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Five Phase DSTATCOM with Fuzzy Controller for Industrial and Domestic Applications

K. P. Prasad Rao, P. Srinivasa Varma, RBR Prakash

Abstract*: *To attain good products from the industry, industry required the quality of power and efficiency of the systems like machines, lighting system and other equipments. This power quality problems are going to mitigate by the FACTS devices or controllers. The problems like voltage sag (Power Quality) because of the load increases suddenly, voltage swell because of load decreases suddenly may happened. In this paper, sag of voltage as a quality problem in power system arises, since of sudden amplified the load and it is going to mitigate with Static Synchronous Compensator (STATCOM).

Index Terms*: *DSTATCOM, Ten Pulse VSC, Fuzzy Logic Controller.

I. INTRODUCTION

The Indian economy has been growing at a fast, since the beginning of this millennium. Foreign direct investments in India by many leading multinational organizations, especially in automobile manufacturing and information technology, have resulted in an accelerated need for additional power. Hence, there is a need for rapid growth of the power generation sector. However, due to constraints in the availability of fuel and environmental concerns, the power generation sector has not kept speed with other industrial sectors. One way of increasing the power availability is by reducing the high losses in the existing power transmission and distribution systems. In addition, here is a demand for high quality power from customers for custom power devices. Compensation for reactive power plus unbalance into the power distribution system are key factors in improving the power quality to the end user. Excessive reactive power in the system increase feeder losses and reduce the active power flow capability of the distribution system but unbalance affect the action of generators plus transformers in the system. DTATCOM is linked parallel to load at the pcc as a custom power device injects the reactive component based current to nullify the PQ problems.

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*Correspondence Author(s)
K. P. Prasad Rao, Department of Electrical and Electronics Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, INDIA.
P. Srinivasa Varma, Department of Electrical and Electronics Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, INDIA.
R. B. R. Prakash, Department of Electrical and Electronics Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, INDIA.

II. SYNCHORONOUS COMPENSATOR (STATCOM)

In this, the principle of working of a DSTATCOM is explained and its mathematical model is derived. Regulating reactive power and regulating voltage at the bus is going to supply with STATCOM by comparing with synchronous condenser. The corresponding model circuit of a synchronous condenser be exposed here figure. 1.

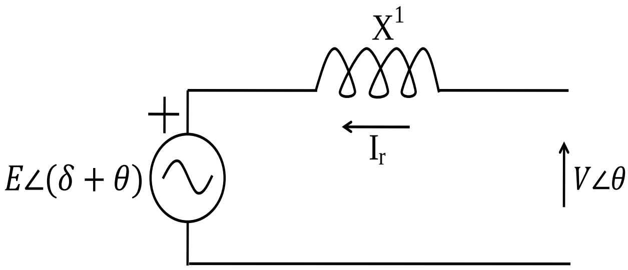

Fig. 1: A Synchronous Condenser

Regulated AC source, which the voltage amplitude is modified by varying the current in field. Loss will not taken in to account, the phase angle difference can be assumed to be zero, between the generator and the bus voltages.

By regulating the amplitude of AC source, the reactive current injected with synchronous condenser can be regulated.

E = V, the reactive current output is '0'.

E > V, the SC acts as a capacitor.

E < V, the SC acts as an inductor.

δ = 0, the reactive current drawn (Ir) is given by

$$I_r = \frac{(V-E)}{X'} \qquad (1)$$

Similarly a STATCOM has corresponding circuit as of SC. The voltage of AC is straightforwardly relative to the voltage of DC voltage (Vdc) diagonally the capacitor. If an energy source is in attendance on the DC part, the voltage Vdc detained constant.

III. A SIMPLE ANALYSIS OF A 5-PH, TEN SWITCHES STATCOM

The ten IGBT based STATCOM is shown in figure: 2. Within ten steps the total circuit operation will be explained. In step-1, ωt is in between 0 and π/5, conducting the switches 1, 7, 8, 9, 10. Every one of impedances are similar as well as Z1, Z4, Z5 be similar having +ve signal and Z2, Z3 be similar having –ve signal. There are in series each other explained as two combinations in above.

