PV Cell Fed 3-Level Full-MOSFET Inverter Using MPPT Technique

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Abstract: This paper emphasizes on PV cell fed 3- Level Full MOSFET which works using P&O MPPTtechnique and comprises super junction MOSFETs. This proposed Multilevel Inverteris used to feed singlephase Induction motor drive which serves for rural pumping applications. Generally in a standalone system, the PV unit will charge the battery and the battery set up in turn will serve as a source for the inverter. A new single stage battery-less power conversion is employed by designing a maximum power point tracker (MPPT). Reduction in switching losses is achieved by using an improved 3- level full MOSFET inverter topology.

KeyTerms:--MOSFET Inverter, Multi-level, Flying capacitor, Soft-switching, Photovoltaic cell, MPPT.

I INTRODUCTION

Photovoltaic cell is an electrical device that converts the energy of light directly into electricity. But the problem is sun radiation is not consistence throughout the day because of clouds cover and sun angle with respect to the solar panel. Due to this kind of conditions photovoltaic cell exhibits a nonlinear voltage and currentrelationship.Therefore, a photo voltaic system with a controller named MPPT is used to find automatically the maximum power operating point (MPP) at all environmental conditions and then force the PV system to operate at this MPP, to ensure the optimal use of the available solar energy. MPPT Controllers can follow several strategies[1-2] to optimize the power output of an array such as Perturb and observe, Incremental conductance,Current sweep and Constantvoltage. Condition for MPPT is dp/dv=0. If the condition satisfies maximum power will be achieved. If we get any value we need to consider that as error value. In order to compensate the error value a PI controller is implemented, controller generates reference signal which is compared with sawtoothcarrier signal to generate pulse. These generated pulses areapplied to theboost converter to get maximum power. Boost converter step-up process is controlled by varying duty ratio.
Switches can be implemented either by MOSFETS or by IGBTS. MOSFET is better than IGBT due to its high switching speed and efficient at low voltages. The IGBT has the disadvantages of a comparatively large current tail.The inverter is benefits from super junction MOSFET [4]. The device concept is based on charge compensation in the drift region of the transistor, we increase the doping of the vertical driftregion roughly by one order of magnitude and counterbalance this additional charge by the implementation of fine structured columns of the opposite doping type. The blocking voltage of the transistor remains thus unaltered. The charge compensating columns do not contribute to the current conduction during the turn-on state. Nevertheless the drastically increased doping of the drift region allows reduction of the on-resistance. Silicon super junction MOSFET provide excellent static and dynamic performances.But body diode demonstrates poor switching behavior such as reverse recovery charge and slow commutation speed [5].By increasing doping concentration and base thickness MOSFET performance can be improve but diode performance degrades [4, 6]. Because of body diode poor switching behavior IGBTs are preferred to MOSFETS in many AC application. If the demerits caused by the body diode are eliminated then the MOSFET works efficiently.The problem associated with the body diode is resolved by forcing currents through external diodes or inductors. Switching losses, stress across the switch, electromagnetic interference problems are alleviated by making diodes inactive.
In this paper, section II contains photovoltaic system,section III contains P&O MPPT based super junction MOSFET multilevel inverter, section IV contains MATLAB/Simulation results and section V contains conclusion.

II PHOTOVOLTAIC SYSTEM

A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a grid by using proper energy conversion devices. This photovoltaic system consists of three main parts which are PV module, balance of system and load. The major balance of system components in this systems are charger, battery and inverter.

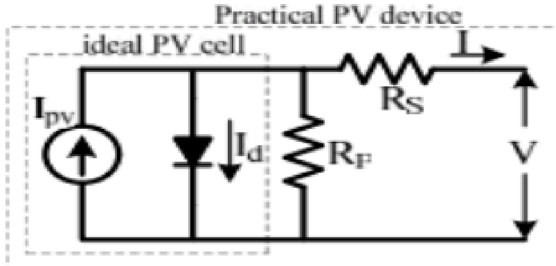


Fig 1 Practical PV device

A photovoltaic cell is basically a semiconductor diode whose p–n junction is exposed to light. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes. The incidence of light on the cell generates charge carriers that originate an electric current if the cell is short circuited.

