Cascaded Two Level Inverter Based Multilevel Statcom for High Power Applications

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***Abstract*-A simple static var compensating scheme using a cascaded two-level inverter-based multilevel inverter is proposed. It consists of two-level inverters and connected through the cascaded open-end windings of a three-phase transformer. The dc-link voltages of the inverters are regulated at two levels to obtain five-level operation. To verify the efficiency of the proposed control strategy, the MATLAB simulation results are verified at balanced and unbalanced conditions. A laboratory prototype is also developed to validate the simulation results. To investigate the behavior of the converter, the complete dynamic model of the system is developed from the equivalent circuit. The model is linearized and transfer functions are derived and system behavior is analyzed for different operating conditions.**

Key Words: DC link voltage, cascaded multilevel inverter, static compensator, PI controller

I.INTRODUCTION

The application of flexible ac transmission systems (FACTS) controllers, such as static compensator (STATCOM) and static synchronous series compensator (SSSC), is increasing in power systems. This is due to their ability to stabilize the transmission systems and to improve power quality (PQ) in distribution systems. This STATCOM is accepted as a reactive power controller and replacing conventional reactive power compensators, such as the Thyristor-switched capacitor and Thyristor-controlled reactor. This device can be used for var compensation, voltage regulation etc. [1].

In this paper in high-power applications, reactive power compensation is achieved using cascaded multilevel inverters [2]. These inverters consist of a high number of dc voltage sources which are usually realized by capacitors. Hence, the converters draw a small amount of active power to maintain dc voltage of capacitors and to compensate the losses in the converter. However, due to mismatch in conduction and switching losses of the switching devices, the capacitors voltages are unbalanced. Balancing these voltages is a major research challenge in multilevel inverters. In different control schemes using different topologies are reported in [3]–[7]. However, the aforementioned topology requires a large number of dc capacitors. The control of static dc-link voltage of the capacitors is difficult.

Static reactive power compensation by cascading conventional multi-level inverter is an attractive solution for high-power applications. The topology consists of standard multilevel/two-level inverters connected in cascade through open-end windings of a three-phase transformer. Such topologies are popular in high-power drives [8]. One of the advantages of this topology is that by maintaining asymmetric voltages at the dc links of the inverters, the number of levels in the output voltage waveform can be increased. This improves PQ [8]. Therefore, overall control is simple compared to conventional multilevel inverters.

A three -level inverter and two-level inverter are connected on both side of the transformer low-voltage winding. The dc-link voltages are maintained by separate converters. In [11], standard two-level inverters is used to maintain the three level operation. The reactive power supplied to the grid that affects the dc-link voltage balance between the inverters.

Generally, a static var compensation scheme is explain a cascaded two-level inverter with multilevel inverter. Its uses standard two-level inverters to achieve five level operation. The dc-link voltages of the inverters are controls by asymmetrical levels to obtain five-level operation. The simulation found at balanced and unbalanced supply - voltage conditions. A laboratory prototype is also developed to validate the simulation results.

From this section of simulation and experimentation are found that the dc-link voltages of two inverters collapse for certain operating conditions when there is a sudden change in reference current. To develop the behavior of the converter, the complete dynamic model of the system from the equivalent circuit. The model is linear zed and transfer functions are derived. Using the transfer functions, system behavior is analyzed for different operating conditions.

This paper is organized as follows: The proposed control scheme is presented in Section II. Simulation result is presented in Section III respectively.

II.CASCADED TWO-LEVEL INVERTER-BASED MULTILEVEL STATCOM

The cascaded two level inverter-based multilevel STATCOM to obtained five level operation. The inverters are connected on the low-voltage (LV) side of the transformer and the grid connected to high-voltage (HV) side of the transformer. The dc-link voltages of the inverters are Maintained constant and modulation indices are controlled to achieve the required objective. The proposed control scheme is derived from the ac side of the equivalent circuit.