In steady state analysis which is a simple to understand the operation of STATCOM, we assume that

(i) Infinite size of capacitor with that assumes the constant DC voltage.

(ii) Neglecting the losses.

The voltages $E_{an}, E_{bn}, E_{cn}, E_{dn}$ and E_{en} are to be obtain as of the equations below:

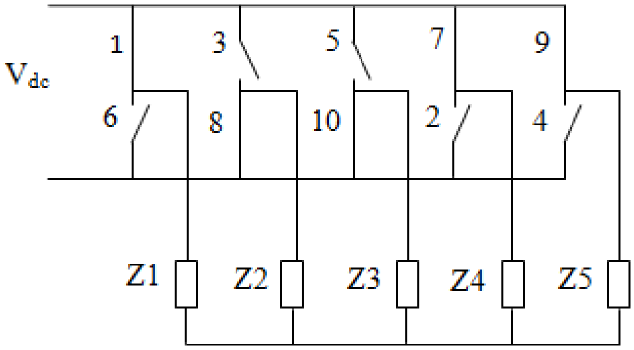

Fig. 2: A Ten Pulse VSC Circuit

$$E_{an} = E_{aN} + V_{Nn} \quad (2)$$

$$E_{bn} = E_{bN} + V_{Nn} \quad (3)$$

$$E_{cn} = E_{cN} + V_{Nn} \quad (4)$$

$$E_{dn} = E_{dN} + V_{Nn} \quad (5)$$

$$E_{en} = E_{eN} + V_{Nn} \quad (6)$$

If the circuit is symmetry

$$E_{an} + E_{bn} + E_{cn} + E_{dn} + E_{en} = 0 \quad (7)$$

from the above all equations

$$E_{aN} + E_{bN} + E_{cN} + E_{dN} + E_{eN} + 5V_{Nn} = 0$$

$$V_{Nn} = -\frac{E_{aN} + E_{bN} + E_{cN} + E_{dN} + E_{eN}}{5} \quad (8)$$

and

$$E_{an} = \left(\frac{5E_{aN} - E_{aN}}{5}\right) - \left(\frac{E_{bN}}{5}\right) - \left(\frac{E_{cN}}{5}\right) - \left(\frac{E_{dN}}{5}\right) - \left(\frac{E_{eN}}{5}\right)$$

$$E_{an} = \left(\frac{4E_{aN}}{5}\right) - \left(\frac{E_{bN}}{5}\right) - \left(\frac{E_{cN}}{5}\right) - \left(\frac{E_{dN}}{5}\right) - \left(\frac{E_{eN}}{5}\right) \quad (9)$$

similarly

$$E_{bn} = \left(\frac{4E_{bN}}{5}\right) - \left(\frac{E_{cN}}{5}\right) - \left(\frac{E_{dN}}{5}\right) - \left(\frac{E_{eN}}{5}\right) - \left(\frac{E_{aN}}{5}\right) \quad (10)$$

$$E_{cn} = \left(\frac{4E_{cN}}{5}\right) - \left(\frac{E_{dN}}{5}\right) - \left(\frac{E_{eN}}{5}\right) - \left(\frac{E_{aN}}{5}\right) - \left(\frac{E_{bN}}{5}\right) \quad (11)$$

$$E_{dn} = \left(\frac{4E_{dN}}{5}\right) - \left(\frac{E_{eN}}{5}\right) - \left(\frac{E_{aN}}{5}\right) - \left(\frac{E_{bN}}{5}\right) - \left(\frac{E_{cN}}{5}\right) \quad (12)$$

$$E_{en} = \left(\frac{4E_{eN}}{5}\right) - \left(\frac{E_{aN}}{5}\right) - \left(\frac{E_{bN}}{5}\right) - \left(\frac{E_{cN}}{5}\right) - \left(\frac{E_{dN}}{5}\right) \quad (13)$$

