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Fuzzy logic control of two switch & three switch serial input interleaved forward converters

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ABSTRACT

This manuscript manages F-L-C of "two-switch & three-switch-interleaved-forward- converters" with DC-engine-load. Numerous modern applications require DC-power. This forward-converter convert's unregulated DC-capacity to controlled DC-control. It contains high recurrence transformer which is additionally called 'isolation-transformer'. This gives disconnection among load & fundamental-circuit. The AC- control is amended utilizing half-wave-rectifier. The swell in the yield is separated utilizing pi- filter. FLC is intended for two-switch and three-switch forward-converter-systems. The simulation is completed by utilizing MATLAB-simulink. The controller execution is considered for different estimations of load-torque for both two-switch & three-switch forward-converter -frameworks.

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1. INTRODUCTION

DC to DC-converters (with disengagement) convert one DC voltage level to another, by putting away the input energy briefly and afterward discharging that energy to the yield at an alternate voltage level. The energy can be put away in the attractive field storage segments (inductors, transformers) or electric field storage parts (capacitors). "This transformation technique is more valuable-than direct-voltage-control which disperses-undesirable-power as- warmth". The aptitude is enlarged by the 'utilization of intensity-FETs', which works at high -recurrence than 'power-bipolar-transistors'. 'DC-DC-converters' are vital in convenient-electronic gadgets, for ex..,, 'phones & PC which are afforded with-power from-batteries'.

Galvanic-isolation is the standard of disengaging functional segments of electrical framework by keeping the moving of the charge conveying particles starting-with one-segment then-onto the-next, i.e. "there is electric-flow-streaming specifically starting with one-area then onto-the-next". Energy and additionally data can in any case be traded between the segments by different means e.g. "capacitance, `inductance electromagnetic-waves, `optical, acoustic/mechanical" means. Such a rule is utilized in these DC to DC converters (with isolation). Two sorts of converter with galvanic segregation are Fly back converter and Forward converter. -Forward-converter is a "switched-mode power-supply"(SM-PS) circuit that is utilized for generating-segregated & controlled-DC-voltage from the unregulated-DC input supply. Uses of these forward converters are Power supply for DC engine, Battery charging, Battery worked Electric vehicle, Telecom applications and so on.

Nowadays Electronic DC-DC converter plays an important role in the field of power electronics and control. Forward DC-DC converter has number of benefits over other DC-DC converter and forward converter becomes beneficial for high power applications. Therefore different topologies have been proposed

[1-12] for various applications. Some of those topologies are of renewable type and few of them are regenerative type. Fuzzy logic controller (FLCs) which is suitable for power system dynamic studies caused by power electronics converter. Because fuzzy logic controllers (FLCs) can handle complex systems in a simple way without knowing much about the systems mathematical model, they are widely used for a wide range of applications [13-17].

To improve the dynamic response of closed loop DC to DC forward converter system suitable Fuzzy Logic controller is used. A detailed study on time domain specifications is done between Fuzzy controlled two switch and three switch converter and the results are tabulated. In this work, the execution of FLC with two-switch and three-switch forward converter is assessed.

2. PROPOSED METHOD

The block-diagram of forward converter with FLC is appeared in Figure 1. Forward converter changes over unregulated DC capacity to controlled DC control. It contains high recurrence transformer which is additionally called isolation- transformer. This gives segregation among load and principle circuit. As the recurrence expands, the extent of the transformer diminishes. Since the transition diminishes with the expansion in the recurrence of the transformer. The power switches BJT, control MOSFET, IGBT and so on can be utilized for forward converter planning. Since the qualities of the MOSFET are quick exchanging and voltage driven, it is decided for the power exchanging in this structuring prerequisite.

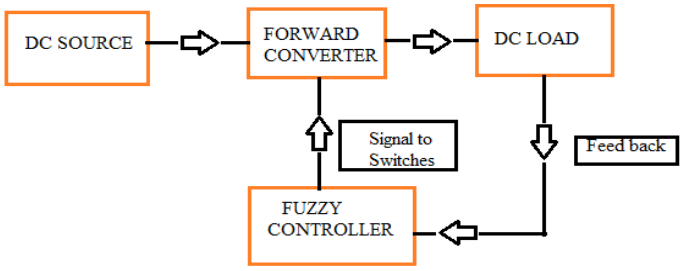

Figure 1. “Block-Diagram of Forward-Converter-system with-FLC”

2.1. DC-Load

The Yield-power is normalized by direct-current-power which can be exploited for- applications like speed-control of the motor, battery-charging, tele-communication, computers, robotics, cellular-phones, electrical-drives & other applications which requires DC- power.

