IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Volume 10, PP 16-22

Fuzzy Logic Based DC –DC Converter: A Review

Garima Gurjar[1], Priynka Sharma[2], Sangeeta Jain[3], Rashmi Chaugle[4], Shreyashi De[5]

[1] *(Department, Of Electrical Engineering, Atharva College Of Engineering Malad (W) Mumbai)*
[2] *(Department, Of Electrical Engineering, Atharva College Of Engineering Malad (W) Mumbai)*
[3] *(Department, Of Electrical Engineering, Atharva College Of Engineering Malad (W) Mumbai)*
[4] *(Department, Of Electrical Engineering, Atharva College Of Engineering Malad (W) Mumbai)*
[5]*(Department, Of Electrical Engineering, Atharva College Of Engineering Malad (W) Mumbai)*

Abstract: *In This Paper Reviewd Différent Approach For DC-DC Converter Fuzzy Logic Based Approach Is Used For DC-DC Converters. Design Of Fuzzy Controllers Is Based On Heuristic Knowledge Of Converter Behavior, And Tuning Requires Some Expertise To Minimize Unproductive Trial And Error. The Design Of PID Control Is Based On The Frequency Response Of The Dc–Dc Converter. . The Fuzzy Logic Controller Has Been Implemented To The System By Developing Fuzzy Logic Control Algorithm. The Design And Calculation Of The Components Especially For The Inductor Has Been Done To Ensure The Converter Operates In Continuous Conduction Mode. The Design Of A Fuzzy Logic Controller Using Voltage Output As Feedback For Significantly Improving The Dynamic Performance Of Boost Dc-Dc Converter By Using MATLA On Simulink Software.*

Keywords – *Fuzzy Logic, Adaptive Fuzzy Logic Controller, Neural Network, DC-DC Converter*

I. INTRODUCTION

Power Electronic Converters Can Be Used Extensively In Personal Computers, Computer Peripherals, And Adapters Of Consumer Electronic Devices To Provide Dc Voltages By Switching Action [1]. A Power Converter Is An Electrical Circuit That Changes The Electric Energy From One Form Into The Desired Form Optimized For The Specific Load. A Converter May Do One Or More Functions And Give An Output That Differs From The Input. It Is Used To Increase Or Decrease The Magnitude Of The Input Voltage, Invert Polarity, Or Produce Several Output Voltages Of Either The Same Polarity With The Input, Different Polarity, Or Mixed Polarities Such As In The Computer Power Supply Unit. The DC To DC Converters Are Used In A Wide Range Of Applications Including Computer Power Supplies, Board Level Power Conversion And Regulation, Dc Motor Control Circuits And Much More. The Converter Acts As The Link Or The Transforming Stage Between The Power Source And The Power Supply Output. There Are Several Kings Of Converters Based On The Source Input Voltage And The Output Voltage And These Falls Into Four Categories Namely The AC To DC Converter Known As The Rectifier, The AC To AC Cyclo-Converter Or Frequency Changer, The DC To DC Voltage Or Current Converter, And The DC To AC Inverter . Dc-Dc Converter Is Widely Used For Traction Motor In Electric Automobiles, Trolley Cars, Marine Hoists, And Forklift Trucks. They Provide Smooth Acceleration Control, High Efficiency, And Fast Dynamic Response. General Idea Of Dc-Dc Converter Is To Convert A Fixed Voltage Dc Source Into A Variable Voltage Dc Source. One Of The Key Difficulties In Control Of Non-Inverting Buck-Boost Topology Is The Smooth Transition From Buck To Boost Operation Or Boost To Buck Operation, Depending On The Input/Output Voltage Relationship. Design And Implementation Of A Control System Require The Use Of Efficient Techniques That Provide Simple And Practical Solution In Order To Fulfill The Performance Requirement Despite The System Disturbances And Uncertainties.