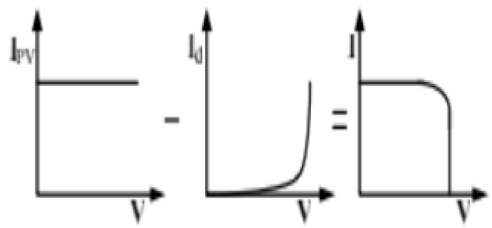


Fig 2 Characteristics I-V curve of the PV cell

The equivalent circuit of PV cell is as shown in the Fig. 1 [7-8].An ideal solar cell may be modelled by a current source in parallel with a diode; in practice no solar cell is ideal, so a shunt resistance and a series resistance component are added to the model.The output current and voltage form PV cell are represented by I and V. TheV-I Characteristics of PV cell are shown in Fig.2. The net cell current I is composed of the light generated current I_{PV} and the diode current I_D

III P&O MPPT BASED SUPER JUNCTION MOSFET MULTILEVEL INVERTER

The Inverter is an electrical device which converts direct current (DC) to alternate current (AC). The inverter is used for emergency backup power in a home. The need of multilevel converter is to give ahigh output power from medium voltage source. The multilevel inverter consists of several switches. Multilevel inverters are three types [10-13],Diode clamped multilevel inverter,flying capacitors multilevel inverter and cascaded H-bridge multilevel inverter. An improved topology allowing the full use of super junction MOSFETs in a highly-efficient multilevel single-phase inverter is presented. The topology makes use of soft-switching snubber to tackle the switching losses. High switching frequencies were used in proposed model. Switching frequency is an operating parameter which effects performance characteristic of supply as well as the cost. The benefits of high switching frequency are small converter size, cost of converter reduce and transient response can be improved. But the problem is high switching frequency causes switching losses. Switching losses are directly proportional to switching frequency.A very common term in electrical field is switching loss. In normal inverter circuits when the switches swap their positions they consume some powers, as they conduct their activities when both current and voltage are nonzero. As a result of imperfect switching power loss will occur. As expected smaller size filter components needed at higher frequencies. So the invented solution for avoiding the power loss by using a new type of inverter which is one of the resonant inverter. The most significant part of resonant inverter is, here switching takes place when voltage and current are zero which is known as soft switching [14]. Since switching takes place in zero voltage and current stage there is no possibility of power loss in resonant inverter.

To keep the switching losses low, fast and quick switching devices is desirable. The increase of switching frequency minimizes the lower order harmonics in PWM type application which in turn reduce the size of reactive component and filter circuits. The increase of switch stress and EMI has new design challenge. One way of dealing with stress on switch is to use snubber circuits. Snubbers are included in circuit so that during turn ON/OFF the stress is bypassed through the snubber. As a result stress on switch reduces but not the loss during switching. A new solution that can reduce switching losses is the idea of resonant converters[16]where the concept of LC resonance is utilized during switching instances. The current and/or voltage of an LC resonant circuit undergo zero level periodically. If the switching of the converters turn on/off is synchronized with zero voltage /current level, the switching losses, stress on devices, EMI generated reduced.

The inductor L_{sn} controls the dynamics of current and significantly reduces turn on losses (ZCS). The capacitors C_{sn1} and C_{sn2} are used to perform ZVS. Inductor and capacitor forms a series resonant circuit. The oscillation of L and c initiated by turning ON and OFF the switch. We need to select inductor and capacitor values in such a way that resonance happens in the circuit and zero impedance is achieved. Selection of inductor and capacitor value is done by using the following formula.

$$f_r = \frac{1}{2\pi\sqrt{LC}}\ Hz$$

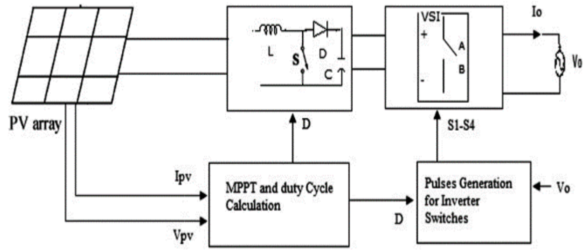


Fig 3Block diagram representation of proposedmodel

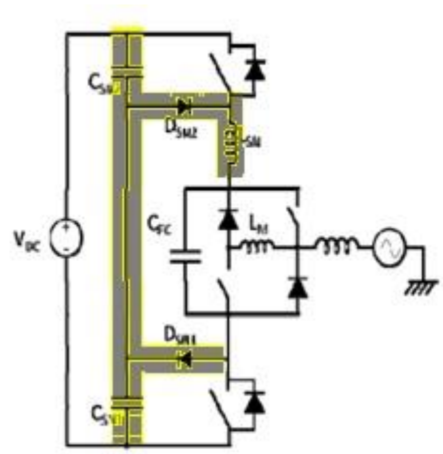


Fig 4 soft switching3-level flying capacitor (single-leg)

A. Turn-on transitions of M1/ Turn-off transitions of M2

Stage 1: Linear charge/discharge of the snubber capacitors C_{SN1}&C_{sn2}

M_1 and M_2 both the switches are in turn OFF condition. The current is flowing through C_{sn1} and $C_{sn2}$is turned off.