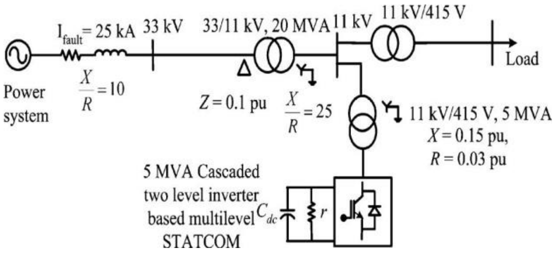

Fig. 1. Power system and the STATCOM model.

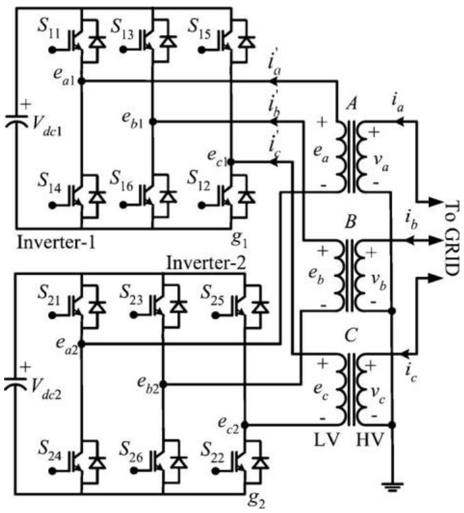

Fig. 2. Cascaded two-level inverter-based multilevel STATCOM.

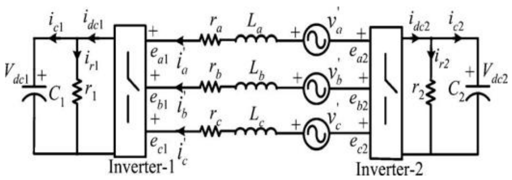

Fig. 3. Equivalent circuit of the cascaded two-level inverter-based multilevel STATCOM

Appling KCL on the ac side, the dynamic model can be derived using [14] a

Assuming r_a=r_b=r_c= r, L_a=L_b=L_c=L

Appling KVL for 'a' phase

$$-v_a'+r_a i_a'+L_a \frac{di_a'}{dt}+(e_{a1}-e_{a2})=0 \quad (1)$$

Similarly for 'b' and 'c' phases

$$-v_b'+r_b i_b'+L_b \frac{di_b'}{dt}+(e_{b1}-e_{b2})=0 (2)$$

$$-v_c'+r_c i_c'+L_c \frac{di_c'}{dt}+(e_{c1}-e_{c2})=0 \quad (3)$$

Where

v_a' , v_b' , v_c': Source voltage referred to LV side of transformer

r_a , r_b , r_c: Resistance which represent the losses of transformer

L_a , L_b , L_c: Leakage inductance of transformer winding

e_{a1} , e_{b1} , e_{c1}: Output voltage of inverter 1

e_{a2} , e_{b2} , e_{c2}: Output voltage of inverter 2

r_1 , r_2: Leakage resistance of DC link capacitor C_1 , C_2

The above three equation written as

$$\begin{bmatrix} \frac{di_a'}{dt} \\ \frac{di_b'}{dt} \\ \frac{di_c'}{dt} \end{bmatrix} = \begin{bmatrix} \frac{-r}{L} & 0 & 0 \\ 0 & \frac{-r}{L} & 0 \\ 0 & 0 & \frac{-r}{L} \end{bmatrix} \begin{bmatrix} i_a' \\ i_b' \\ i_c' \end{bmatrix} + \frac{1}{L} \begin{bmatrix} v_a' - (e_{a1}-e_{a2}) \\ v_b' - (e_{b1}-e_{b2}) \\ v_c' - (e_{c1}-e_{c2}) \end{bmatrix} \quad (4)$$

The above equation represent mathematical model in stationary reference frame. The system model is transformed to synchronous rotating reference frame [14].