2.2. Fuzzy-Controller

A FLC is a controlling-technique used to control the system, that explores input-values- FLC-system are mapped by sets-of membership functions. “Membership-purposes” can portray-realistic-complications. Membership-functions are symbolized by graphical-plots.

3. RESEARCH METHOD

3.1. Open-Loop-Controlled Three-Switch-Forward-Converter with Motor-Load

The open-loop-control of ‘three-switch-DC-DCconverter’ is summarized in Figure 2. The scopes are correlated to verify yield. An ‘input--300V dc-power’ is applied to the ‘open-loop-system’. The 3 switch-forward converter as 3-switches (T1, T2 & T3) -which-turns -on, transmit-energy-through-the-transformer-primary-into the-secondary. ‘On the-secondary, the forward- rectifying diode-conducts & conveys the energy into the yield- filter & load’. DC input- voltage is represented in Figure 3 its value is 300Volts.

Since the most fundamental necessity of DC Motor (DCM) is that it ought to pivot at the coveted speed for consistent speed applications. Another execution prerequisite for DCM is that it must quicken to its steady state speed when it turns on. Open-loop&-closed-loop-operation of the dc-motors is executed by using two-switch & three-switch-forward-converter. The speed & torque of the Open-loop controlled three-switch-forward-converter with motor-load is represented in the Figures 4 and 5. The speed settles at 1.1sec & torque settles at 0.9 sec.