A. DC- DC CONTROLLER

DC-To-DC Converters Have Been Dominating Controlled By Analogue Integrated Circuit Technology And Linear System Control Design Techniques. In Recent Years, With Rapidly Development Of Advanced High-Speed Digital Circuits, Digital Control Will Slowly Replace The Currently Used Analogue Controller In High Frequency Switching Converters. The Intelligent Power Supplies Are Expected To Play An Important Role In Aerospace, Communication, And Automobile Industries In The Near Future. Conventionally, PI, PD And PID Controller Are Most Popular Controllers And Widely Used In Most Power Electronic Closed Loop Appliances However Recently There Are Many Researchers Reported Successfully Adopted Fuzzy Logic Controller (FLC) To Become One Of Intelligent Controllers To Their Appliances. With Respect To Their Successful Methodology Implementation, Control Closed Loop Boost Converter And Opened Loop Boost Converter Will Compare The Efficiency Of The Converters. This Kind Of Methodology Implemented In This Paper Is Using Fuzzy Logic Controller With Feedback By Introduction Of Voltage Output Respectively. The

Introduction Of Voltage Output In The Circuit Will Be Fed To Fuzzy Controller To Give Appropriate Measure On Steady State Signal. The Fuzzy Logic Controller Serves As Intelligent Controller For This Propose. [1]This Methodology Can Be Easily Applied To Many Dc-Dc Converter Topologies Such As Buck, Boost And Buck-Boost.

B. FUZZY LOGIC

Fuzzy Logic Idea Is Similar To The Human Being's Feeling And Inference Process. Unlike Classical Control Strategy, Which Is A Point-To-Point Control, Fuzzy Logic Control Is A Range-To-Point Or Range-To-Range Control. The Output Of A Fuzzy Controller Is Derived From Fuzzifications Of Both Inputs And Outputs Using The Associated Membership Functions. A Crisp Input Will Be Converted To The Different Members Of The Associated Membership Functions Based On Its Value. [18] From This Point Of View, The Output Of A Fuzzy Logic Controller Is Based On Its Memberships Of The Different Membership Functions, Which Can Be Considered As A Range Of Inputs Fuzzy Logic Techniques Have Been Widely Applied In All Aspects In Today's Society. To Implement Fuzzy Logic Technique To A Real Application Requires The Following Three Steps:

1. Fuzzifications – Convert Classical Data Or Crisp Data Into Fuzzy Data Or Membership Functions (Mfs)
2. Fuzzy Inference Process – Combine Membership Functions With The Control Rules To Derive The Fuzzy Output
3. Defuzzification – Use Different Methods To Calculate Each Associated Output And Put Them Into A Table: The Lookup Table. Pick Up The Output From The Lookup Table Based On The Current Input During An Application.

C. FUZZY LOGIC CONTROLLER

Analytical Studies On Transient Response, Stability And Reliability Gives Dynamical Performance Of Conventional Proportional Integral Derivative (PID) Controllers In Normal Operating Conditions. However, The Capacity Of Conventional Controllers Is Significantly Reduced When Applied To Systems With Non-Linarite. Fuzzy Systems Can Improve The Performance Of Conventional Proportional Integral Derivative (PID) Controllers. A Number Of Approaches Have Been Proposed And Implemented Fuzzy Control Systems For Controlling The Process. The Aim Of Incorporating Fuzzy Techniques In Process Control Systems Is To Get Ahead Of The Limits Of Conventional Techniques And To Improve The Existing Tools By Optimizing The Dynamical Performances. Fuzzy Control Is A Versatile And Effective Approach To Deal With Non-Linear And Uncertain System. [16]

A Fuzzy Control Process Can Be Performed By Fuzzifications, Fuzzy Inference And De-Fuzzification Components As Shown In Figure 1

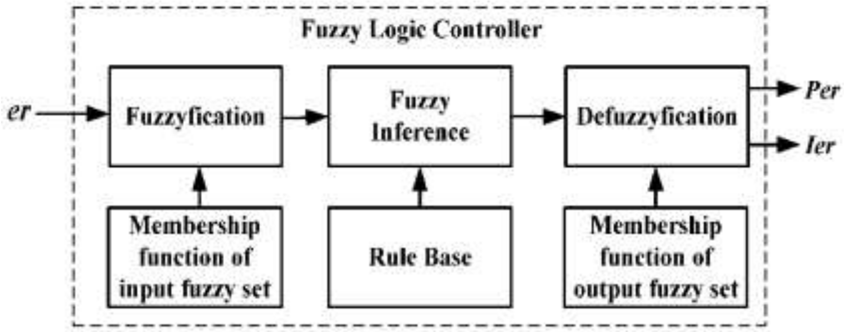

Figure 1: Schematic Of Fuzzy Logic Control.