$$\begin{bmatrix} \frac{di_d'}{dt} \\ \frac{di_q'}{dt} \end{bmatrix} = \begin{bmatrix} \frac{-r}{L} & \omega \\ -\omega & \frac{-r}{L} \end{bmatrix} \begin{bmatrix} i_d' \\ i_q' \end{bmatrix} + \frac{1}{L} \begin{bmatrix} v_d' - e_d^* \\ -e_q^* \end{bmatrix} (5)$$

Comparison speaks to the numerical model of the fell two-level inverter-based multilevel STATCOM in the stationary reference outline. This model is changed to the synchronously turning reference outline. The – tomahawks reference voltage segments of the converter $e_d^*$and e_q^* are controlled as[1

$$e_d^* = -x_1 + \omega L i_q' + v_d' \quad (6)$$

$$e_q^* = -x_2 + \omega L i_d' + v_q' \quad (7)$$

Where v_d' is the - hub voltage segment of the air conditioner source andi_d',$i_q'$are dq - tomahawks current segments of the fell inverter, individually. The synchronously turning casing is adjusted to source voltage vector so that the q- segment of the source voltage$v_q'$is made zero. The control parameters x1 and x2 are controlled as takes after:

$$x_1 = \left(k_{p1} + \frac{k_{i1}}{s}\right)(i_d^* - i_d') \quad (8)$$

$$x_1 = \left(k_{p2} + \frac{k_{i2}}{s}\right)(i_q^* - i_q') \quad (9)$$

The -axis reference current$i_d^*$is achieved by

$$i_d^* = \left(k_{p3} + \frac{k_{i3}}{s}\right)[(V_{dc1}^* - V_{dc2}^*) - (V_{dc1} + V_{dc2})] \quad (10)$$

Where $V_{dc1}^{*}, V_{dc2}^{*}$and$V_{dc1}, V_{dc2}$are the reference and real dc-join voltages of inverters 1 and 2, individually. The q –axis reference current i_q^* is acquired either from an external voltage regulation circle when the converter is utilized as a part of transmission-line voltage bolster or from the heap if there should arise an occurrence of burden remuneration.

A. Control Strategy

The control unit outline is appeared in Fig.4. The square flags cos ωt and sin ωt are created from the stage bolted circle (PLL) by method for three-stage supply voltages (V_a , V_b , V_c). The converter streams (i_a' , i_b' , i_c') are changed to the synchronous turning reference casing utilizing the unit signals. The exchanging recurrence swell in the converter current segments is dispensed with utilizing a low-pass channel(LPF)From$V_{dc1}^{*} + V_{dc2}^{*}$ and i*q circles, the controller creates d-q tomahawks reference voltages, e*d and e*q for the fellinverter. With these reference voltages, the inverter supplies

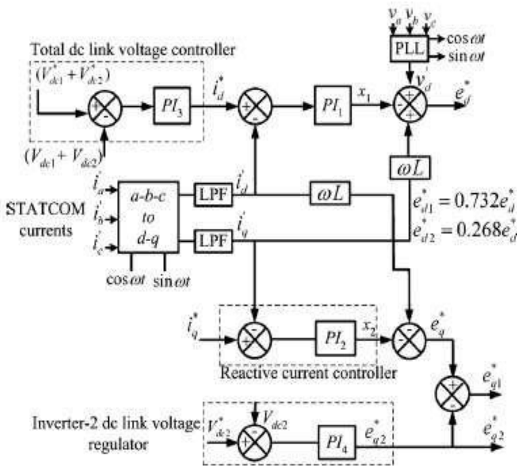

Fig. 4. Control block diagram.

the sought receptive current and draws required dynamic current to manage complete dc-join voltage $V_{dc1}^{*} + V_{dc2}^{*}$.

B. *DC-Link Balance Controller*

The dynamic force exchange between the source and inverter relies on upon $\delta$and is generally little in the inverters supplying var to the matrix. Henceforth,canbethoughttobecorrespondingtoe_q.