The fundamental component frequency in terms of rms of E_{an} is

$$E_{a1} = \frac{4}{\pi\sqrt{2}}\left[\int_{0}^{\pi/5} \frac{V_{dc}}{2.5}\sin\omega t + \int_{\pi/5}^{2\pi/5} \frac{V_{dc}}{1.665}\sin\omega t + \int_{2\pi/5}^{\pi/2} \frac{V_{dc}}{2.5}\sin\omega t\right] \quad (14)$$

$$E_{a1} = 0.45V_{dc}$$

The component of harmonic is obtain as

$$E_{ah} = \left(\frac{E_{a1}}{h}\right) = \left(\frac{(0.45 * V_{dc})}{h}\right), h = 6k \pm 1, k = 1,2,3,...$$

The rms of the primary element of current i.e., reactive current, Ir be designed

$$I_r = \left(\frac{V - 0.45V_{dc}}{\omega L}\right) \quad (15)$$

The harmonic current in terms of rms be obtain when

$$I_h = \left(\frac{(0.45 * V_{dc})}{(h^2 * \omega * L)}\right) \quad (16)$$

The waveform of E_{an} is shown in figure: 3.

IV. FUZZY LOGIC CONTROLLER

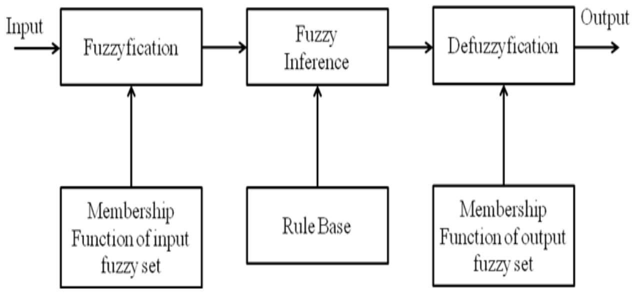

Fig. 4: Schematic diagram of Fuzzy controller

Fig. 4, shows the block diagram or processes flow diagram of fuzzy controller. In fuzzyfication stage inputs are to be analyzed and weights to be updated which are available in between input layer to the hidden layer. Fuzzy inference stage, the rules formation takes place based on and, or and and-or based with different types of operators like mamdani, centroid, etc as a member ship functions. Defuzzyfication stage, the outputs from the fuzzy inference, converting into crisp values to numerical values based on these controlling of the system depends. The rules matrix which 5 X 5, illustrated in Appendix.

V. MATLAB SIMULATION, RESULT AND DISCUSSION

Five Phase DSTATCOM which is going to be compensate the power quality problem like sag of voltage in the 5-Ph distribution is shown in fig. 5. In fig. 6, voltages at load waveform when the sag is happen in the system with healthy condition the voltage is equal to 400V and unhealthy condition the voltage is equal to 320V. As per the IEEE standard the sag is in between 10% to 90% of its rated voltage.

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Angle in Degrees	0^0	36^0	72^0	108^0	144^0	180^0	216^0	252^0	288^0	324^0	360^0
Leg-1	S1					S6					
Leg-2	S8		S3					S8			
Leg-3	S10				S5				S10		
Leg-4	S7	S2					S7				
Leg-5	S9		S4						S9		
Conduction period	Step-I	Step-II	Step-III	Step-IV	Step-V	Step-VI					
	$0 \leq \omega t < \pi/5$	$\pi/5 \leq \omega t < 2\pi/5$	$2\pi/5 \leq \omega t < 3\pi/5$	$3\pi/5 \leq \omega t < 4\pi/5$	$4\pi/5 \leq \omega t < \pi$	$\pi \leq \omega t < 6\pi/5$					
	1,8,10, 7,9	1,8,10, 2,9	1,3,10, 2,9	1,3,10, 2,4	1,3,5, 2,4	6,3,5, 2,4					

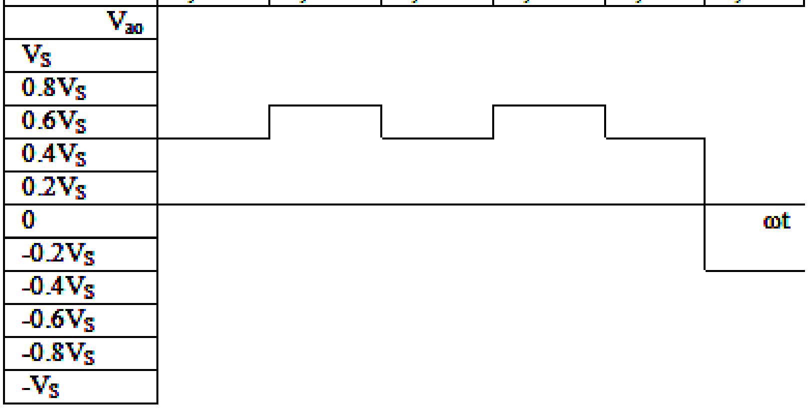

Fig. 3: Output waveform of Five Leg Inverter Phase – A.