Stage 2: Resonant Mode

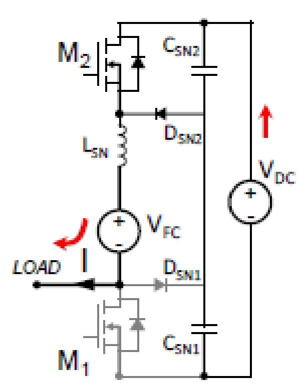
Resonance occurs between the snubber elements $L_{SN}$and C_{SN1}&C_{SN2}. This stage continues until the diode D_{SN1}gets conductive.

Stage 3: Final demagnetization of L_{SN} via the flying capacitor:

D_{SN1} and D_{SN2} are conductive. The snubber inductor finishes discharging linearly through flying capacitor

Stage 4: Parasitic resonance involving C_{OSS} and L_{SN}:

The parasitic capacitance C_{OSS} of M2 resonates with L_{SN}. Demagnetization of L_{SN} achieved



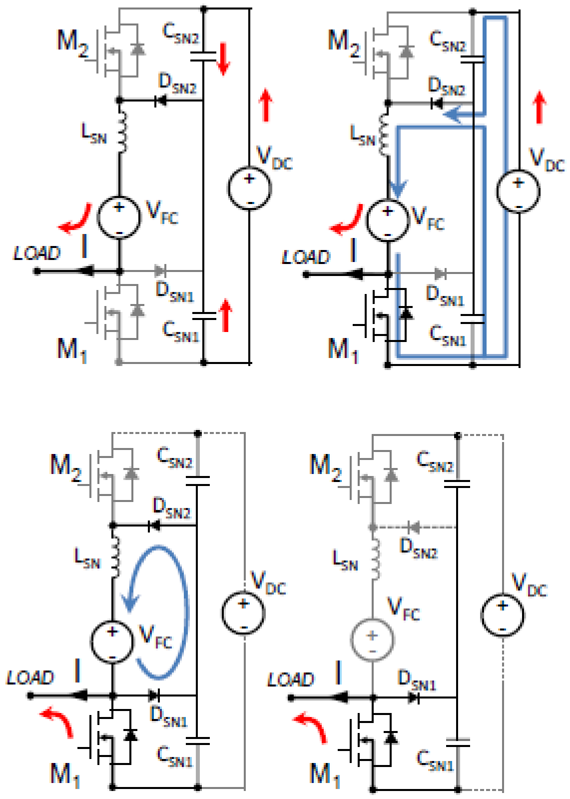


Fig 3Turn-on transitions of M1/ Turn-off transitionsof M2

Turn-off transitions of M1/ Turn-on transitions of M2

Stage 1: Linear magnetization of the snubber inductor L_{SN}:

M_2 is turned on. The voltage across M_2drops to zero and the currents in L_{SN} and in the conductive channel of M_2 raises linearly.

Stage 2: Resonant Mode

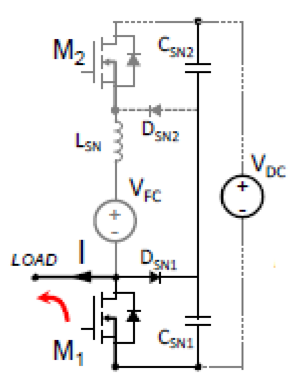
Resonance occur between snubber elements L_{SN} and C_{SN1}&C_{SN2} in order to discharge C_{SN2} and charge C_{SN1}.This stage continues until the complete charge of C_{SN1}.

Stage 3: Final demagnetization of L_{SN} via the flying capacitor:

$D_{SN1}$and D_{SN2} are conductive. The voltage V_{FC} is applied across the snubber inductor which is linearly demagnetizes down to the load current I.

d) Stage 4: Parasitic resonance involving C_{OSS} and L_{SN}:

When the demagnetization of L_{SN} is complete,
D_{SN2} gets blocked.