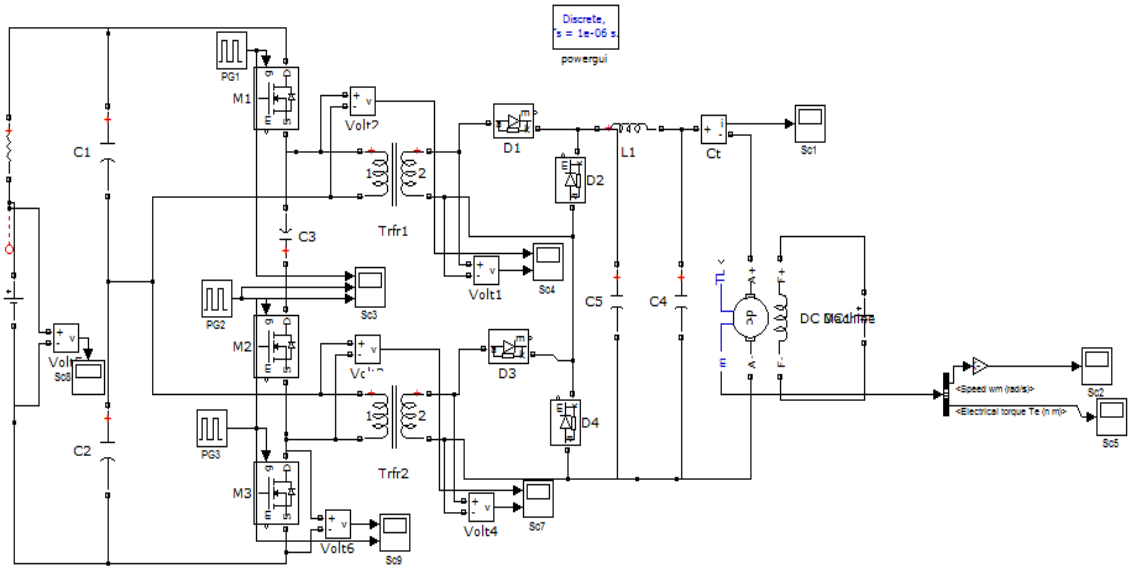

Figure 2. Open-loop control of 'three-switch forward-converter' with motor-load

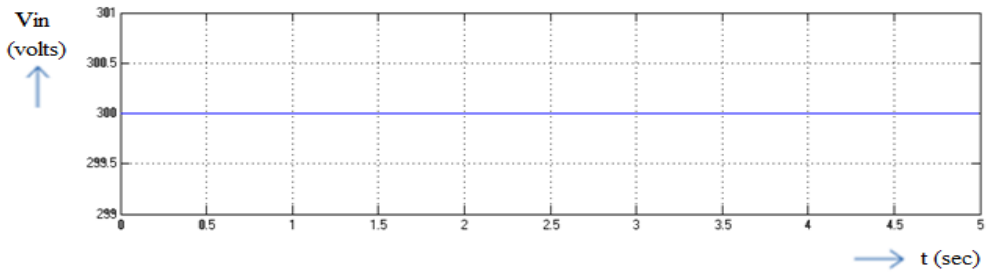

Figure 3. Input-voltage

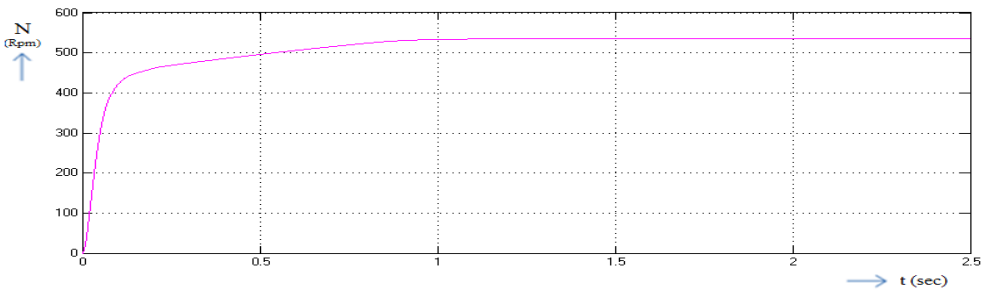

Figure 4. Motor-speed

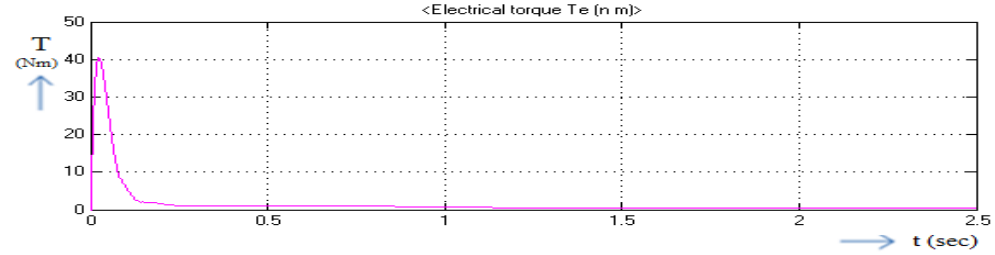

Figure 5. Motor-Torque

3.2. Closed-Loop-Controlled-Three Switch-Forward-Converter with-FL-Controller

FLC have additional benefits when evaluated to additional classical-controller like simplicity of control, little price & the possibility to plan. The FLC is intended to control motor- speed by utilizing error & its change. Forward converter have nonlinear trademark because of the parasitic components, polarizing inductance of the transformer and due-switching of the converter. With the end goal to defeat this disadvantage the structure of FLC is presented. FLC is a basic control technique comprises of fuzzy-sets that permit partial enrollment and "if, then" rules, to take care of a control issue. The FLC comprises of Fuzzifier, Decision making device and Defuzzifier. In which Fuzzifier changes over information into linguistic qualities, Decision making device comprises manage base i.e. control rules and the linguistic factors and the Defuzzifier changes over control activities in to crisp signals which can be connected to signal-comparator. The execution of the driver framework was assessed. Figure 6 delineates the closed-loop controlled three-switch forward-converter with FLC.