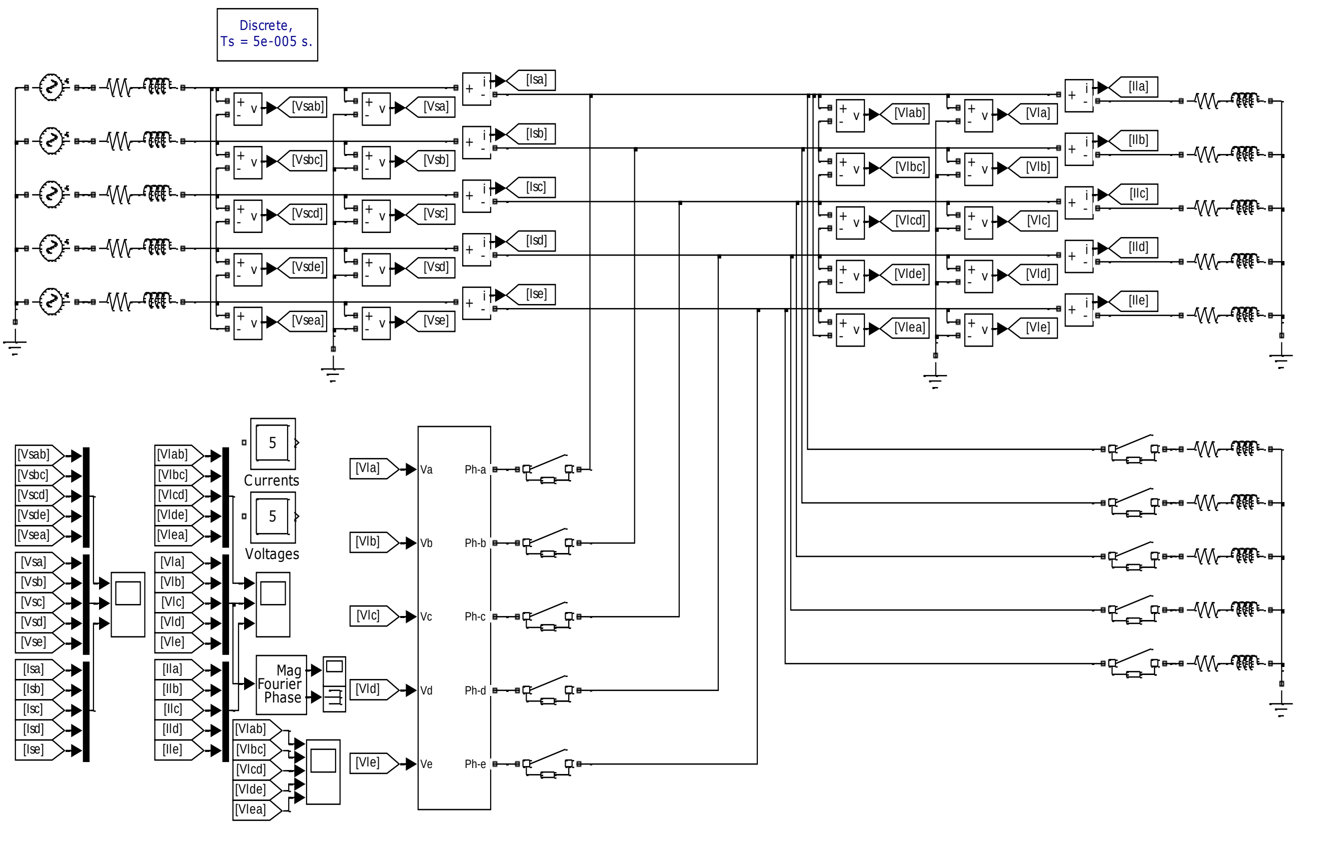

Fig. 5: MATLAB Simulink model (Five Phase DSTATCOM)