D. PID CONTROLLER

PID Controllers Are The Most Popular Controller System Used In Industries, Robust PID Controller Gives More Robust Output Than Classical PID Controller [9]. Their Parameters Are Tunned According To The Instability And Delay Induced By Networked System And Creates A Safety Margin In Terms Of Phase And Gain Margins. In PID Controller There Are Some Parameters That That Are Used For Tuning Methods And Methods As Well That Are Proposed By Various Researchers Practically And Theoretically And They Can Be Summarized As Follows. A. Tuning Parameters Various Research Papers Defines Various Terms That Are Used To Stabilize Or Set The System To Near Steadied Condition, These Terms Are The Tuning Parameters. The Basic Parameters That Defines The Characteristics Of PID Controller Can Be Written As:

PID(S, K) = (KI + KP S+ Kds 2) / S (1 + Trs) ---- (1)

G(S,L,Q) = [A(S, Q) / R(S, Q)] E−Sl -----(2)
Where K = (KI, KP, KD) T Are The Controller Parameters
. L And R = Plants Parameters (L>0)

The Characteristic Function Of The Loop:- P(S,K,L,Q)=(KI + KP S+ Kds 2) A(S,Q) + S (1 + Trs)R(S,Q)E−Sl

Some Researchers Like Hohenbitchler And Ziegler Nichols Uses Gain And Phase Margins To Find The Stability Regions. B. Common Methods Tuning Rules Are Originally Based On Controller Parameters And Originally Proposed By Ziegler And Nichols (1942), They Uses The Tangent Method To Determine The Parameters. The Graphical Methods Are Also Proposed By Shinskey In 2001 And Hay By 1998. Another Tuning Rule Can Be Named As "Ultimate Cycling Tuning Rule" That Can Be Formed By Gains Of Controller And Period Of Oscillation Period At Ultimate Frequency, Such Model Is Firstly Proposed In 1942 By Ziegler Nochols [19]. The Other Model That Is Based On Gain And Phase Margin In IPD Form Was Given By KOOKOS Et Al. 1999. Tuning Rules That Are Based On Direct Synthesis Uses Frequency Domain Techniques. HO And Xu 1998 WANG And CAI 2002 Describe Such System For Stable And Unstable Systems. In Fine Tuning The Individual Values Of Kp, Ki, And Kd Are Fine-Tuned Until Acceptable Output Obtained. Some Other Methods That Are Studied By The Researchers Are "Chin, Hornes And Reswick Method", "Lambda Tuning Method", "Direct Tuning Methods" Iterative Methods Can Be Used As Manual Tuning Which Is Very Appropriate Method Where Compensator Parameters May Be Achieved Experimentally That's Why It Is Called Manual Tuning. However, Such Methods Are Time Intense And The Steps Of Processes Has To Follow Its Stability Limit [17].

II. Literature Review

Case Study 1. PID Controller

In This Author Has Shown, Digital PID Type And Fuzzy-Type Controllers Are Compared For Application To The Buck And Boost Dc–Dc Converters. Comparison Between The Two Controllers Is Made With Regard To Design Methodology, Implementation Issues, And Experimentally Measured Performance. Design Of Fuzzy Controllers Is Based On Experimental Knowledge Of Converter Performance, And Tuning Requires Some Expertise To Minimize Unproductive Trial And Error. The Design Of PID Control Is Based On The Frequency Response Of The Dc–Dc Converter. Implementation Of Linear Controllers On A Digital Signal Processor Is Direct, But Realization Of Fuzzy Controllers Increases Computational Burden And Memory Requirements. The Fuzzy Controller Was Able To Achieve Closer Transient Response In Most Tests, Had A More Stable Steady-State Response, And Was More Robust Under Some Operating Conditions. In The Case Of The Buck Converter, The Fuzzy Controller And PID Controller Produced Comparable Performances [8]. Design And Implementation Issues And Experimental Results For The PID And PI Controllers And Fuzzy Controller Were Compared. The Design Of Linear Controllers And Fuzzy Controllers Required Quite Different Procedures. Design Of The Fuzzy Controller Did Not Need A Mathematical Model, While A Small Signal Model Was Necessary For The Design Of PID Controllers Using Frequency Response Methods.