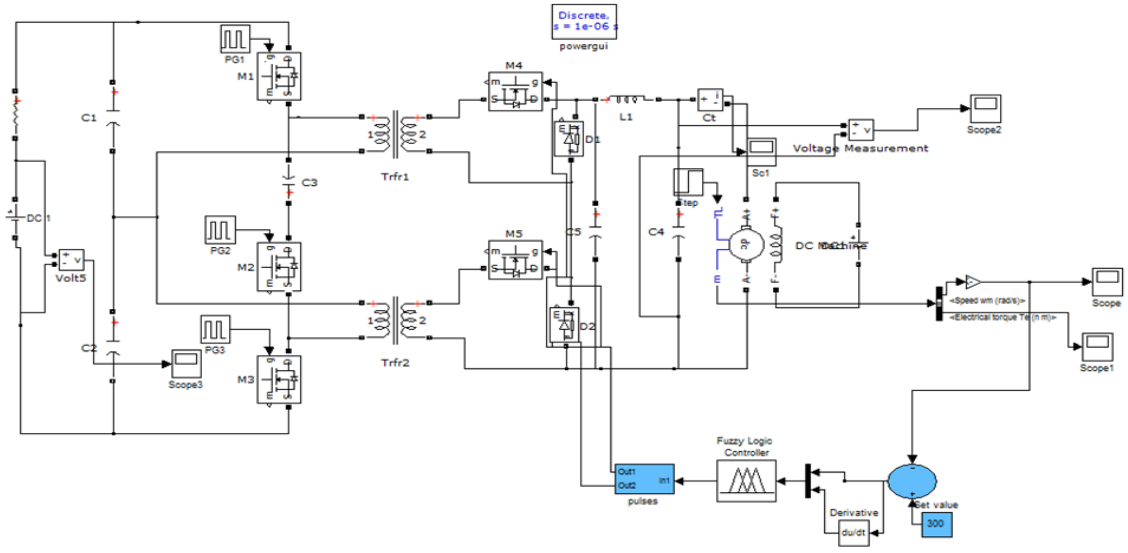

Figure 6. Closed-loop-controlled three-switch forward-converter with FLC

Fuzzy controllers are intended to conform to changing working focuses. FLC is intended to control the speed of the DC engine with the set esteem i.e. 300 RPM utilizing Mamdani style fuzzy-inference-framework. The triangular participation capacities are picked at end focuses to think about varieties in information and yield factors. For the inputs same membership functions are picked and are appeared in Figure 7. A membership-function is a plot that characterizes the info space mapping to a membership-value somewhere in the range of 0 and 1. The guidelines utilize the info enrollment esteems as weighting components to decide their impact on the fuzzy yield sets of the last yield end. When the capacities are depicted, scaled, and joined, they are defuzzified into a fresh yield. Here, FIS type is mamdani, FIS name is tuty, two information variable and one yield variable is utilized. Figure 7 demonstrates the input-variables & output- variable.

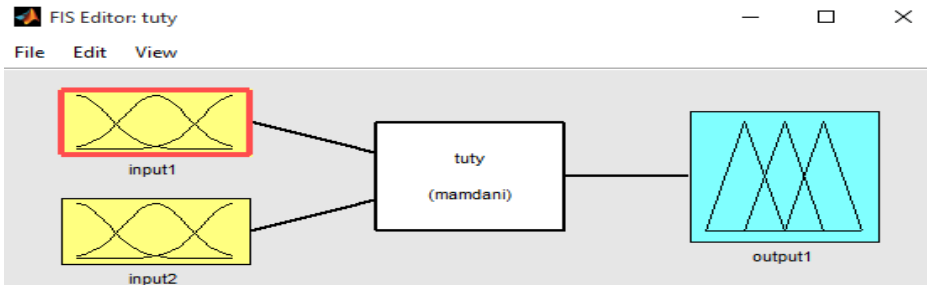

Figure 7. Input-variables & output-variable

Figure 8 represents the 'membership-functions of input-variable-1'. Figure 9 symbolizes-the 'membership-functions of the-input-variable-2'& Figure 10 symbolizes the 'membership-functions of-the-output-variable.

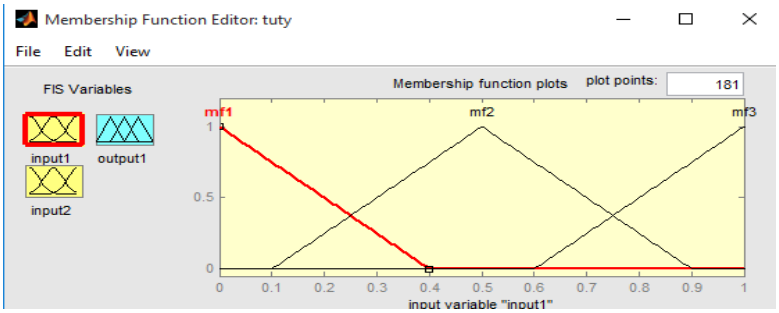

Figure 8. The membership-functions of input-variable—1

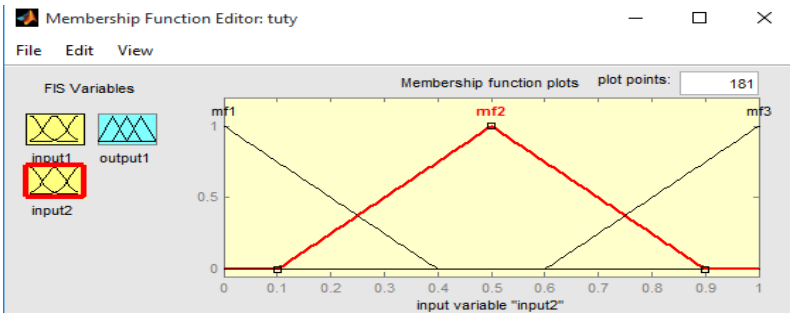

Figure 9. The membership-functions-of-input-variable—2

The 'FCS (forward-converter--system) with F.L.C had controlled the-speed of the DC-motor by driving-it to run at-desired-speed'. For 'various-value-of change-in-load-torque', the-"time- specifications-of-speed-waveform" is analyzed. The speed & torque of Closed-loop controlled three-switch forward-converter with FLC is represented in the Figure 11 and Figure 12.