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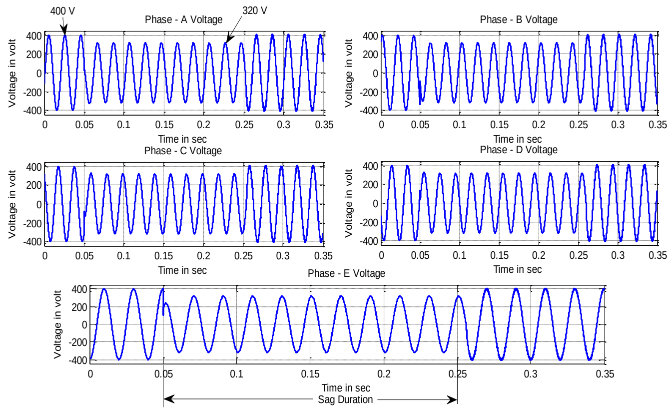

Fig. 6. Voltages under power quality problem

Fig. 7, represents the voltage waveform after cleared the sag in the load voltages and the value is equal to 400V in all the phases after introduce the reactive current in to the system.

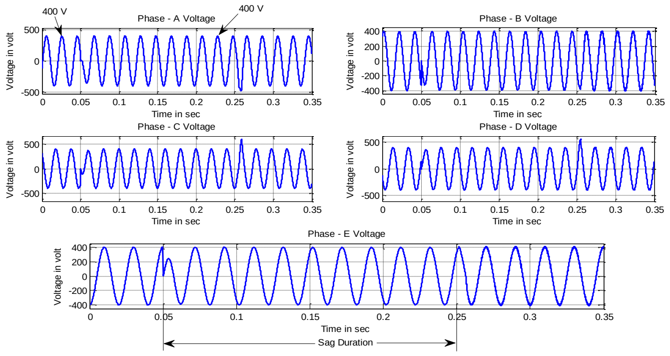

Fig. 7. Voltages without power quality problem

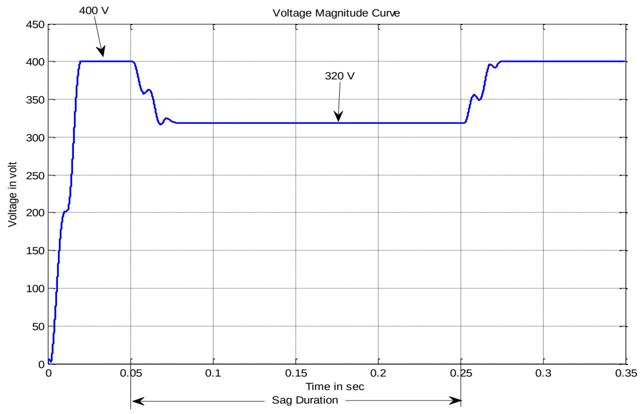

Fig. 8. Level of voltage with PQ problem

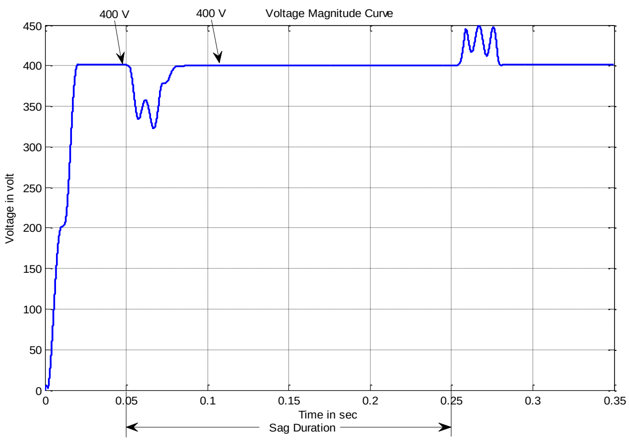

Fig. 9. Level of voltage without PQ problem

Fig. 8, shows, magnitude of the voltage when the system is in power quality problem because of sudden change in the load. Normally the load is supplied by the 400V and once sag is occurred with sudden change in load, the voltage is equal to 320V. Fig.9, shows the magnitude of the voltage waveform in term of 400V before the sag happened and after the sag happened. It is possible with the help of DSTATCOM.