Consequently, the - hub reference voltage part of inverter-2 $e_{q2}^{*}$is inferred to control the dc-join voltage of inverter-2 as is derived to control the dc- link voltage of inverter-2as

$$e_{q2}^{*} = \left(k_{p4} + \frac{k_{i4}}{s}\right)(V_{dc1}^{*} + V_{dc2}^{*}) \quad (11)$$

The reference voltage part of inverter- 1 e_q1* is gotten asThe dc-join voltage of inverter-2 V_{dc2} is controlled at 0.366 times the dc-join voltage of inverter-1 V_{dc1}. It results in four-level operation in the yield voltage and enhances the consonant range. Communicating dc-join voltages of inverter-1 and inverter-2 regarding complete dc-join voltage,V_{dc} as

$$V_{dc1} = 0.73V_{dc} \quad (12)$$

$$V_{dc2} = 0.268V_{dc} \quad (13)$$

Since the dc-join voltages of the two inverters are directed, the reference - pivot voltage part e_d^* is partitioned in the middle of the two inverters in extent to their individual dc-join voltage as

$$e_{d1}^{*} = 0.732e_d^{*} \quad (14)$$

$$e_{d2}^{*} = 0.268e_d^{*} \quad (15)$$

Diminishes. Hence, power exchange to inverter-2 increments, when it decreases for inverter-1 The force exchange to inverter-2 is straight measured, when for inverter-1, it is controlled by implication. Along these lines, through unsettling influences, the dc-join voltage of inverter-2 is restored to its reference fatly contrasted with that of inverter-1. Utilizing and, the reference voltages are created in stationary reference outline for inverter-1 and utilizing and forinverter-2.The reference voltages produced for inverter-2 are in stage restriction to that of inverter-1. From the reference voltages, door signs are produced utilizing the sinusoidal heartbeat width regulation (PWM) strategy. Since the two inverters' reference voltages are in stage resistance, the prevalent symphonies show up at twofold the exchanging recurrence.

III SIMULATION RESULTS

The implemented Simulink model consisted of three phase voltage source it is acts as a supply system which is distributed the power to load by utilizing the distribution transformers at normal and abnormal conditions. In any distribution mechanism the efficiency levels are reduced due to the presence of disturbances which leads to reduced power quality in thenetworks.

To improve the power quality levels in the system facts technology provided in this model. The model designed with cascaded two level STATCOM is interconnected in parallel in distribution network. The block diagram which is shown in figure 5.

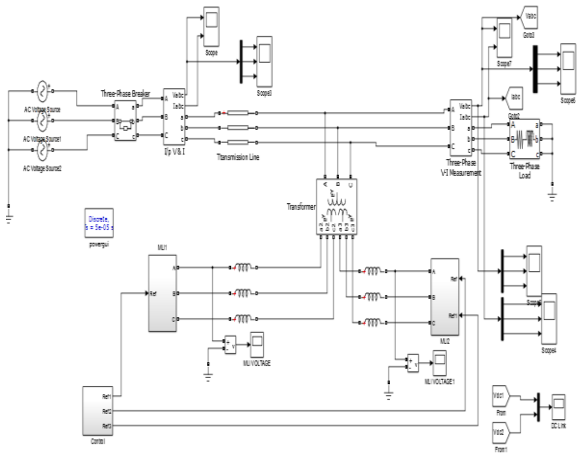

Fig 5: Simulink model for two level STATCOM connected distribution system

The statcom consisted the two voltage source converter which is used identify the faulted conditions in the networks by the controlling strategies. Each voltage source converter having six IGBTS to detect the faults and to compensate the faults by proper firing pulses from the controller. The dc-link capacitance which is used to charge the energy at normal conditions and to release energy levels at abnormal conditions.