Case Study II Fuzzy Controller

This Paper Presents An Implementation Of A Fuzzy Controller For Dc–Dc Converters Using An Inexpensive 8-B Microcontroller. An "On-Chip" Analog-To-Digital (A/D) Converter And PWM Generator Eradicate The External Components Needed To Perform These Functions. Implementation Issues Comprise Limited On-Chip Program Memory Of 2 Kb, Unsigned Integer Arithmetic, And Computational Delay. Another Important Result Is That The Same Microcontroller Code, Without Any Modifications, Can Control Both Converters Because Their Behavior Can Be Described By The Same Set Of Linguistic Rules [7]. The Contribution Shows That A Nonlinear Controller Such As Fuzzy Logic Can Be Inexpensively Implemented With Microcontroller Technology. The Fuzzy Controller Is Able To Regulate The Output Voltage Of Buck Or Boost Configurations To A Desired Value Without Steady-State Oscillations Despite Change In Load Or Input Voltage. Since Both Buck-Boost Converters Are Controlled Using The Same Fuzzy Control Algorithm, This Shows That The Fuzzy Controller Is Developed Based On The Semantic Description Of The System And Not The Authors Have Described A Fuzzy-Logic Based Controller For Dc–Dc Converter Output Voltage Control, Implemented On An Inexpensive 8-B Microcontroller. Modifications Are Made To A Well-Known Fuzzy Control Algorithm To Meet The Challenges Of Programming The Microcontroller For Real-Time Feedback Control [15]. The Experimental Results Show That The Implementation Of A Fuzzy-Based Control Algorithm On A Microcontroller Platform Is Feasible For The Dc–Dc Converter Application. The Fuzzy Controller Is Able To Regulate The Output Voltage Of Buck Or Boost Configurations To A Desired Value Without Steady-State Oscillations Despite Change In Load Or Input Voltage. Both Buck-Boost Converters Are Controlled Using The Same Fuzzy Control Algorithm (Without Any Modifications To The Program), This Shows That The Fuzzy Controller Is Developed Based On The Linguistic Description Of The System And Not Its Mathematical Model.

The Paper Also Shows That Control Schemes Like Fuzzy Logic Can Be Implemented To Control Dc–Dc Converters Without Using Expensive Digital Signal Processors Or Specialized Hardware [3]

Case Study III Basic PWM Buck Converter

The Proposed PWM Buck Converter With DCM Operation Not Only Can Reach High Efficiency In Heavy-Load (Over 95% At 100 Ma Loading), But Also Has Great Improvement In Light-Load Efficiency (36.14% Higher Than The Conventional PWM Converter At 10 Ma Loading) Without Using Any PFM Techniques. The Output Accuracy And The Output Ripples Are Better Than PFM Converters Under Light-Load, And As Good As A Normal PWM Converter Under Heavy-Load. The Proposed PWM Converter Is Designed At 1.8 V Supply And IV Output Voltage, And The Maximum Output Power Is 500 Mw. Maintain High Efficiency Under A Wide Loading Range Is Important In Extending The Battery Life. For Some Applications Like Cell Phones, The System Works Under Heavy-Load Only When It Is Communicating, And The System Mostly Works Under Light-Load When It Is Standby. Thus, It Is Not Enough That Converters Are High Efficient Only Under Heavy-Load Or Light-Load.[11] Several Techniques Were Proposed To Achieve This Requirement, And A Dual-Mode (PWM+PFM) Converter Is The Most Widely Used Technique In Different Applications.

