Journal of Engineering and Applied Sciences 13 (Special Issue 5): 4570-4579, 2018
ISSN: 1816-949X

Soft Start Improvement of Induction Motor Using Photovoltaic Fed Switched Inductor Quasi-Z Source H-Bridge Multilevel Inverter

[1]R. Murugesan and [2]M. Manikandan
[1]Department of Electrical and Electronics Engineering, Saint Peter's University, Chennai, Tamil Nadu, India
[2]Department of Electronics and Communication Engineering, Anna University, Chennai, Tamil Nadu, India

Abstract: The general configuration of induction motor is generating a high initial current and high torque while it is undergone heavy load operation. The torque and current problems is depends on mechanical internal and external structure and control arrangement. In order to control of initial torque and motor performance via. current control an adequate circuit and control schemes are required to obtain desired motor performance. This study is proposes switched inductor based quasi Z source circuit is applied on dual source simplified H-bridge multilevel inverter for high step up PV power generation and controlled torque as well as stator current. Voltage control scheme is introduces to control of H-bridge circuit using reference voltage generation for 3 phase proposed circuit. The present circuit is used to control of over voltage and over current in proposed topology. This control loops is not required any complex control, here, we control and generate reference signals using direct sensing of DC-link voltage circuit. Dual power supply based switched inductor quasi Z source on simplified H-bridge multilevel inverter is controlled by single carrier multi-reference Phase Opposition and Disposition (POD) pulse width modulation. The 0.5 Hp induction motor is undergone for this circuit to verify about soft start and torque-current control using MATLAB/Simulink Software.

Key words: Switched Inductor Quasi Z Source (SIQZS), Simplified H-Multi level Inverter (SHMLI), Phase Opposition Disposition Pulse Wdth Modulation (POD-PWM), floating capacitor, Induction Motor (IM), India

INTRODUCTION

The generalized reason for induction motor acceleration, a high starting current is generated across phase or stator terminals. An integrity of motor and control parameters are varied is depends on stator starting current variation. The high starting current results a voltage magnitude variation, stator insulation failure by generation of magnetic failure across induction motor drive (McElveen and Toney, 2001; Gomez and Morcos, 2002). The frequent operation of induction motor causes high starting current andhigh starting torque creates a stator insulation failure via. stator current (Melfi and Umans, 2012). In literatures explain about soft starting of induction motor and it is given bellow as electromechanical solid state variable frequency drive (Gastli and Ahmed, 2005; Giannoutsos and Manias, 2015; Djokic *et al*., 2005; Pires *et al*., 2016; Zhang *et al*., 2009). In recent days, an impedance source inverter circuit is introduces across induction motor for soft start operations via. limiting initial stator current and smoothing voltage (Amudhavalli and Narendran, 2012, 2013). Z source inverter circuit is combined application of voltage source inverter and current source inverter and also single stage high step up operation by utilizing of shoot through states. Multilevel inverter circuit was added in Z source circuit for induction motor control in order to improving soft start performance (Kwak and Toliyat, 2006; Guruprasath and Dhivya, 2013) and stator current control using harmonics minimization of angle control over Z source circuit without multi-level inverter circuit. High step up using less number of passive components is obtained by switched inductor quasi Z source network. It has high step up and less number of passive components even it has low range of passive elements (Ellabban and Abu-Rub, 2016). Cascaded multilevel inverter scheme is used with quasi impedance source circuit for grid interface application for the aim of high step up operation and minimizing of load current.

The proposed multilevel inverter circuit is utilizes on switched inductor quasi Z source circuit for high step up

Corresponding Author: R. Murugesan, Department of Electrical and Electronics Engineering, Saint Peter's University, Chennai,Tamil Nadu, India

with single stage of power conversion. Proposed control scheme is offers reduced torque via. current limiting and DC-link capacitor control. Control of inverter phase voltage and current is obtained by proposed phase opposition disposition pulse width modulation using reference voltage generated by proposed control scheme. The given circuit and control scheme is applied for photovoltaic power generation in single stage of power conversion.

MATERIALS AND METHODS

Proposed circuit scheme: The proposed circuit scheme is capable of converting variable photovoltaic DC to fixed AC using switched inductor based proposed multi-level inverter which is shown in Fig. 1. Switched inductor quasi impedance source circuit is capable of step up power 1:2 ratio from photovoltaic source. Photovoltaic is usually suffered from lagging of current with variable DC power generation (Fig. 2). Here, roposed switched inductor quasi Z source impedance circuit is to improving photovoltaic power generation via. lag to lead power generation. Proposed nine-level multilevelinverter circuit is capable of generating controlled power for induction motor application. Sinusoidal AC power generated without need of any additional filters and transformer and any complex control.

The shoot through and non-shoot through state are explained about operation of proposed switched quasi Z source inverter state. In shoot through state, two-switches is ON in same leg of inverter circuit for short time duration. The same time diode D_{in} and D_2 are off state remains D_1 and D_3 are ON. The inductors (L_1, L_2) are connected in parallel with capacitor circuit, capacitors (C_1, C_2) are discharged in this mode and inductors are charged or stored energy during this mode. The relationship between inductor voltage, capacitor voltage and input voltage of proposed switched quasi z source inverter configuration is obtained by:

$$V_{L3} = V_{in} + V_{C1} \tag{1}$$

$$V_{L1} = V_{L1} = V_{in} + V_{C2} \tag{2}$$

where as in non-shoot through state, diodes D_{in} and D_2 are ON when D_1 and D_3 are OFF; The inductors (L_1, L_2) are connected in parallel with capacitor circuit, capacitors (C_1, C_2) are charged in this mode and inductors are discharged in this mode. The relationship between input DC link voltage, capacitor voltage and inductor voltage is obtained by:

$$V_{in} = V_{dc} - V_{C1} + V_{L3} \tag{3}$$

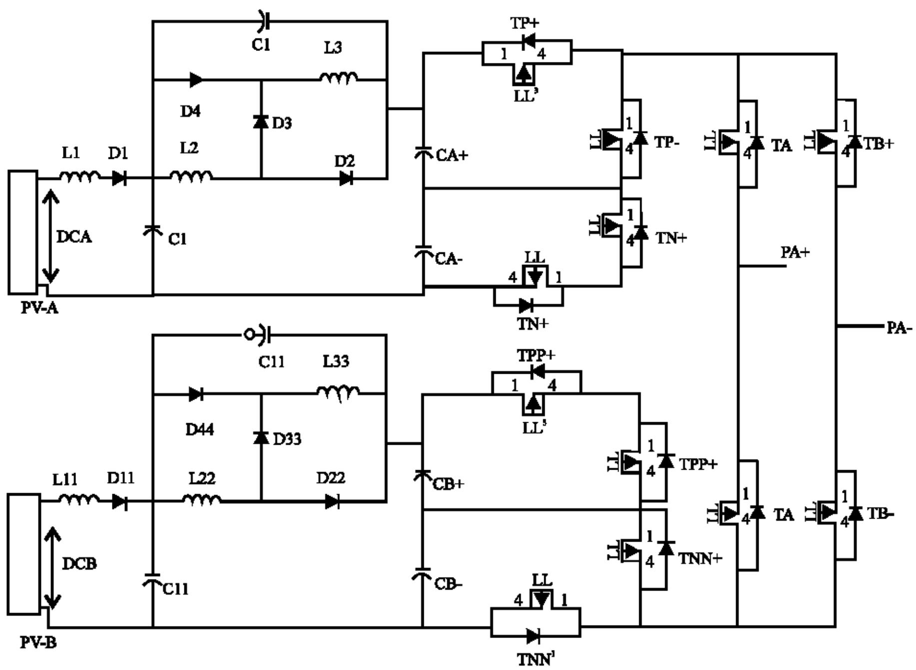

Fig. 1: Proposed photovo fed switched inductor quasi Z source multilevel inverter

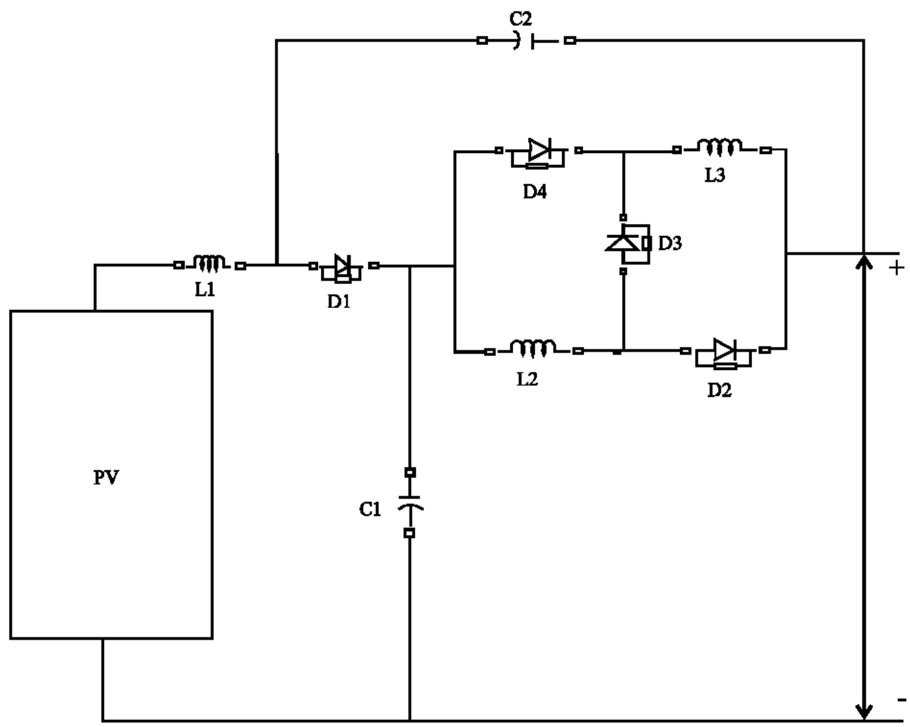

Fig. 2: Proposed photovoltaic fed switched inductor quasi Z source circuit

$$V_{L3} = -V_{C2} \quad (4)$$

$$V_{L1} = V_{L2} = -\frac{1}{2}V_{C1} \quad (5)$$

$$V_{dc} = V_{in} = V_{C1}+V_{C2} \quad (6)$$

The inductor voltage V_{L3} is calculated by applying voltage-second balance principles on Eq. 8 and 2 equation is resulting as Eq. 7, similarly voltage-second balance principles is applied on Eq. 2 and 6 is resulting as Eq. 8:

$$V_{C1} = (1\text{-}D)V_{dc}\text{-}V_{in} \quad (7)$$

$$V_{C2} = \frac{(1\text{-}D)V_{dc}\text{-}(1+D)V_{in}}{1+D} \quad (8)$$

Equation 7 and 8 is used to calculate V_{dc} is expressed by:

$$V_{dc} = \frac{1+D}{1\text{-}2D\text{-}D^2}V_{in} \quad (9)$$

The boost factors of proposed switched inductor quazi Z source inverter is calculated by following expression as Eq. 10 and peak DC-link voltage across present inverter circuit is calculated as Eq. 11:

$$\frac{1+D}{1\text{-}2D\text{-}D^2} \quad (10)$$

Peak DC-link voltage across inverter circuit is explained by:

$$V_{PN} = BV_{DC} \quad (11)$$

The topology of proposed simplified Z source multilevel inverter is having 2DC power source. A clamping circuit is involved (C_{A+}, C_{A-}) and (C_{B+}, C_{B-}) for DC-source A and DC Source B, respectively. The capacitor elements (C_{A+}, C_{A-}) and (C_{B+}, C_{B-}) are controlled by clamping circuits. The involved switches (T_{P+}, T_{P-}) and (T_{N+}, T_{N-}) is used for positive and negative cycle control of capacitor, respectively. Similarly another Dc-source B clamping circuit is involved (T_{PP+}, T_{PP-}) and (T_{NN+}, T_{NN-}) for control of capacitors (C_{B+}, C_{B-}). A Common H-bridge structure (T_{A+}, T_{A-}, T_{B+}, T_{B-}) is uses to create a multilevel to combine with clamping circuits. In order to achieve 9-level two clamping circuit is used in this study.