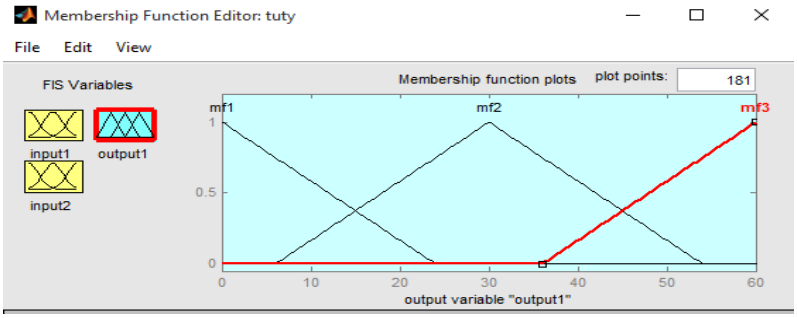

Figure 10. The membership-functions-of-output-variable

3.3. Open-Loop-Controlled-Two-Switch-Forward-Converter-With Motor-Load

The circuit is modelled utilizing the fundamentals of simulink & the simulation is executed using matlab. "Two-switch-serial-input interleaved-forward-converter with motor-load" is presented in Figure 13. The energy in the upper-capacitor is transmited to the transformer-T1 & the energy in the lower-capacitor is transmitted to the transformer-T2. They stepup the voltage & the secondary -voltage is rectified using an uncontrolled-rectifier.

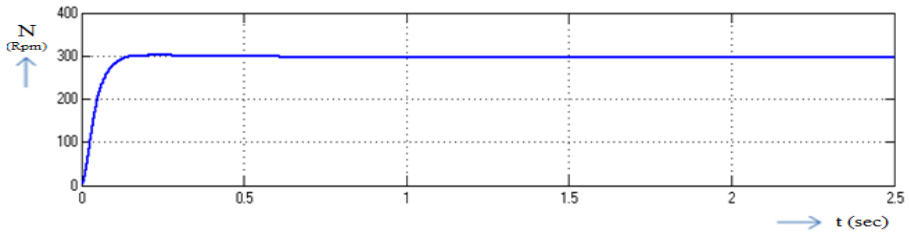

Figure 11. Motor-speed

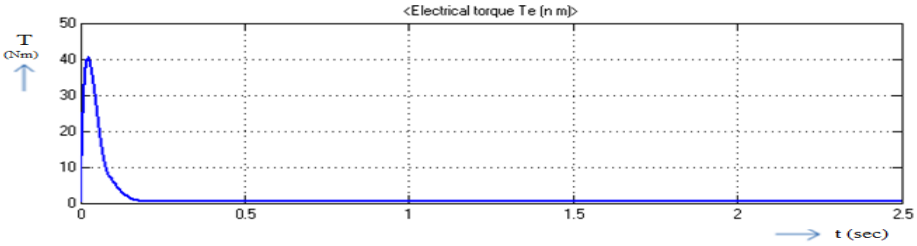

Figure 12. Motor-Torque

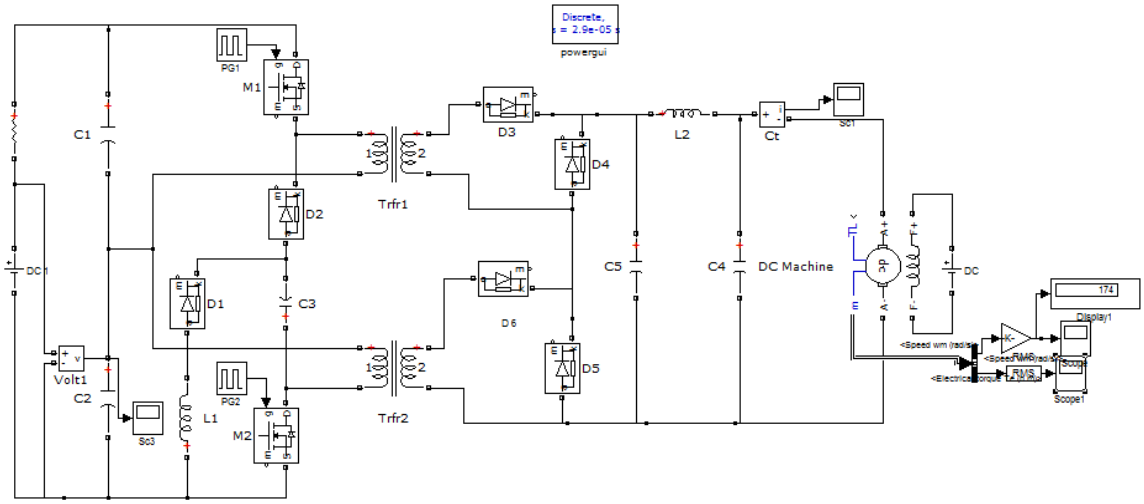

Figure 13. "Open-loop-control of-two-switch-forward-converter-with motor-load"