***Ca*se Study IV. Zero-Voltage-Transition PWM Buck Converter**

In This Family Of Converters, Zero-Voltage-Switching (ZVS) Condition Is Attained For The Main And Rectifier Switches. Also, Zero-Current Switching Is Achieved For The Auxiliary Switch. In Addition, The Applied ZVS Technique Can Eliminate The Reverse Recovery Losses Of The Rectifier Switch Body Diode. The ZVT Buck Converter With SR Is Analyzed, And The Presented Experimental Results Confirm The Theoretical Analysis.[2]

Case Study V Integral T–S Fuzzy Control

In This Paper, Author Propose A T–S Fuzzy Controller Which Combines The Merits Of: I) The Capability For Dealing With Nonlinear Systems; Ii) The Powerful LMI Approach To Obtain Control Gains; Iii) The High Performance Of Integral In This Paper, We Propose A T–S Fuzzy Controller Which Combines The Merits Of: I) The Capability For Dealing With Nonlinear Systems; Ii) The Powerful LMI Approach To Obtain Control Gains; Iii) The High Performance Of Integral Controllers; Iv) The Workable Rigorous Proof For Exponential Convergence Of Error Signals; And V) The Flexibility On Tuning Decay Rate. Controllers; Vi) The Workable Rigorous Proof For Exponential Convergence Of Error Signals; And V) The Flexibility On Tuning Decay Rate. An Interesting Result Is That The Obtained Control Law Is Formed Only By The Linear State Feedback Signals Weighted By Grade Functions. [5]

Integral Fuzzy Control Is Proposed To Achieve Output Regulation. For The Sake Of Easy Application, We Mainly Focus On The Derivation Of The Reduced Control Law And Its Stability Analysis [6]. Compared To The Local Stability For Typical Nonlinear Integral Control, The Exponential Stability Holds In A Large Region. The Proposed Integral Fuzzy Controller Has Been Applied To The Basic Buck Converter And The ZVT Buck Converter, Where The State Equations Are With Nonlinear Input Vector And Nonlinear System Matrix, Respectively. Integral Fuzzy Control Is Proposed To Achieve Output Regulation [14].For The Sake Of Easy Application, Author Mainly Focus On The Derivation Of The Reduced Control Law And Its Stability Analysis. Compared To The Local Stability For Typical Nonlinear Integral Control, The Exponential Stability Holds In A Large Region. The Control Gains Are Obtained By Solving A Set Of Lmis And Its Robustness Due To Disturbance Is Further Analyzed In The Form Of A Criterion. The Proposed Integral Fuzzy Controller Has Been Applied To The Basic Buck Converter And The ZVT Buck Converter, Where The State Equations Are With Nonlinear Input Vector And Nonlinear System Matrix, Respectively. The Simple But Efficient Control Law Has Been Verified By Both Satisfactory Numerical Simulations And The Experimental Results [5].

Case Study VI. Adaptive Network-Based Fuzzy Control

In This Apper Author Prposed Adaptive Network Architecture, ANFIS, And A Learning Algorithm By Which The ANFIS Could Construct A Desired Input–Output Plotting Are Proposed.[10] The Basic Structure Of A Converter Topology With Adaptive Network Architecture Is Given In Fig. 2 The Converter Is Represented By A “Black Box” From Which We Only Extract The Terminals Corresponding To The Input Voltage (Vi), Output Voltage (Vo), And Controlled Switch (S). From These Measurements, ANFIS Provides A Signal Proportional To A Percentage Duty Cycle Signal For A Peripheral Interface Microcontroller PIC16F877 That Generates The Converter Actual Duty Cycle. A Control Topology (Fig. 2) Is Developed And Investigated[13]. Both Fuzzy Logic Principles And Learning Functions Of Neural Networks Are Employed Together To Construct The Adaptive Fuzzy. Network Inference System For The Control Topology