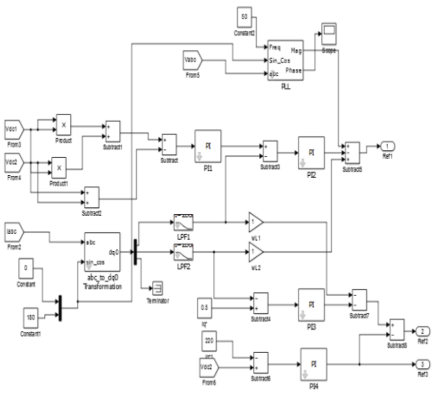

Fig. 6. Simulation of control diagram

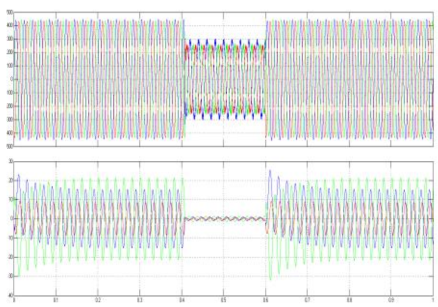

Fig. 7. Results of supply side voltage and current measurement

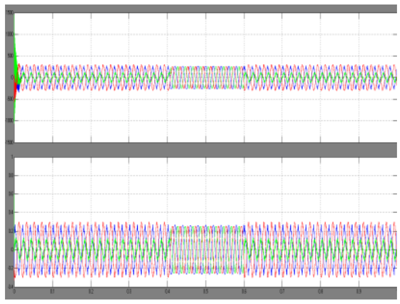

Fig. 8. Results of load side voltage and current measurement

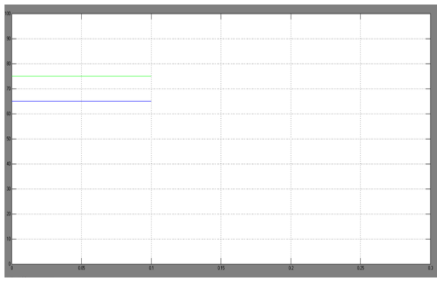

Fig. 9. Dc link voltage

IV CONCLUSION

DC-link voltage balance is one of the main problems in cascaded inverter-based STATCOMs. In this paper, a simple var compensating scheme is proposed for a cascaded two-level inverter- based multilevel inverter. The scheme provides regulation of dc-link voltages of inverters at asymmetrical levels and reactive power compensation. The performance of the scheme is validated by simulation and experimentations under balanced and unbalanced voltage conditions. Further, the cause for instability when there is a change in reference current is investigated. The dynamic model is developed and transfer functions are derived. System behavior is analyzed for various operating conditions. From the analysis, it is inferred that the system is a nonminimum phase type, that is, poles of the transfer function always lie on the left half of the -plane. However, zeros shift to the right half of the -plane for certain operating conditions. For such a system, oscillatory instability for high controller gains exists.

REFERENCES

[1] N. G. Hingorani and L. Gyugyi, Understanding FACTS. Delhi, India: IEEE, 2001, Standard publishers distributors.

[2] Singh, R. Saha, A. Chandra, and K. Al-Haddad, “Static synchronous compensators (STATCOM): A review,” IET Power Electron., vol. 2, no. 4, pp. 297-324, 2009.

[3] H. Akagi, H. Fujita, S. Yonetani, and Y. Kondo, “A 6.6-kV transformerless STATCOM based on a five-level diode-clamped PWM converter: System design and experimentation of a 200-V 10-kVA laboratory model,” IEEE Trans. Ind. Appl., vol. 44, no. 2, pp. 672-680, Mar./Apr. 2008.

[4] Shukla, A. Ghosh, and A. Joshi, “Hysteresis current control operation of flying capacitor multilevel inverter and its application in shunt compensation of distribution systems,” IEEE Trans. Power Del., vol. 22, no. 1, pp. 396-405, Jan. 2007.

[5] H. Akagi, S. Inoue, and T. Yoshii, “Control and performance of a transformerless cascaded PWM STATCOM with star configuration,” IEEE Trans. Ind. Appl., vol. 43, no. 4, pp.