The speed & torque of the Open-loop controlled-two switch forward-converter with motor load is delineated in the Figure 14 and Figure 15. The speed settles at 1.9sec & torque settles at 3.1 sec

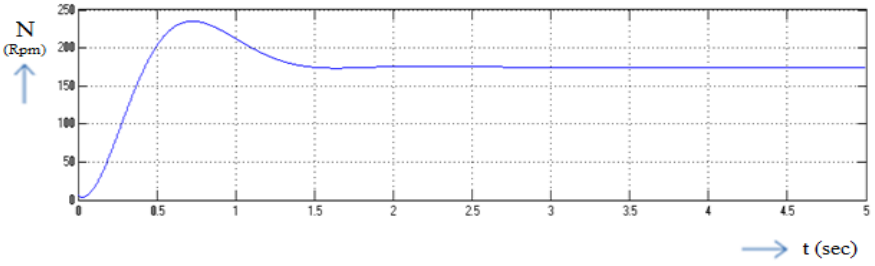

Figure 14. Motor-speed

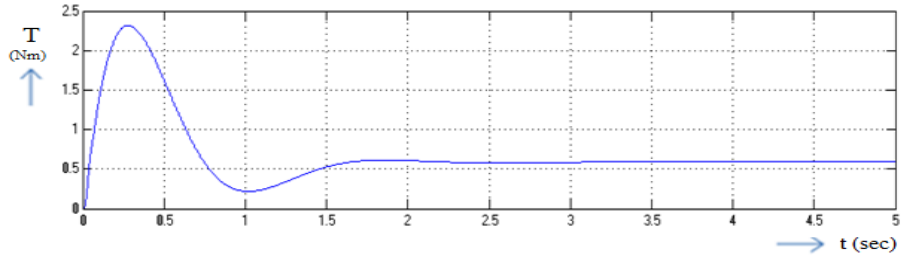

Figure 15. Motor-Torque

3.4. Closed-Loop-Controlled-Two--Switch-Forward—Converter-With-FL-Controller

The F.L.C is intended to 'control-motor-speed of the two-switch-forward-converter'. The set-value of the speed is 300RPM. "The-performance of the driver-system was assessed". Figure 16 characterizes ' the-closed-loop-controlled-two-switch-forward-converter' with FLC.