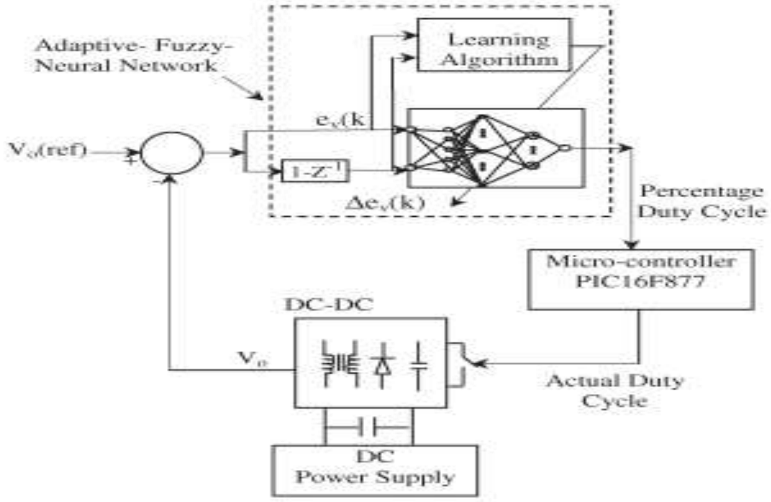

Figure 2. Structure Of Converter Topology Adaptive Network Architecture

Case Study VII **Neural-Fuzzy Controller (NFC)**

A Fuzzy–Neural Sliding-Mode (FNSM) Control System Is Developed To Control Power Electronic Converters. The FNSM Control System Comprises A Neural Controller And A Compensation Controller. In The Neural Controller, An Asymmetric Fuzzy Neural Network Is Utilized To Mimic An Ideal Controller. , To Investigate The Effectiveness Of The FNSM Control Scheme, It Is Applied To Control A Pulse Width-Modulation-Based Forward Dc–Dc Converter. Experimental Results Show That The Proposed FNSM Control System Is Found To Achieve Favorable Regulation Performances Even Under Input-Voltage And Load-Resistance Variations [20]. To Attain High-Quality Power Systems, Many Researchers Have Absorbed Their Attention On The Study Of Switching Control Techniques. Among Various Switching Control Methods, Pulse Width Modulation (PWM) Is The Most Widely Considered. For Many Years, The Controller For PWM Switching Control Is Limited To A Proportional–Integral (PI) Controller Structure. [12]The Selection Of The Controller Parameters In The PI Controller Is A Tradeoff Between Robustness And Transient Response. A FNSM Control Scheme Has Been Adopted To Control A Forward Dc–Dc Converter. The FNSM Control Using An AFNN Is Investigated To Mimic An Ideal Controller, And A Compensation [4]. The Proposed Control Algorithm Is Realized In A Pentium Personal Computer With The “Turbo C” Language. Two Experimental Cases Are Addressed As Follows: 1) The Nominal Case (The Input Voltage Is Set As Vi = 20 V) And 2) The Input Variation Case (The Input Voltage Is Changed To Vi = 25 V). In Both Cases, Some Load-Resistance Variations With Step Changes Are Tested, Namely: 1) From 20 To 4 Ω At 300 Ms;2) From 4 To 20 Ω At 500 Ms; And 3) From 20 To 4 Ω At 700 Ms. The Circuit Parameter Values Of The Forward Dc–Dc Converter Are Chosen As NP : Ns = 4 : 3, R = 20 Ω, L = 500 *M*h, And*c* = 2200 *M*f. The Converter Runs At A Switching Frequency Of20 Khz, And The Controller Runs At A Sampling Frequency Of1 Khz. The Duty Cycle Is Generated By A PWM IC SG1825;

The Generated Duty Cycle Is Directly Proportional To The Analog Output Of The Controller. First, The PI Control Scheme That Is Proposed Is Applied To The Forward Dc–Dc Converter To Compare The Regulation Efficiency.

The PI Controller Output Is Computed As

$\Delta dpd = Kpe + Kd$

Where Kp And Kd Are Designed By The Users. It Is Proportional–Differential Control For Δd, And It Can Be Regarded As PI Control For D.