1041-1049, Jul./Aug. 2007.
Y. Liu, A. Q. Huang, W. Song, S. Bhattacharya, and G. Tan, "Small-signal model-based control strategy for balancing individual dc capacitor voltages in cascade multilevel inverter-based STATCOM," IEEE Trans. Ind. Electron., vol. 56, no. 6, pp. 2259-2269, Jun. 2009.

[6] H. P. Mohammadi and M. T. Bina, "A transformerless medium-voltage STATCOM topology based on extended modular multilevel converters," IEEE Trans. Power Electron., vol. 26, no. 5, pp. 1534-1545, May 2011.

[7] X. Kou, K. A. Corzine, and M. W. Wielebski, "Overdistention operation of cascaded multilevel inverters," IEEE Trans. Ind. Appl., vol. 42,no. 3, pp. 817-824, May/Jun. 2006.

[8] K. K. Mohaptra, K. Gopakumar, and V. T. Somasekhar, "A harmonic elimination and suppression scheme for an open-end winding induction motor drive," IEEE Trans. Ind. Electron., vol. 50, no. 6, pp. 1187-1198, Dec. 2003.

[9] Y. Kawabata, N. Yahata, M. Horii, E. Egiogu, and T. Kawabata, "SVG using open winding transformer and two inverters," in Proc., 35th Annual IEEE Power Electron. Specialists Conf., 2004, pp. 3039-3044.
S. Ponnaluri, J. K. Steinke, P. Steimer, S. Reichert, and B. Buchmann, "Design comparison and control of medum voltage STATCOM with novel twin converter topology," in Proc., 35th Annu. IEEE Power Electron. Specialists Conf., 2004, pp. 2546-2550.

[10] N. N. V. Surendra Babu, D. Apparao, and B. G. Fernandes, "Asymmetrical dc link voltage balance of a cascaded two level inverter based STATCOM," in Proc., IEEE TENCON, 2010, pp. 483-488.
IEEE Criteria for Class IE Electric Systems, IEEE Standard 141-1993.
C. Schauder and H. Mehta, "Vector analysis and control of advanced static VAr compensators," in Proc. Inst. Elect. Eng. C., Jul. 1993, vol. 140, no. 4, pp. 299305.

[11] G. Holmes and T. A. Lipo, "IEEE series on power engineering," in Pulse Width Modulation for Power Converters: Principles and Practice. Piscataway, NJ, USA: IEEE, 2003.

[12] B. Blazic and I. Papic, "Improved D-statcom control for operation with unbalanced currents and voltages," IEEE Trans. Power Del., vol. 21, no. 1, pp. 225-233, Jan. 2006.

A. Leon, J. M. Mauricio, J. A. Solsona, and A. Gomez-Exposito, "Software sensor-based STATCOM control under unbalanced conditions, "IEEE Trans. Power Del., vol. 24, no. 3, pp. 1623-1632, Jul. 2009.
Y. Suh, Y. Go, and D. Rho, "A comparative study on control algorithm for active front-end rectifier of large motor drives under unbalanced input," IEEE Trans. Ind. Appl., vol. 47, no. 3, pp. 825-835, May/Jun. 2011.

[13] K. Ogata, Modern Control Engineering, 4th ed. Delhi, India: Pearson, 2004.

[14] Ali, A. Nazar. "Cascaded Multilevel Inverters for Reduce Harmonic Distortions in Solar PV Applications." Asian Journal of Research in Social Sciences and Humanities 6.Issue : 11 (2016): 703-715.

[15] Ali, A. Nazar. "A Single phase Five level Inverter for Grid Connected Photovoltaic System by employing PID Controller." African journal of Research 6.1 (2011): 306-315.

[16] ali, A.Nazar. "A SINGLE PHASE HIGH EFFICIENT RANSFORMERLESSINVERTER FOR PV GRID CONNECTED POWER SYSTEM USING ISPWM TECHNIQUE." International Journal of Applied Engineering Research 10.ISSN 0973-4562 (2015): 7489-7496.