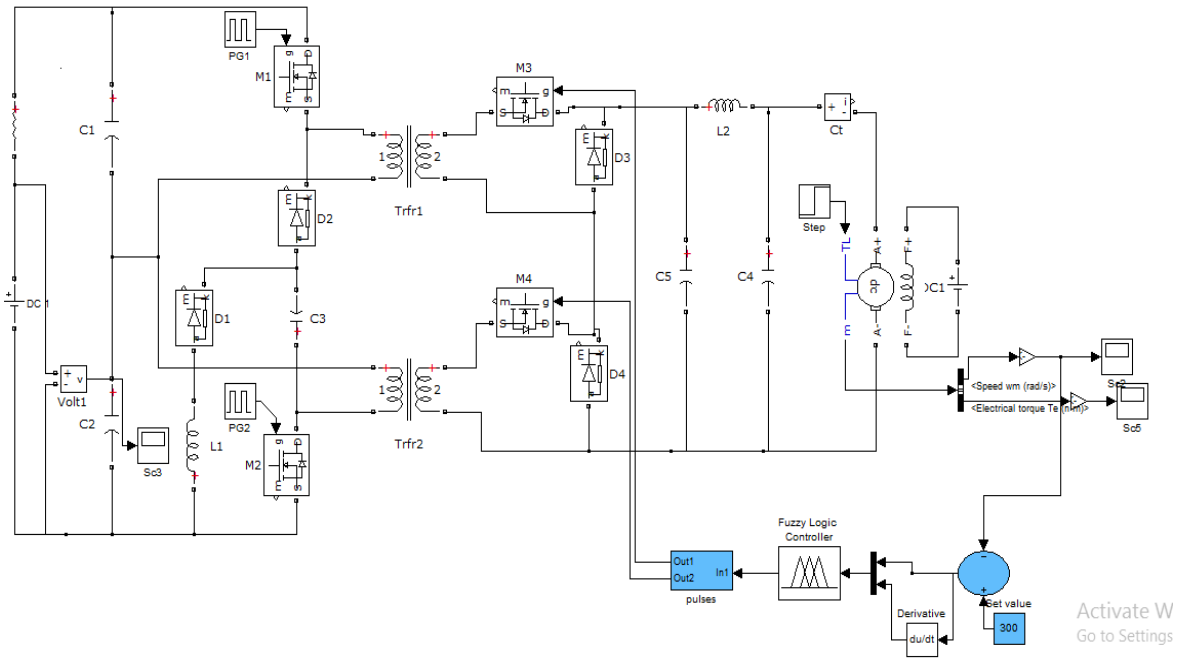

Figure 16. "Closed-loop-controlled-two-switch-forward-converter with-FLC"

The "speed &-torque of Closed-loop-controlled-two-switch forward-converter with FLC" is represented in the Figure 17 & Figure 18.

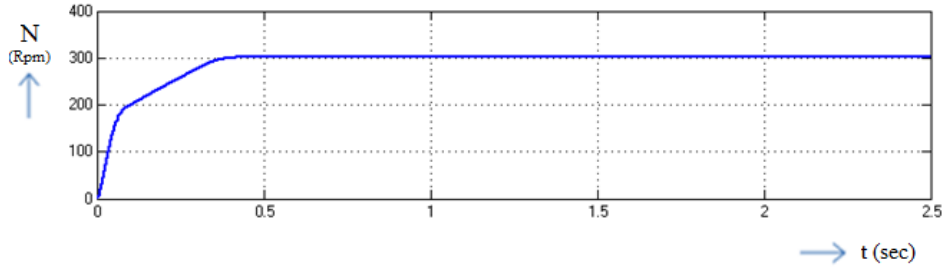

Figure 17. Motor-speed

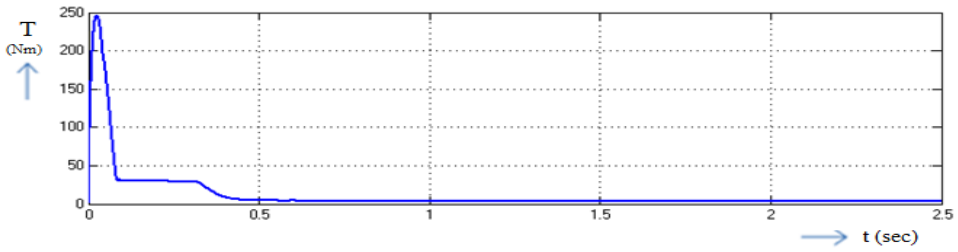

Figure 18. Motor-Torque

4. RESULTS AND DISCUSSION

The "maneuver of three-switch-forward-converter with DC-motor-load controlled by-FLC" is studied on the basis of the time-domain-specifications such as rise-time, settling-time &error for the speed-waveform which is evaluated under the various-value of change in torque-applied to the DC-motor. From the Table 1 it is scrutinized that the value-of rise-time, peak-time &error. With augment in the load-torque, 'the response of the FLC' is better & the speed of the motor-settles at 300Rpm with a smaller-amount of time.

Table 1. Specifications of Fuzzy-Logic Controlled Three-Switch Forward-Converter with Various-Change in Load Torque

Change in Torque	Rise-time (s)	Settling-time (s)	Error
3	0.145	0.945	0.3
3.5	0.14	0.95	0.25
4	0.135	0.995	0.2
4.5	0.13	1	0.1
5	0.12	1.03	0.16

The 'operation-of-two-switch-forward-converter-with-DC-motor-load' controlled by FLC is studied. From the tabulation Table 2 it is monitored that fast response is attained in two-switch forward-converter when compared to that of three-switch-forward-converter-in terms-of -rise-time& settling-time for the same-value of change-in load-torque. But-error is elevated in case of two-switch-forward-converter-system.

Table 2. Specifications-of Fuzzy-Logic-Controlled Two-Switch-Forward-Converter with Various-Change In Load Torque

Change in Torque	Rise-time (s)	Settling-time (s)	Error
3	0.094	0.442	0.3
3.5	0.096	0.44	0.4
4	0.097	0.445	0.26
4.5	0.1	0.45	0.25
5	0.105	0.46	0.21

5. CONCLUSION

The "FL-controlled-two-switch & three-switch-serial-input-interleaved-forward-converters" are modeled & simulated using MATLAB-Simulink. From the outcome, it is concluded-that F.L.C have-better controlling in 'two-switch-forward-converter' when evaluated with 'three-switch-forward-converter-system.' Smooth-variation is possible by utilizing FLC and fast response is achieved within short-time. The simulation-results are in line with the predictions. The contribution of this work is to categorize suitable-converter & controller for DC-DC-conversion.