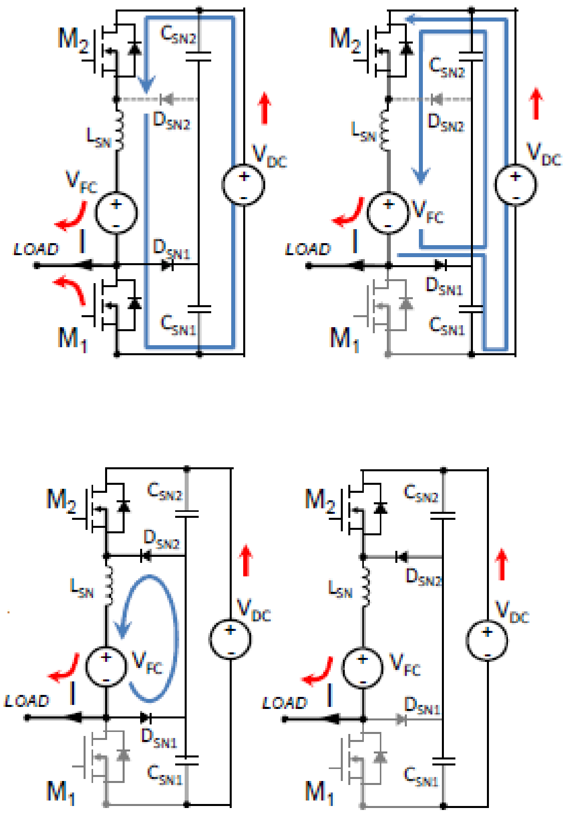


Fig 4Turn-off transitions of M1/ Turn-on transitions of M2

IV MATLAB/SIMULATION RESULTS

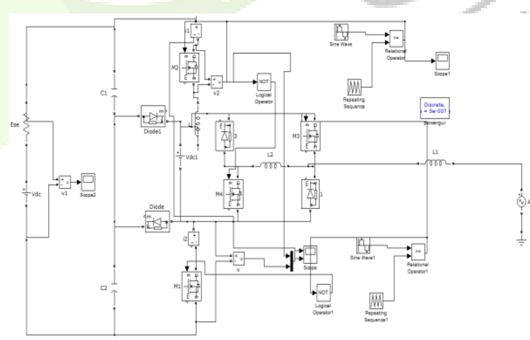


Fig 7 Simulation model for soft switching 3 level flying capacitor topology when transitions turn off mode

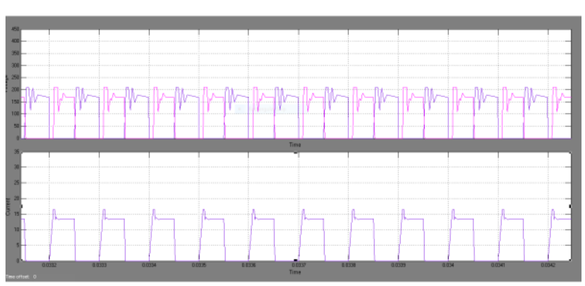


Fig 8 Simulation waveform for during the turn off transmissions M1 with MOSFET

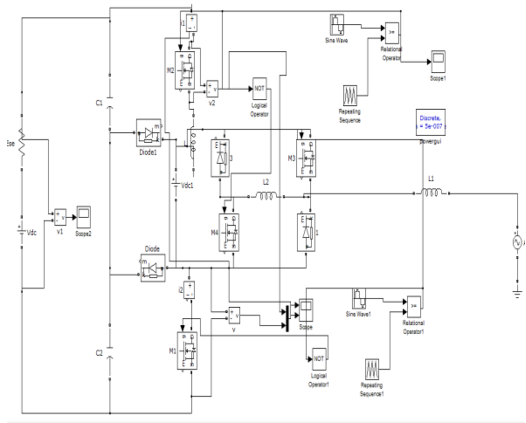


Fig 9 Simulation model for soft switching 3 level flying capacitor topology when transitions turn on mode