Proposed control topology: The proposed control of multi-level inverter is implemented using simplified pulse width modulation which is single carrier multi-reference Phase Opposition Disposition Pulse Width Modulation (POD-PWM). The reference voltage is generated using

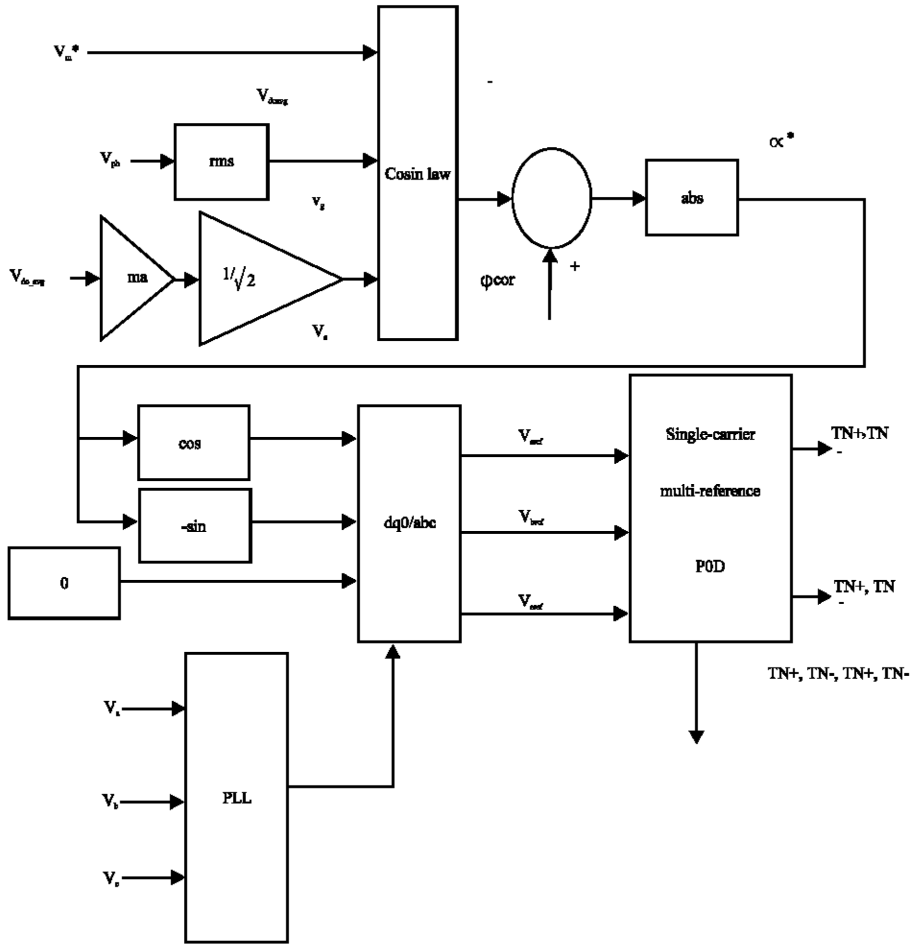

Fig. 3: Control topology for photovoltaic fed switched inductor

park transformation and DC-link voltage control without using of any control schemes (PI, PID and fuzzy logic control approach (Pati *et al*., 2014). In order to regulate the DC-link voltage across clamping capacitor of multilevel inverter, proposed scheme sensing the DC-link capacitor voltage and stator voltage of induction motor directly to perform reference voltage generation which is shown in Fig. 3 quasi Z source multi-level inverter. The basic nature of voltage control on induction is depends on alpha control scheme which involved in proposed above control structures. The alpha control is described using given diagram which is shown in Fig. 4.

Voltage V_m is assumed as reference voltage, voltage V_a is calculated by multiplying of $ma/\sqrt{2}$ is used to calculate by following expressions. The average voltage (V_{dc} avg) is calculated by given expression bellow as:

$$V_{dc}\ avg = \frac{V_{dc}a+V_{dc}b+v_{dc}c}{3} \quad (12)$$

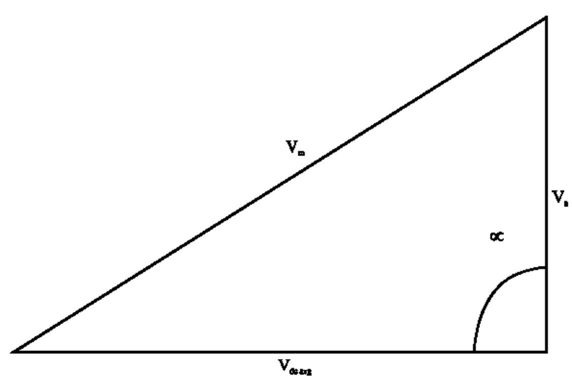

Fig. 4: Vector diagram for alpha (∝) angle control

where $V_{dc}a$, $V_{dc}b$ and $V_{dc}c$ are DC-link voltage for phase a-c voltage , ... is a modulation index is assumed as 1.12. Phase correction signal (φcoϒ) is compared with cosine law of output signals. Cosine law is calculated by following expression:

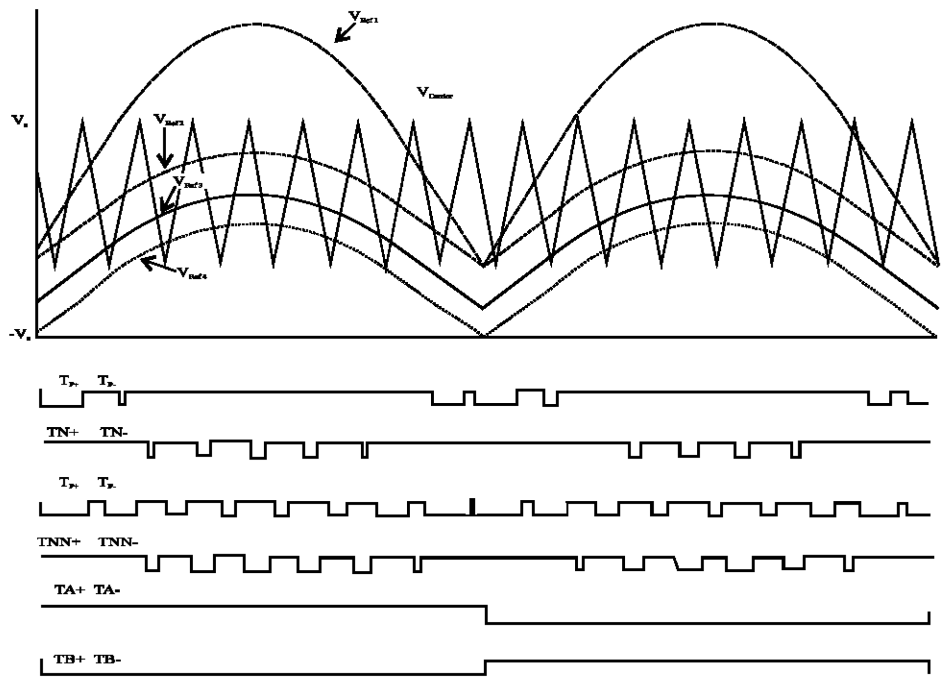

Fig. 5: Single carrier multi-reference based phase opposition disposition pulse width modulation

Table 1: Output voltage and corresponding switching table

Output Voltage (V_0)	Switching conditions								
	TP+	TP-	TN+	TN-	TPP+	TPP-	TNN+	TNN-	TA+, TB-	TB+, TA-
2 V_{dc}	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF
1.5 V_{dc}	ON	OFF	OFF	ON	OFF	ON	OFF	ON	ON	OFF
V_{dc}	ON	OFF	OFF	ON	OFF	ON	ON	OFF	ON	OFF
0.5 V_{dc}	ON	OFF	ON	OFF	OFF	ON	ON	OFF	ON	OFF
0	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON
-0.5 V_{dc}	ON	OFF	ON	OFF	OFF	ON	ON	OFF	OFF	ON
-V_{dc}	ON	OFF	OFF	ON	OFF	ON	ON	OFF	OFF	ON
-1.5 V_{dc}	ON	OFF	OFF	ON	OFF	ON	OFF	ON	OFF	ON
-2 V_{dc}	ON	OFF	OFF	ON	ON	OFF	OFF	ON	OFF	ON

$$\text{COS} \propto \times = \frac{(V_a)^2 + (V_g)^2 + (V_m)^2}{2.v_b.v_g} \quad (13)$$

where, V_g is calculated from V_{Ph} voltage using rms calculation. In proposed controller generate dq and abc reference voltage using PLL block. PLL block is undergone to phase voltage or stator voltage of induction motor. Here, phase angle control scheme is used as unique merits over other control scheme. Single carrier multi-reference phase opposition and disposition pulse width modulation scheme using this reference signals (V_{aref}, V_{bref}, V_{cref}) which is shown in Fig. 5.

Voltage control of proposed photovoltaic fed switched inductor quasi impedance source multi-level inverter: Classical multilevel inverter scheme (Wang *et al*., 2014; Shukla *et al*., 2010) is was facing challenges to control of DC-link capacitor voltage. Here, a simplified Phase Opposition Disposition Pulse Width Modulation (PODPWM) scheme applied to control of DC-link capacitor and control of load voltage. Aim of multi-level inverter schemes offers harmonics less load voltage performance without need of passive filters circuit. Operation is described for corresponding switching table which is mentioned Table 1 and 2.

Dual photovoltaic power supply uses in proposed circuit system, 0.5 DC is generated via control of capacitor link circuits (C_{A+}, C_{A-}) and (C_{B+}, C_{B-}) by TP+, TP- of positive cycle of DCA whereas TN-,TN+ of negative half cycle of DCB and also TPP+, TPP- of positive cycle of DCA whereas, TNN-, TNN+ of negative half cycle of DCB.