[17] Ali, A. Nazar. "Performance Enhancement of Hybrid Wind/Photo Voltaic System Using Z Source Inverter with Cuk-sepic Fused Converter." Research Journal of Applied Sciences, Engineering and Technology 7.ISSN: 2040-7459; (2014): 3964-3970.

[18] Ali, A. Nazar. "Ride through Strategy for a Three-Level Dual Z-Source Inverter Using TRIAC." Scientific Research publication 7.ISSN Online: 2153-1293 (2016): 3911-3921.

[19] Ali, A. Nazar. "An ANFIS Based Advanced MPPT Control of a Wind-Solar Hybrid Power Generation System." International Review on Modelling and Simulations 7.ISSN 1974-9821 (2014): 638-643.

[20] Nazar Ali, A. "Performance Analysis of Switched Capacitor Multilevel DC/AC Inverter using Solar PV Cells." International Journal for Modern Trends in Science and Technology 3.05 (2017): 104-109.

[21] Ali, A.Nazar. "FPGA UTILISATION FOR HIGH LEVELPOWER CONSUMPTION DRIVES BASEDONTHREE PHASE SINUSOIDAL PWM -VVVF CONTROLLER." International Journal of Communications and Engineering 4.Issue: 02 (2012): 25-30.

[22] ali, A.Nazar. "A SINGLE PHASE HIGH EFFICIENT TRANSFORMERLESS INVERTER FOR PV GRID CONNECTED POWER SYSTEM USING ISPWM TECHNIQUE." International Journal of Applied Engineering Research 10.ISSN 0973-4562 (2015): 7489-7496.

[23] JAIGANESH, R. "Smart Grid System for Water Pumping and Domestic Application using Arduino Controller." International Journal of Engineering Research & Technology (IJERT) 5.13 (2017): 583-588.

[24] Pau1l, M. Mano Raja, R. Mahalakshmi, M. Karuppasamypandiyan, A. Bhuvanesh, and R. Jai Ganesh."Classification and Detection of Faults in Grid Connected Photovoltaic System."

[25] Ganesh, Rajendran Jai, et al. "Fault Identification and Islanding in DC Grid Connected PV System." Scientific Research Publishing 7.Circuits and Systems, 7, 2904-2915. (2016): 2904-2915.

[26] Jaiganesh, R., et al. "Smart Grid System for Water Pumping and Domestic Application Using Arduino Controller." International Journal for Modern Trends in Science and Technology 3.05 (2017): 385-390.

[27] Kalavalli,C., et al. "Single Phase Bidirectional PWM Converter for Microgrid System." International Journal of Engineering and Technology (IJET) ISSN : 0975-4024 Vol 5 No 3 Jun-Jul 2013.

[28] Lilly Renuka, R., et al. "Power Quality Enhancement Using VSI Based STATCOM for SEIG Feeding Non Linear Loads. " International Journal of Engineering and Applied Sciences (IJEAS) ISSN: 2394-3661, Volume-2, Issue-5, May 2015.

[29] Karthikeyan,B. JEBASALMA. "RESONANT PWM ZVZCS DC TO DC CONVERTERS FOR RENEWABLE ENERGY APPLICATIONS ."International Journal of Power Control and Computation(IJPCSC)Vol 6. No.2 – Jan-March 2014 Pp. 82-89©gopalax Journals, Singaporeavailable at :www.ijcns.comISSN: 0976-268X.

[30] Gowri,N, et al. "Power Factor Correction Based BridgelessSingle Switch SEPIC Converter Fed BLDC

[31] Motor."ADVANCES in NATURAL and APPLIED SCIENCES. ISSN: 1995-0772 AENSI PublicationEISSN: 1998-1090 http://www.aensiweb.com/ANAS2016 March 10(3): pages 190-197.

[32] Ramkumar,R., et al." A Novel Low Cost Three Arm Ac AutomaticVoltage Regulator" ADVANCES in NATURAL and APPLIED SCIENCESISSN: 1995-0772 AENSI PublicationEISSN: 1998-1090 http://www.aensiweb.com/ANAS2016 March 10(3): pages 142-151.