TABLE I
COMPARISON OF THE CHARACTERISTICS BETWEEN PI CONTROL AND FNSM CONTROL

Controller	Nominal Case		Input Variation Case		Stability Analysis	Self-Learning Ability	Load Variation Regulation
	overshoot (%)	settling time (msec)	overshoot (%)	settling time (msec)			
PI controller with $k_p = 0.0005$ and $k_d = 0.02$	0	34	0	32	Yes	No	Low
PI controller with $k_p = 0.01$ and $k_d = 0.2$	13	14	15	16	Yes	No	High
FNSM controller	12	42	15	40	Yes	Yes	Median
Trained FNSM controller	5	27	6	26	Yes	Yes	High

A FNSM Control Scheme Has Been Adopted To Control Forward Dc–Dc Converter. The FNSM Control Using An AFNN Is Investigated To Mimic An Ideal Controller, And A Compensation Robust Controller Is Designed To Recover The Residual Of The Approximation Error. The FNSM Control-Design Method Can Online Tune The Controller Parameters Based On The Lyapunov Stability Theorem, So That The Stability Of The System Can Be Guaranteed [10]

III. CONCLUSION

In This Paper We Reviewd 21 Papers On Fuzzy Logic Based DC- DC Converter And Other Techniques Like PID Controller, Adaptive Network Based Fuzzy Control, Integral T–S Fuzzy Control, Zero-Voltage-Transition PWM Buck Converter, Zero-Voltage-Transition PWM Buck Converter In This Review Procsses We Have Observed Various Facts From Papers Which Is Summarised In Paper These Studies Could Solve Many Types Of Problems Regardless On Stability Because As We Know That Fuzzy Logic Controller Is An Intelligent Controller To Their Appliances The Paper Also Shows That Control Schemes Like Fuzzy Logic Can Be Implemented To Control Dc–Dc Converters Without Using Expensive Digital Signal Processors.

References

[1] Smith, T.A.; Dimitrijev, S.; Harrison, H.B.; "Controlling A DC-DC Converter By Using The Power MOSFET As A Voltage Controlled Resistor," Circuits And Systems I: Fundamental Theory And Applications, IEEE Transactions On, Vol. 47, No.3, Pp. 357-362, March 2000.

[2] Prashant Agnihotri, Naima Kaabouch, Hossein Salehfar, And Wen-Chen Hu," FPGA-Based Combined PWM-PFM Technique To Control DC-DC Converters", IEEE Publication.

[3] Tarun Gupta, Member, IEEE, R. R. Boudreaux, Student Member, IEEE, R. M. Nelms, Senior Member, IEEE, And John Y. Hung, Senior Member, IEEE "Implementation Of A Fuzzy Controller For DC–DC Converters Using An Inexpensive 8-B Microcontroller" IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 44, NO. 5, OCTOBER 1997

[4] Wing-Chi So, Member, IEEE, Chi K. Tse, Member, IEEE, And Yim-Shu Leeent Development Of A Fuzzy Logic Controller For C Converters: Design, Computer Ation, And Experimental Evaluation IEEE TRANSACTIONS ON POWER ELECTRONICS, VDL 11, NO. 1, JANUARY 1996

[5] Kuang-Yow Lian, Member, IEEE, Jeih-Jang Liou, And Chien-Yu Huang LMI-Based Integral Fuzzy Control Of DC-DC Converters

[6] IEEE TRANSACTIONS ON FUZZY SYSTEMS, VOL. 14, NO. 1, FEBRUARY 2006

[7] Ahmed Rubaai, Senior Member, IEEE, Abdul R. Ofoli, Student Member, IEEE, Legand Burge, III, Member, IEEE, And Moses Garuba" Hardware Implementation Of An Adaptive Network-Based Fuzzy Controller For DC–DC Converters" IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 41, NO. 6, NOVEMBER/DECEMBER 2005

[8] R. Etz* D. Petreus, D. Moga, M. Abrudean, T. Patarau "Fuzzy Digital Control For DC-DC Converters Used In Renewable Energy Systems" Elsevier Journal

[9] Liping Guo, Member, IEEE, John Y. Hung, Senior Member, IEEE, And R. M. Nelms, Fellow, IEEE "Evaluation Of DSP-Based PID And Fuzzy Controllers For DC–DC Converters" IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 56, NO. 6, JUNE 2009

[10] Bhim Singh, Senior Member, IEEE, Brij N. Singh, Member, IEEE, Ambrish Chandra, Senior Member, IEEE, Kamal Al-Haddad, Senior Member, IEEE, Ashish Pandey, Member, IEEE, And Dwarka P. Kothari, Senior Member, IEEEA Review Of Three-Phase Improved Power Quality AC–DC Converters IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 51, NO. 3, JUNE 2004