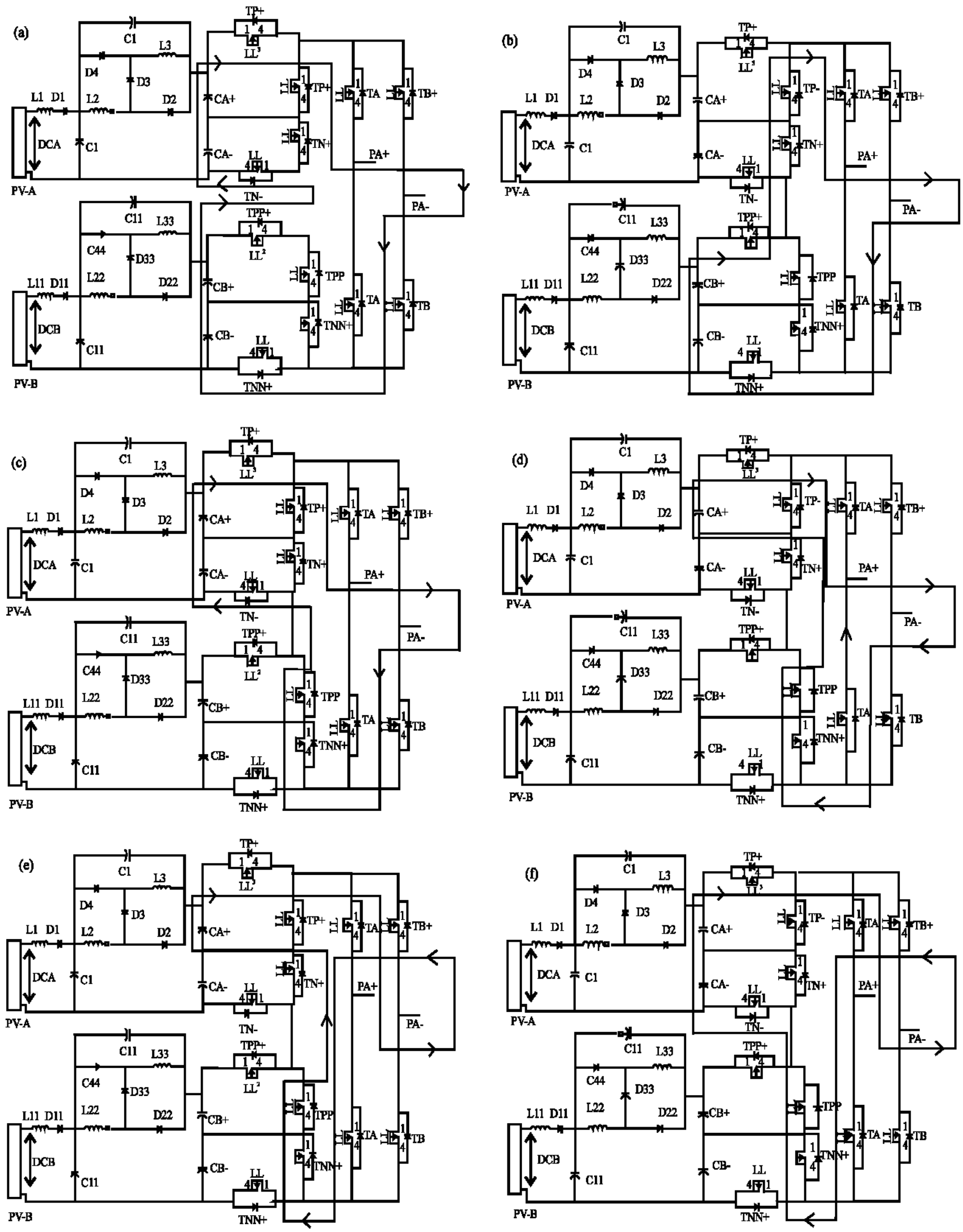

Fig. 6: Continue

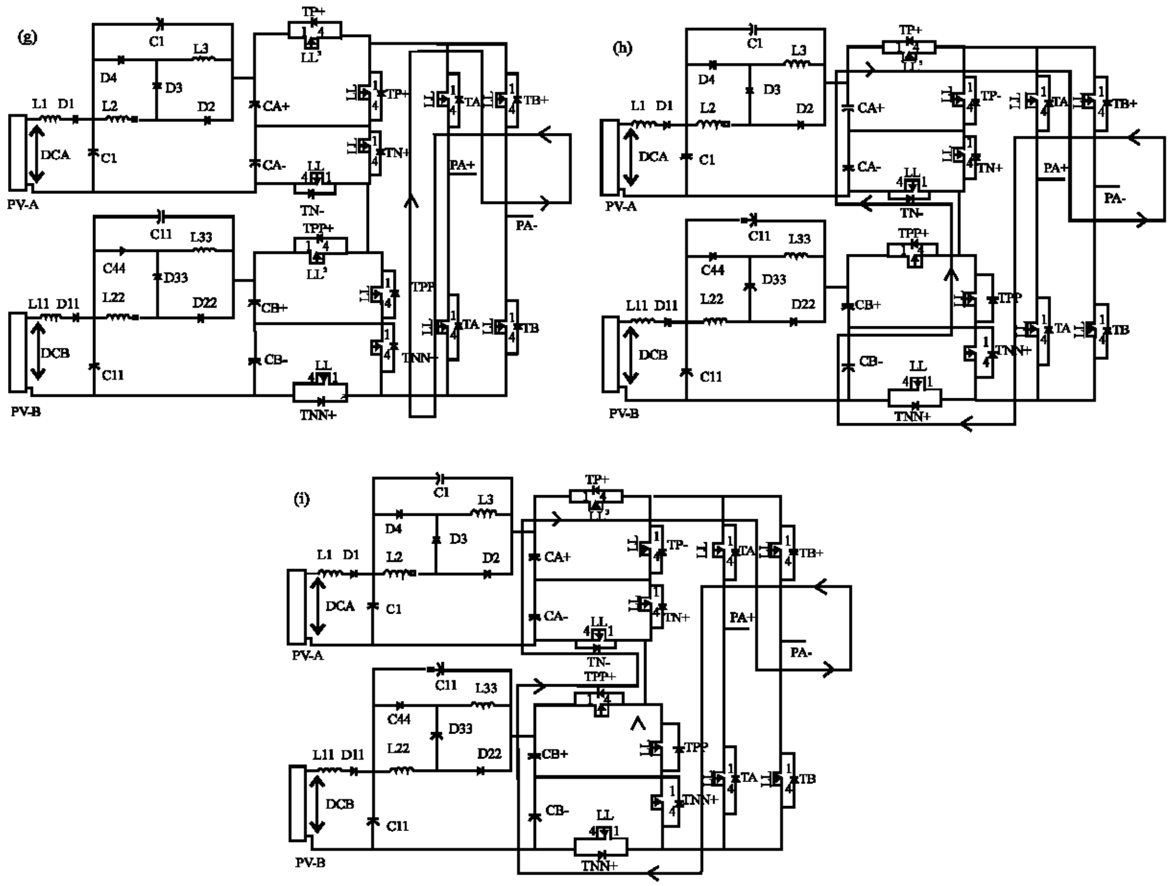

Fig. 6: a-i) State of multilevel inverter for corresponding of Table 1 and 2

Table 2: Operating stage of proposed SLQ source simplified H-bridge MLI

Operating stage	References voltage conditions	Output voltage
1	$0 \leq V_{ref} \leq 2\ V_c$	$2\ V_{dc}$
2	$2\ V_c \leq V_{ref} \leq 4\ V_c$	$1.5\ V_{dc}$
3	$0 \leq V_{ref} \leq V_c$	V_{dc}
4	$V_c \leq V_{ref} \leq 2\ V_c$	$0.52\ V_{dc}$
5	$V_c \leq V_{ref} \leq 2\ V_c$	0
6	$-2V_c \leq V_{ref} \leq -V_c$	$-0.5\ V_{dc}$
7	$-V_c \leq V_{ref} \leq 0$	$-V_{dc}$
8	$-4\ V_c \leq V_{ref} \leq -2V_c$	$-1.5\ V_{dc}$
9	$-2\ V_c \leq V_{ref} \leq 0$	$-2\ V_{dc}$

Equal voltage balancing for both DC-power supplies are achieves in controlled and equal magnitude form by proposed control topology. The state of proposed inverter schemes is described from state 1-8 which is shown in Fig. 6.

RESULTS AND DISCUSSION

Improving performance of switched inductor quasi impedance source multi-level inverter is controlled using phase angle control and reference voltage generation

Table 3: Proposed parameters

Parameters	Ranges
Induction motor	
Power	0.5 (Hp)
Voltage/Frequency	800 (V)
R_s	1.115 (Ω)
R_r	1.083 (Ω)
$L_s = L_r$	0.005974 (H)
J	1.662 (kg.m^2)
RPM	1560
SLQZS	
L1, L11	0.1 (mH)
L2, L3, L22, L33	1 (mH)
C1, C2	1000
MLI	
CA+, CA-, CB+, CB-	2200 (μF)
PV	
Power/Voltage	440 (W/220 V)

is introduced for PV application and it is parameters is shown in Table 3. It is used to improving induction motor performance via. inverter switching performances. DC-link voltage control is a part of control of inverter performance. So, proposed phase angle control based DC-link voltage control and reference current generation