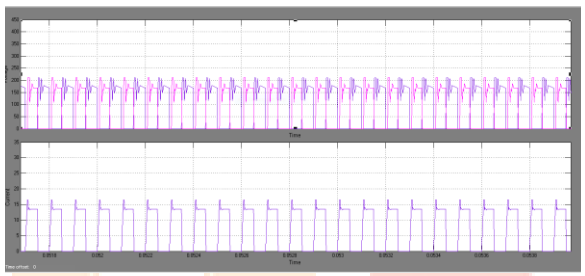


Fig 10 Simulation waveform for during the turn on transmissions M1 with MOSFET

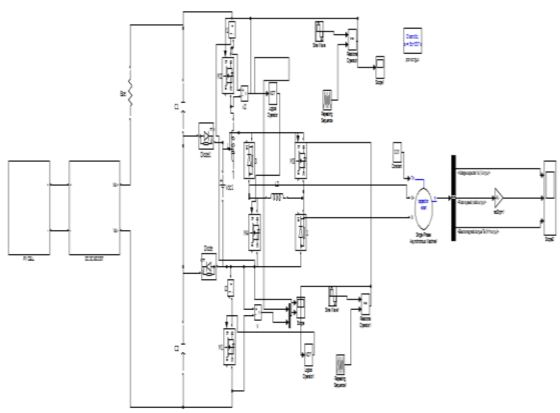


Fig 11 Simulation model for PV based 3 level inverter fed IM

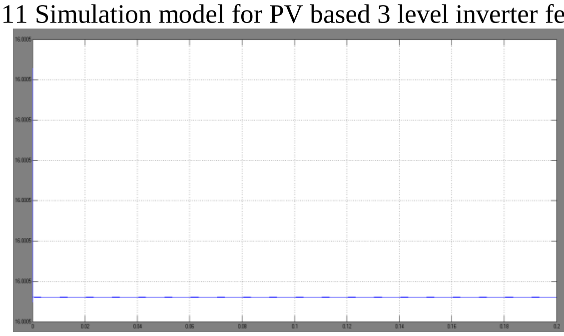


Fig 12 Simulation model for Voltage extracted from PV system

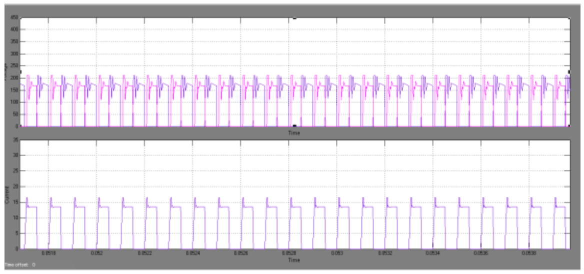


Fig 13 Simulation model for transmissions MOSFET operated

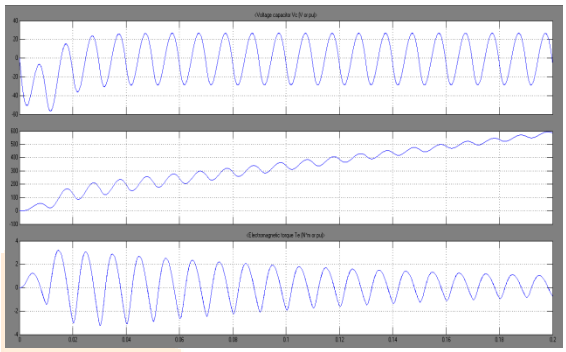


Fig 14 Simulation waveform of voltage capacitor, rotor speed and torque of the IM

V CONCLUSION

This paper presents a PV cell fed 3-level flying capacitor full-MOSFET inverter where body-diode switching limitations are alleviated with a lossless snubber. As we are using high switching frequency efficiency of the system is increased and it reduces the heat sink volume since overall cost of the system. But high switching frequency results high switching losses. Switching losses are reduced by implementing soft-switching technique. When the concept of LC resonance is used switching losses, stress on the device, EMI generated is reduced. The presented topology clearly outperforms standard hard switching implementation in terms of efficiency.