VI. CONCLUSION

Industry and domestic required the quality of power and efficiency of the systems like machines, lighting system and other equipments. The power quality problems are mitigate by the FACTS devices or controllers. If the load is suddenly increased or raised then sag of voltage appear and then finally mitigate with the help of DSTATCOM. The controller is Fuzzy logic controller used to mitigate the sag of voltage by controlling the switching operation of the DSTATCOM.

APPENDIX

Table 1: System Data used in Simulation

Parameters	Values
System Frequency	50Hz
Carrier frequency	2000Hz
Voltage of the load	420V
Voltage at DC bus	50V
Inductance & Capacitance of the Filter	2.25mH & 2.75μF
Load - 1	10 KW & 100 VAR
Load - 2	15 KW & 10 VAR

Table 2: Fuzzy Rule Matrix

		Error in Load Voltage				
		Negative Big (N B)	Negative Small (N S)	Zero (Z)	Positive Small (P S)	Positive Big (P B)
Derivative Error in Load Voltage	Negative Big (N B)	N B	N B	N B	N S	Z
	Negative Small (N S)	N B	N B	N S	Z	P S
	Zero (Z)	N B	N S	Z	P S	P B
	Positive Small (P S)	N S	Z	P S	P S	P B
	Positive Big (P B)	Z	P S	P B	P B	P B

REFERENCES

1. Atif Iqbal, Shaik Moinuddin, M.Rizwan Khan, Sk.Moin Ahmed, and Haithen Abu-Rub,A Novel Three-Phase to Five-PhaseTransformation using a special transformer connection" *IEEE Transactions on power delivering*, vol. 25, no.3, JULY 2010, p. no: 1637 –1644.
2. G. K. Singh, "Self excited induction generator research – a servy," Elect. Power syst. Res., vol. 69, pp. 107 – 114, 2004.
3. S.Singaravelu, S.Sasikumar, "A novel steady statemodeling andanalysis of six-phase self-excited induction generators forrenewable energy generation," *International Journal of Emerging Electrical Power Systems*, vol. 12 Issue 5, Article 7, 2011.