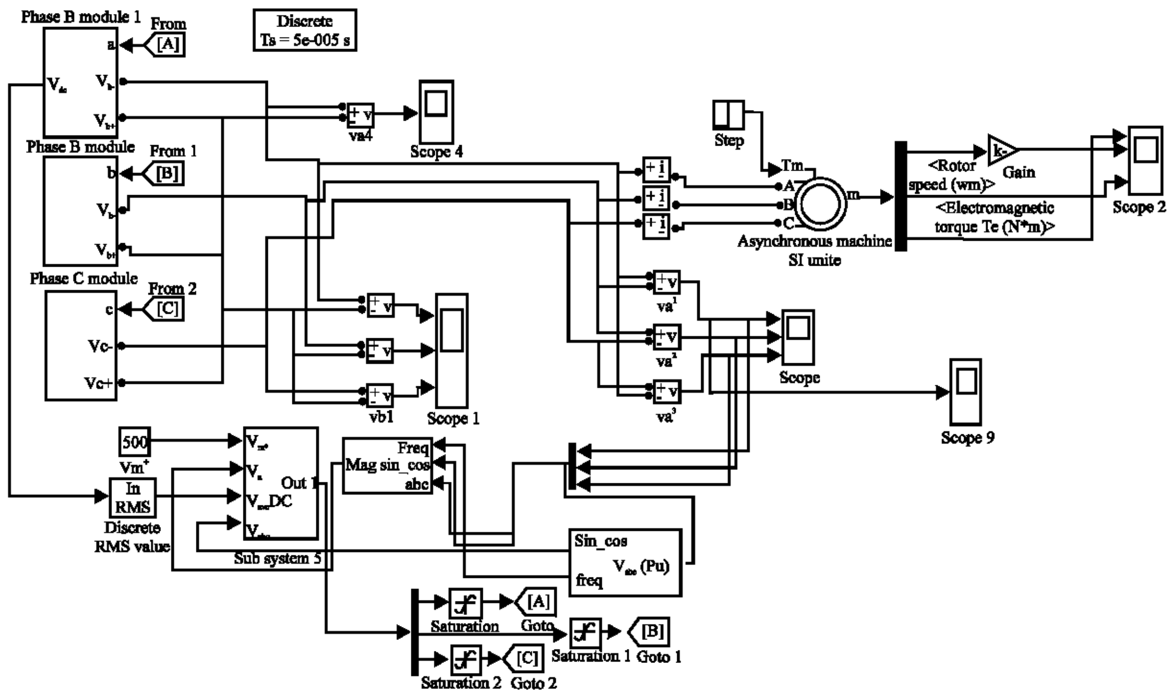

Fig. 7: Simulation implementation of proposed circuit and control topology

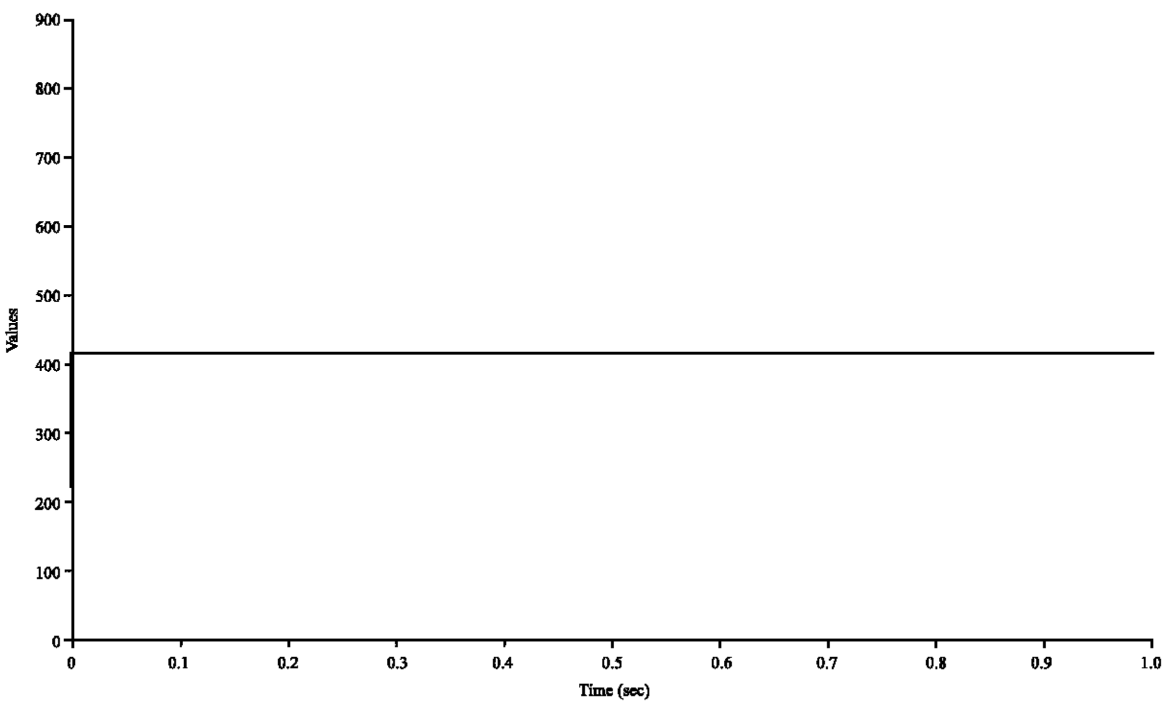

Fig. 8: High step up DC-link voltage using switched inductor Z source circuit

is draws a motor performance and improves voltage control capability. Simulation implementation circuit is given in Fig. 7 switched inductor quasi z source circuit performances are drawn in