[33] Kodeeswaran, S., T. Ramkumar, and R. Jai Ganesh. "Precise temperature control using reverse seebeck effect." In Power

and Embedded Drive Control (ICPEDC), 2017 International Conference on, pp. 398-404. IEEE, 2017.

[34] Subramanian, AT Sankara, P. Sabarish, and R. Jai Ganesh. "An Improved Voltage follower Canonical Switching Cell Converter with PFC for VSI Fed BLDC Motor." *Journal of Science and Technology (JST)* 2, no. 10 (2017): 01-11.

[35] Murugesan.S, R. Senthilkumar."DESIGN OF SINGLE PHASE SEVEN LEVEL PV INVERTER USING FPGA."International Journal of Emerging Technology in Computer Science & Electronics, 2016, Vol.20, No.2, pp.207-2012.

[36] S. Murugesan, C. Kalavalli, " FPGA Based Multilevel Inverter With Reduce Number of Switches For Photovoltaic System", International Journal of Scientific Research in Science, Engineering and Technology(IJSRSET), Print ISSN : 2395-1990, Online ISSN : 2394-4099, Volume 3 Issue 6, pp.628-634, September-October 2017.

[37] Vikram, A. Arun, R. Navaneeth, M. Naresh Kumar, and R. Vinoth. "Solar PV Array Fed BLDC Motor Using Zeta Converter For Water Pumping Applications." *Journal of Science and Technology (JST)* 2, no. 11 (2017): 09-20.

[38] Nagarajan, L. Star Delta Starter using Soft Switch for Low Power Three Phase Induction Motors. *Australian Journal of Basic and Applied Sciences*, *9*(21), 175-178.

[39] Vinusha, S., & Nagarajan, L. (2015). CURRENT SOURCE INVERTER FED INDUCTION MOTOR DRIVE USING MULTICELL CONVERTER WITH ANFIS CONTROL.

[40] Nagarajan, L., & Nandhini, S. (2015). AN EFFICIENT SOLAR/WIND/BATTERY HYBRID SYSTEM WITH HIGH POWER CONVERTER USING PSO.

[41] Subramanian, AT Sankara, P. Sabarish, and R. Jai Ganesh. "An Improved Voltage follower Canonical Switching Cell Converter with PFC for VSI Fed BLDC Motor." *Journal of Science and Technology (JST)* 2.10 (2017): 01-11.

[42] Compensator, D. S. (2015). AN ADAPTIVE CONTROL AND IMPROVEMENT OF POWER QUALITY IN GRID CONNECTED SYSTEM USING POWER ELECTRONIC CONVERTERS.

[43] Sabarish, P., Sneha, R., Vijayalakshmi, G., & Nikethan, D. (2017). Performance Analysis of PV-Based Boost Converter using PI Controller with PSO Algorithm. *Journal of Science and Technology (JST)*, *2*(10), 17-24.

[44] T.Vishnu Kumar, V. Suresh Kumar, T. Sumeet, M.Srimaha “Hybrid Front end Interface DC-DC Converter with ANFIS Based Control of EMS System”. International Journal of Scientific Research in Science and Technology, Volume 3, Issue 8, Print ISSN: 2395-6011, 2017.

[45] T. Vishnu kumar, V. Suresh Kumar, A new approach to front end interface DC-DC converter” International Journal of Multidisciplinary Research and Modern Education (IJMRME) ISSN(online): 2454-6119 Volume I, Issue II, 2015

[46] V.Suresh kumar, T. Vishnu kumar, A certain investigation for the battery charging system” International Journal of Multidisciplinary Research and Modern Education (IJMRME) ISSN(online): 2454-6119 Vol.1 Issue.1 2015.

[47] S.Enimai, S.Jayanthi, T.Vishnu kumar Isolated Power System Design Using Modified P&O Technique” Middle-East Journal of Scientific Research 24 (S2): 150-156, 2016, ISSN 1990-9233