[11] Kuo-Hsiang Cheng, Chun-Fei Hsu, Member, IEEE, Chih-Min Lin, Senior Member, IEEE, Tsu-Tian Lee, Fellow, IEEE, And Chunshien Li "Fuzzy–Neural Sliding-Mode Control For DC–DC Converters Using Asymmetric Gaussian Membership Functions" IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 54, NO. 3, JUNE 2007

[12] Kuo-Hsiang Cheng, Chun-Fei Hsu, Member, IEEE, Chih-Min Lin, Senior Member, IEEE, Tsu-Tian Lee, Fellow, IEEE, And Chunshien Lichu-Hsiang Chia Pui-Sun Lei Robert Chen-Hao Chang " High-Efficiency PWM DC-DC Buck Converter With A Novel DCM Control Under Light-Load" IEEE Publication.

[13] B. Bryantand M. K. Kazimierczuk, "Voltage Loop Of Boost PWM Dc-Dc Converters With Peak Current-Mode Control," IEEE Transactions On Circuits And Systems I,Vol. 53, No. 1, Pp. 99-105, Jan. 2006.

[14] Ertan, H.B.; Simsir, N.B.; "Comparison Of PWM And PFM Induction Drives Regarding Audible Noise And Vibration For Household Applications," Industry Applications, IEEE Transactions On, Vol. 40, No. 6, Pp. 1621-1628, December2004.

[15] Man Siu; Mok, P.K.T.; Ka Nang Leung; Lam, Y. H.; Wing Hung Ki;"A Voltage-Mode PWM Buck Regulator With Endpoint Prediction," Circuits And Systems II: Express Briefs, IEEE Transactions On,Vol.53,No.4,Pp.294-298,April2006.

[16] Scharrer, M.; Halton, M.; Scanlan, T.; Rinne, K.; "FPGA Based Multi-Phase Digital Pulse Width Modulator With Dual Edge Modulation," Applied Power Electronics Conference And Exposition (APEC), 2010Twenty-Fifth Annual IEEE, Pp.1075-1080, February 2010.

[17] Rahul Malhotra1 , Narinder Singh2 , Yaduvir Singh3 "SOFT COMPUTING TECHNIQUES FOR PROCESS CONTROL APPLICATIONS" International Journal On Soft Computing (IJSC), Vol.2, No.3, August 2011.

[18] Daya Sagar Sahu#1 , Sunil Sharma , "A Survey Paper On PID Control System" International Journal Of Engineering Trends And Technology (IJETT) – Volume 21 Number 7 – March 2015.

[19] Lopez, O.; Alvarez, J.; Doval-Gandoy, J.; Freijedo, F.D.; Nogueiras, A.; Lago, A.; Penalver, C.M.; "Comparison Of The FPGA Implementation Of Two Multilevel Space Vector. PWM Algorithms," Industrial Electronics, IEEE.

[20] Vahid Yousefzadeh, Student Member, IEEE, And Dragan Maksimovic´, Member, IEEE S"Ensor Less Optimization Of Dead Times In DC–DC Converters With Synchronous Rectifiers" IEEE Transactions On Power Electronics, Vol. 21, No. 4, July 2006.

[21] E. Monmasson And M. N. Cirstea, "FPGA Design Methodology For Industrialcontrol Systems—A Review," IEEE Trans. Ind Electron., Vol. 54, No. 4, Pp. 1824–1842, Aug. 2007.

[22] Nikola Milivojevic, , Mahesh Krishnamurthy, Yusuf Gurkaynak, Anand Sathyan, Young-Joo Lee, And Ali Emadi, "Stability Analysis Of FPGA-Based Control Of Brushless DC Motors And Generators Using Digital PWM Technique" IEEE Transactions On Industrial Electronics, Vol. 59, No. 1, January 2012.

BOOKS

[1] H. Daniel, Introduction To Power Electronics, Prentice Hall, October 1996.

[2] R. Erickson, And D. Maksimovic, Fundamentals Of Power Electronics, Norwell, MA: Kluwer, 2001.