Fig. 8 and stator voltage is drawn in Fig. 9 introducing of proposed control scheme is draws an improved motor performance is shown in Fig. 10.

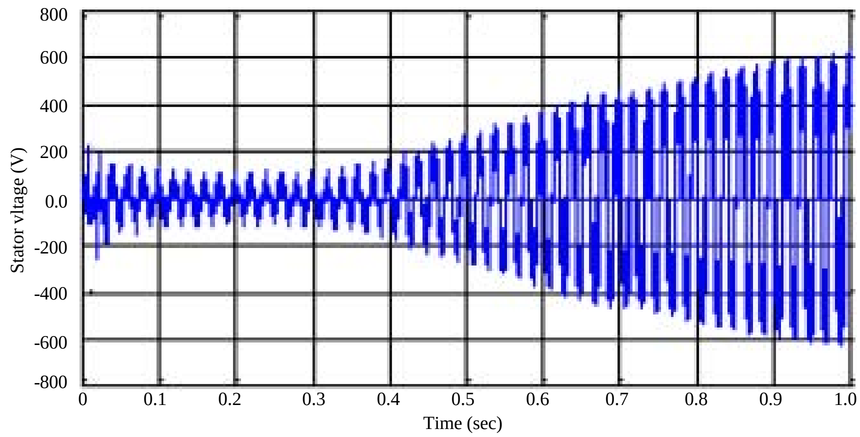

Fig. 9: Phase voltage performance for proposed induction motor control

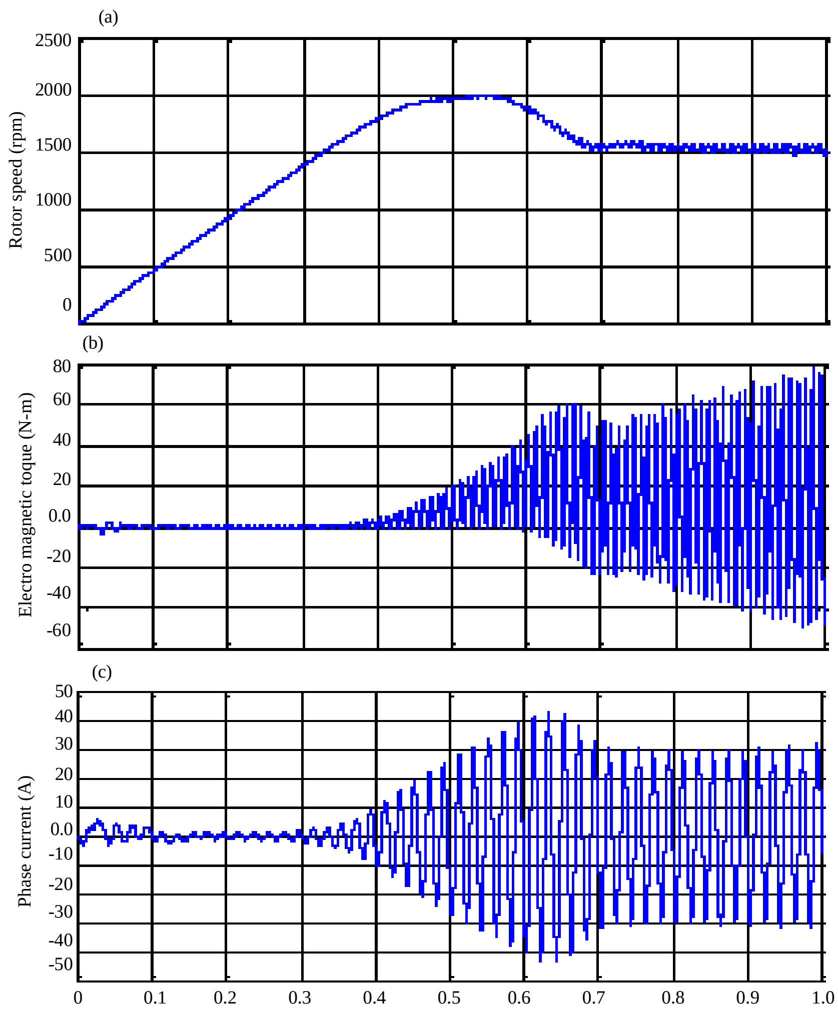

Fig. 10: Motor performance for 0.5 HP induction: a) Rotor speed (rpm); b) Electromagnetic torque N-m and c) Phase current (A)