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4. G.K.Singh, K.B. Yadav, R. P. Saini, "Analysis of a saturated multiphase (six-phase) self-excited induction generator," *International Journal of Emerging Electric Power systems*, vol. 7, Issue 2, Article 5, 2006.
5. A. Zakir Husain, B. Ravindra Kumar Singh & C. Shri NiwasTiwari, "Multi-phase(6-Phase & 12-Phase)Transmission Lines:Performance Characteristics," *International Journal of Mathematics and Computers in Simulation,*Volume 1, Issue 2, 2007, pp.150 –159.
6. P.PAO LAOR, A.Isaramongkolark,T.Kulworawanichpang, "Electromagneticfield distribution of phase-sequence orientation of a doublecircuit power transmission line based on finite element method," *WSEAS Transactions on power systems*, vol. 3, Issue 10, October 2008, pp. 653-663.
7. G. K.Singh, V.PantyY.P.singh, "Voltagesourceinverter driven multiphas induction machine," Computers andElectrical Engineering 29 (2003), pp.813-834.
8. K. N. Pavithran,R. Parimelalagan & M. R Krihnamurthy,"Studies on inverter -fed five -phase induction motor drive" *IEEE Transactionson Power Electronics,* vol. 3, no. 2, April 1988, pp.224 –235.
9. FriedrichW.Fuchs, "Some diagnosismethods for voltagesource inverters in variable speed drives with induction machines a survey," 2003 IEEE, pp. 1378 – 1385.
10. Paul C.Krause, and ThomasA. Lipo, "Analysisand simplified representations of arectifier – inverterinduction motor drive," *IEEE Transactions on Power Apparatus and systems,* vol. pas – 88, no. 5, may 1969, pp. 588 – 596.
11. Edward P.Cornell, andThomasA. Lipo, "Modeling andDesign of Controlled Current Induction Motor Drive Systems," *IEEE Transactions on Industry Applications,* vol. IA-13, NO. 4, JULY/AUGUST 1977, pp. 321 - 330.
12. K. N. Pavithran, R Parimelalagan, G.Sridhara Rao, J. Holtz,Drlng, "Optimum design of an induction motor for operation with current source inverters," *IEEE PROCEEDINGS,* Vol. 134, Pt. B, No. 1, JANUARY 1987.
13. Emil Leni, MartinJones, Slobodan N. Vukosanic, and Hamid A. Toliyat, "A Novel concept of a multiphase, multimotor vector controlled drive system supplied from a single voltagesource inverter,"*IEEE Transaction on Power Electronics,* vol.19, no.2, march 2004, pp. 320 - 335.
14. Dong Liu, Jia-Q Yang, Jin Huang *, Hai-bo Jiang, "Realization of a SPWM inverter for multi-phase induction motor drives," pp. 1287 – 1290.
15. D.Casadei,M.Mengoni, G.Serra, A. Tani,L.Zarri, Bologna,Italy, "Comparisn of DifferentFault-Tolerant ControlStrategies for Seven-Phase Induction Motor Drives".
16. DrazenDujic,Martin Jones,and Emil Levi, "Analysis of Output Current-Ripple RMS in Multiphase Drives Using Polygon Approach," *IEEE Transactions on Power Electronics,* vol. 25, no. 7, JULY 2010, pp. 1838-1849.
17. A. N. Arvindan and P. Pushpakarthick, "24 - Pulse Rectifier Realization by 3 Phase to Four 3-Phase Transformation using Conventional Transformers," NPEC-2010, pp. 1 – 8.
18. Vipin Garg, BhimSingh, G. Bhuvanewsari, "A tapped star connected autotransformer based 24-pulse AC-DC converter for power quality improvement in induction motor drives," *International Journal of Emerging Electric Power Systems,* vol. 7, Issue 4, Article 2, 2006.
19. Bhimsingh, VipinGarg, Gurumoorthy Bhuvaneshwari, "A24-pulse AC-DC converter employinga pulsedoubling technique for vector-controlled induction motor drives."
20. Bhim Singh,Ganjay Gairole, "Anautotransformer – based 36 – pulse controlled AC-DC converter," *IETE Journal of research,* vol. 54,Issue 4, July-August 2008, pp. 255-263.
21. Atif Iqbal, Shaik Moinuddin, M.Rizwan Khan, Sk.MoinAhmed, and Haithen Abu-Rub, "A NovelThree-Phase to Five-Phase Transformation using a special transformer connection," *IEEE Transactions on power delivering,* vol. 25, no. 3, JULY 2010, p. no: 1637 – 1644.
22. P.C.Krause, "Analysis of electric machinery," Newyork: Mc. Graw Hill, 1986.
23. K.P.Prasad Rao,B. KrishnaVeni, D. RaviTeja, "Five LegInverter for Five Phase Supply," *International Journalof Engineering Trends and Technology*- Volume3Issue2- 2012, pp. 144 – 152.
24. DuroBasic, Jain Guo Zhu, Gerard Boardman, "Transient performance study of brushlessdoubly fed twin stator generator,"*IEEE Trans. Energy convers.,* vol. 8, no. 3, pp. 400-408, July 2003.
25. V.Krishna Kumar, V. Kamaraj, S. Jeevananthan, "Parrallel Fuzzy Logic ControllersforIndependentControl ofTwo PermanentMagnet Synchronous Motors fed by a Five Leg Inverter for Electric Vehicles", *Journal of Electrical Engineering,* Volume: 17/2017, Edition: 1.
26. K.P.Prasad Rao, P.Srinivasa Varma, "Five Phase DVR with Fuzzy Logic Controller," *Journal of Advanced Research in Dynamical and Control System*, Vol. 9. Sp- 18/ 2017.
27. K.P.Prasad Rao, P.SrinivasaVarma, "A NovelFive PhaseDSATCOM for Industrial Loads," International Journal of Engineering &Technology, 7 (1.8), 2018 56-61

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