REFERENCES

[1] "Maximum Power Point Tracking". zone.ni.com. zone.ni.com. Retrieved 2011-06-18.
[2] Jump up^ "ADVANCED ALGORITHM FOR MPPT CONTROL OF PHOTOVOLTAIC SYSTEM". Solarbuildings.ca. Retrieved 2013-12-19.
[3] "Boost Converter Operation". LT1070 Design Manual, Carl Nelson & Jim Williams
[4] Deboy G., Marz N., Stengl J.-P., Strack H., Tihanyi J., and Weber H., “A new generation of high voltage MOSFETs breaks the limit line of silicon,” in International Electron Devices Meeting 1998. Technical Digest (Cat. No.98CH36217), 1998, pp. 683–685.
[5] J. P. Harper, “Understanding diode reverse recovery and its effect on switching losses” Fairchild Semiconductor Power Seminar 2007, www.fairchildsemi.com.
[6] Holtz J., Lammert P., and Lotzkat W., “High-Speed Drive System with Ultrasonic MOSFET PWM Inverter and Single-Chip Microprocessor Control,” IEEE Trans. Ind. Appl., vol. IA-23, no. 6, 1987.
[7] Daniel S.H. Chan, member IEEE and Jacob C.H. Phang, member IEEE, ―Analytical Methods for the Extraction of Solar-Cell Singleand Double-Diode Model Parameters from I- V Characteristics‖,
[8] M.T. Benmessaoud_, F.Z. Zerhouni, M. Zegrar, A. BoudgheneStambouli, M. Tioursi‖ New approach modeling and a maximum power point tracker method for solar cells‖ Computers and Mathematics with Applications 60 (2010) 1124-1134,
[9] H. Bourdoucen and A. Gastli ―Analytical Modelling and Simulation of Photovoltaic Panels and Arrays‖ Journal of Engineering Research Vol.4, No.1 (2007) 75-81;
[10] Elena Villanueva, Pablo Correa, José Rodríguez, and Mario Pacas, “Control of a Single-Phase Cascaded H-Bridge Multilevel Inverter for Grid-Connected Photovoltaic Systems”, IEEE Trans. On Industrial Electronics, Vol. 56, No. 11, pp. 4399-4406, Nov. 2009.
[11] E.H. Kim and B.H. Kwon (2013) „Zero voltage and zero current switching full-bridge converter with secondary resonance,‟ IEEE Trans on Industrial Electronics, vol.57, no. 3, pp1017-1025.
[12] G.R. Cha, S.H. Park, Y.C. Jung and C.Y. Won (2008) „High soft switching boost converter for photovoltaic system,‟ Power Electronics and Motion Control Conference, pp383-387.
[13] K. H. Liu and F. C. Lee, “Resonant Switches - a Unified Approach to Improved Performances of Switching Converters,” International Telecommunications Energy Conference; New Orleans, 1984
[14] K. H. Lieu, R. Oruganti, F. C. Lee, “Resonant Switches - Topologies and Characteristics,” IEEE PESC 1985 (France)
[15] Lutz J., Schlangenotto H., Scheuermann U., and De Doncker R., Semiconductor power devices: Physics, characteristics, reliability. Berlin, Heidelberg: Springer Berlin Heidelberg, 2011.
[16] Wensong Y.; Jih-Sheng L.; Hao Q.; Hutchens, C., "High-Efficiency MOSFET Inverter with H6-Type Configuration for Photovoltaic Nonisolated AC-Module Applications," IEEE Transactions on Power Electronics, vol.26, no.4, pp.1253,1260, April 2011

[17] Lefevre G., Rambaud L., Foube L., Mollov S., "Low-cost designs for domestic photovoltaic applications," EPE 2013, pp.1,10, 2-6 Sept. 2013.
[18] Ortiz, G.; Uemura, H.; Bortis, D.; Kolar, J.W.; Apeldoorn, O., "Modeling of Soft-Switching Losses of IGBTs in High-Power High-Efficiency Dual-Active-Bridge DC/DC Converters," IEEE Transactions on Electron Devices, vol.60, no.2, pp.587,597, Feb. 2013
[19] Garcia-Bediaga, A.; Villar, I.; Rujas, A.; Etxeberria-Otadui, I.; Rufer, A., "New optimal design methodology of medium-frequency soft-switching converters," Energy Conversion Congress and Exposition (ECCE), 2013 IEEE , pp.2057,2064, 15-19 Sept. 2013
[20] Naayagi, R.T.; Shuttleworth, R.; Forsyth, A.J., "Investigating the effect of snubber capacitor on high power IGBT turn-off," Electrical Energy Systems (ICEES), 2011, pp.50,55, 3-5 Jan. 2011.
[21] Dowell P. L., "Effects of eddy currents in transformer windings", Proceedings IEE, vol 133, n°8, pp 1387-1394, August 1966.
[22] Lefevre, G.; Chazal, H.; Ferrieux, J.P.; Roudet, J., "Application of Dowell method for nanocrystalline toroid high frequency transformers," Power Electronics Specialists Conference, 2004. vol.2, pp.899,904 Vol.2, 20-25 June 2004.

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