CONCLUSION

Photovoltaic power source and utilizing of photovoltaic power in induction motor control is a difficult task because photovoltaic power interface required a separate converter system or high step converter circuit before applying inverter. Variable DC of photovoltaic source to AC application required passive filters and transformers. The above limitation is overcomes in proposed photovoltaic fed switched inductor quasi Z source multilevel inverter using phase angle control and Phase Opposition Dispositions Pulse Width Modulation (POD-PWM). Phase angle control circuit is introduces to improving performance of DC-link voltage and used to generate exact reference voltage for proposed POD-PWM. Also, it limits a phase angle in limits stator current and DC-link voltage, so, it can able to control in desired limits electromagnetic torque and speed performance. The 05 Hp induction motor was tested using MATLAB/Simulink Software and it is verified about controller and circuit performance using photovoltaic power source.

REFERENCES

Amudhavalli, D. and L. Narendran, 2012. Speed control of an induction motor by V-F method using an improved Z source inverter. Proceedings of the 2012 International Conference on Emerging Trends in Electrical Engineering and Energy Management (ICETEEEM), December 13-15, 2012, IEEE, Chennai, India, ISBN:978-1-4673-4633-7, pp: 436-440.

Amudhavalli, D. and L. Narendran, 2013. Improved Z source inverter for speed control of an induction motor. Proceedings of the 2013 International Conference on Information Communication and Embedded Systems (ICICES), February 25-26, 2016, IEEE, Chennai, India, pp: 1064-1069.

Djokic, S.Z., K. Stockman, J.V. Milanovic, J.J.M. Desmet and R. Belmans, 2005. Sensitivity of AC adjustable speed drives to voltage sags and short interruptions. IEEE. Trans. Power Delivery, 20: 494-505.

Ellabban, O. and H. Abu-Rub, 2016. Z-source inverter: Topology improvements review. IEEE. Ind. Electron. Mag., 10: 6-24.

Gastli, A. and M.M. Ahmed, 2005. ANN-based soft starting of voltage-controlled-fed IM drive system. IEEE. Trans. Energy Convers., 20: 497-503.

Giannoutsos, S.V. and S.N. Manias, 2015. A systematic power-quality assessment and harmonic filter design methodology for variable-frequency drive application in marine vessels. IEEE. Trans. Ind. Appl., 51: 1909-1919.

Gomez, J.C. and M.M. Morcos, 2002. Voltage sag effects on sensitive equipment due to starting cycles of induction motor. IEEE. Power Eng. Rev., 22: 51-52.

Gupta, K.K., A. Ranjan, P. Bhatnagar, L.K. Sahu and S. Jain, 2016. Multilevel inverter topologies with reduced device count: A review. IEEE. Trans. Power Electron., 31: 135-151.

Guruprasath, R. and R. Dhivya, 2013. Comparision betweeen symmetric and new model asymmetric Z-source cascaded multilevel inverter fed IM for selective harmonic minimization and THD reduction with PV Cell input. Proceedings of the 2013 International Conference on Energy Efficient Technologies for Sustainability (ICEETS'13), April 10-12, 2013, IEEE, Nagercoil, India, ISBN:978-1-4673-6149-1, pp: 1347-1353.

Kwak, S. and H.A. Toliyat, 2006. Multilevel converter topology using two types of current-source inverters. IEEE. Trans. Ind. Appl., 42: 1558-1564.

McElveen, R.F. and M.K. Toney, 2001. Starting high-inertia loads. IEEE. Trans. Ind. Appl., 37: 137-144.

Melfi, M.J. and S.D. Umans, 2012. Squirrel-cage induction motors: Understanding starting transients. IEEE. Ind. Appl. Mag., 18: 28-36.

Pati, S., M. Patnaik and A. Panda, 2014. Comparative performance analysis of fuzzy PI, PD and PID controllers used in a scalar controlled induction motor drive. Proceedings of the 2014 International Conference on Circuit Power and Computing Technologies (ICCPCT'14), March 20-21, 2014, IEEE, Nagercoil, India, ISBN:978-1-4799-2405-9, pp: 910-915.

Pires, I.A., S.M. Silva and B.D.J.C. Filho, 2015. Increasing ride-through capability of control panels using square-wave series voltage compensator. IEEE. Trans. Ind. Appl., 51: 1309-1316.

Shukla, A., A. Ghosh and A. Joshi, 2010. Flying-capacitor-based chopper circuit for dc capacitor voltage balancing in diode-clamped multilevel inverter. IEEE. Trans. Ind. Electron., 57: 2249-2261.

Wang, Y., W.W. Shi, N. Xie and C.M. Wang, 2014. Diode-free T-type three-level neutral-point-clamped inverter for low-voltage renewable energy system. IEEE. Trans. Ind. Electron., 61: 6168-6174.

Zhang, P., Y. Du, B. Lu and T.G. Habetler, 2009. A DC signal injection-based thermal protection scheme for soft-starter-connected induction motors. IEEE. Trans. Ind. Appl., 45: 1351-1358.