The scope of this work is the design& implementation of fuzzy-controlled two-switch & three-switch forward-converter. The investigations with P.R.C and S.M.C based TSIFC will be done in future.

REFERENCES

[1] TapanVanker&-GangavarapuGurkumar," Comparative-Analysis of PI& Fuzzy-Control for- a Dual-Input DC/DC-Converter in Hybrid-Energy-Application," (2017) –IEEE-SPICES.

[2] Alexander Abramovitz, Tang Cheng, and KeyueSmedley, "Analysis& Design-of-Forward Converter-with Energy-Regenerative-Snubber," *IEEE-Transactions on-P.E*, Vol 25, No 3, Mar 2010.
[3] Amir Mahmood Soomro et al, "High Output Voltage Based Multiphase Step-Up DC-DC Converter Topology with voltage doubler," *TELKOMNIKA (Telecommunication, Computing, Electronics and Control)*, Vol.11, No.2, February 2013, pp. 1063-1068.
[4] C.S.Liao & K.M.Smedley, " *Design-of-High-Efficiency-Flyback-Converter-with-Energy Regenerative-Snubber*," in Proc.-Appl. Power-Electron.-Conf. -Expo.- (APEC 2008), -24–28 Feb., pp-796-800.
[5] M.Jinno, -P.Y.Chen& K.C.Lin, "-An Efficient-Active LC-Snubber for Forward-Converters," *IEEE-TransP.E.*, vol-24, no.-6, pp.-1522-1531, Jun-2009.
[6] Elamathy, "Bidirectional Battery Charger for PV Using Interleaved Four port DC-DC Converter," *TELKOMNIKA Indonesian Journal of Electrical Engineering*, Vol. 14, No. 3, June 2015, pp. 428-433.
[7] T.H.Ai, " *A Novel Integrated-Non-Dissipative-Snubber for-Flyback-Converter*,"-in-Proc. Intern- Conf. Syst-Signals, 2005, pp.-66-71.
[8] Y.Wei, -X.Wu, -Y.Gu and -H.Ma, "-Wide-Range Dual-Switch-Forward-Flyback-Converter with Symmetrical-RCD-Clamp," -*IEEE Trans-P.E*, -2005
[9] Nor Hanisah Baharudin et al,"Topologies of DC-DC Converter in Solar PV Applications," *Indonesian Journal of Electrical Engineering and Computer Science*, Vol.8, No.2, November 2017, pp. 368-374.
[10] M.R.Reinert,- C.Rech, -M.Mezaroba and -L.Michels, "-Transformerless- Double-Conversion UPS-Using a-Regenerative-Snubber-Circuit," *IEEE-Trans-P.E*-, 2009.
[11] Z.Sajam, -M.Z.Ramli and -L.S.Toh, "-Spike-Suppression-Method of-Bidirectional-High Frequency-Inverter-using a-Regenerative-Snubber," –*IEEE-Trans*. -P.E, -2004.
[12] D. Vidhyalakshmi & K. Balaji, "Performance of Bidirectional Converter Based On Grid Application," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)* Vol. 12, No. 3, December 2018, pp. 1203-1210.
[13] Ravindra Janga and-shushamamalaji, "*Performance-Evaluation of-Active Clamp-Forward Converter-with FLC*," (2017) IEEE–Internati.. Confe.,-on-Intelligent-Computing&-Control.
[14] Al-Nussairi, "*FLC for DC-DC buck-converter with constant-power-load*," (2017) -IEEE 6th intern.., conf., on renewable-energy research&-applications.
[15] N.F.NikIsmail," *FLC on DC/DC-Boost- Converter*," (2010) -IEEE intern..,-conf..,- on power-& energy.
[16] Ping-Zong Lin & -Chun-Fei Hsu, "*Type-2 FLC-Design for-Buck-DC-DC-Converters*," (2005) IEEE-Intern..,-Conf.., on Fuzzy-Systems.
[17] Hanqi Zhuang & Xiaomin," Wu-Membership-Function-based-Fuzzy-Model& Its-Applications To-Multivariable-Nonlinear-Model-predictive-Control," (1994)- *IEEE.*