.Magnetics Japan,p.301,1982]

[10] M.Young,The Technical Writer's *Handbook.Mill Valley*,CA: University Science,1989.

[11] J.Anderson,F.Z .Peng, "*Four Quasi-Z source inverters*," inProc IEEE power Electron.Spec.Conf.,Jun.15-19,2008, pp.2743-2749.

[12] Y. Li, J. Anderson and F.Z.Peng and D.Liu, " Quasi-Z source inverter for photovoltaic power generation system,"in Proc.IEEE APEC, Feb.15-19,2009, pp.918-924.

[13] J.H. Park, H.G. Kim, E.C. Nho, T.W.Chun, and J.Choi, " *Grid connected PV System using a quasi –Z-source inverter*," in Proc.IEEE APEC,Feb.15-19,2009,pp.925-929.

[14]Jose Rodriguez, Johan W. Kolar, Fellow,and Patrick W. Wheeler, "*A Review of Control and Modulation Methods for Matrix Converters*" IEEE Transactions on Industrial Electronics Vol. 59, No. 1, pp. 58-70, January 2012.