Multilevel Integrated AC-DC Converter with Fault Mitigation and Fuzzy control

Kirubakaran G #1, Sundaraperumal M #2
[1] PG Scholar, Department of EEE, Gnanamani College of Engineering,
[2] Assistant Professor, Department of EEE, Gnanamani College of Engineering,
Namakkal, Tamilnadu, India

***Abstract*— This paper deals with a new integrated fuzzy logic controlled multilevel integrated ac-dc converter with fault mitigation system combining the operation of two different modules and integrating it to a common module. The triggering pulses are controlled by fuzzy logic algorithm. The proposed converter integrates the operation of the boost power factor correction and the three-level dc-dc converter. The converter is made to operate with two independent controllers—an input controller that performs power factor correction and regulates the dc bus and an output controller that regulates the output voltage. The input controller prevents the dc-bus voltage from becoming excessive while still allowing a single-stage converter topology to be used. The project explains the operation of the new converter in detail and discusses its features and a procedure for its proper design. Experimental results with fault study and its mitigation plan is also studied are studied and obtained from a prototype are presented to confirm the feasibility of the new converter**

Index Terms*— Three level converter, Fault control , Fuzzy control algorithm , AC- DC converter.

1 INTRODUCTION

Higher power AC–DC converters are used in wide range of power applications. Multilevel AC- DC converters are mainly used in many DC drive applications due to its high flexibility in power control and operating characteristics like torque, speed and output voltage .This discussion presented here contains the design of three level AC-DC converter. Here the driving mechanism is further improved by the advanced fuzzy logic mechanism to get the improved control strategy. Previously a conventional PID controller was used in control of the drive. The main scope of using fuzzy logic is to get a discrete control on the switching sequence and to enhance the performance of power electronic switches. The load is considered as Universal motor the output here is Controlled DC. The Controlled DC is obtained from the half wave rectifiers operating in the load side with the source as input from transformer and its winding setting to build a optimal control system or drive two main functionalities should be studied and solutions should be provided for the same. Fault Analysis and Mitigations plans are most important to drive the application without any discrepancies in stable mode. Fault Control strategy is designed and system performance remains undisturbed even at faulty conditions as even mitigation plan is also implemented. Fault mitigation system has been designed to ensure the continuity and reliability of the drive operation.

The fault condition considered here is to in absence of triggering pulse to base switch remains off due to certain fault conditions fault recovery system has been designed for the same

Failures of Control switches due to varied reasons are studied and to control faulty conditions mitigation circuit design under failure of switches. Each functional blocks of the whole circuit has been explained separately. The Control techniques have been presented with plots, algorithms and waveforms supporting the design. Simulation results have been provided, circuit parameters and operations are elaborated in succeeding chapter.

2 PROPOSED MODIFICATION OF DRIVE

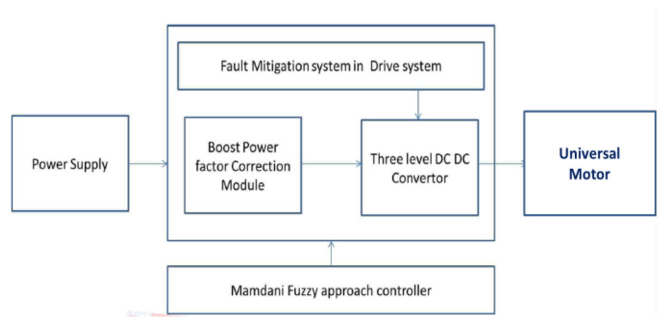


Fig. 1. Block diagram of the proposed drive

2.1 Load varience and control strategy

A new hybrid topology is used for the multilevel drive. Hybrid topology is the combination of boost drive module and three level DC- DC converter module. Mamdani fuzzy approach control module contains fuzzy rules manipulated to get algorithm. Load mentioned here is Universal motor with pulsating DC supply. Power supply is set to 230V input supply of AC, and of 50HZ frequency .The diode bridge rectifier with single switch performs the boost power factor correction module.Three level DC-DC converter is a multilevel converter with three levels switches operating in different cycle and modes getting us continuous output with respect to load

2.2 Fault mitigation and control

The Fault recovery system consists of a recovery diode and recovery capacitor. During the absence operation the charged capacitor and the diode supplies the voltage for the load and this avoids the abrupt reduction in voltage levels to very low level

3 OPERATION OF PROPOSED CONVERTER DRIVE

The proposed converter, which is shown in Fig. 2, integrates an ac–dc boost PFC converter into a three-level dc–dc converter. The ac–dc boost section consists of an input diode bridge, boost inductor Lin , boost diode Dx1 , and switch S4 , which is shared by the multilevel dc–dc section. When S4 is off, it means that no more energy can be captured by the boost inductor. In this case, diode Dx2 prevents input current from flowing to the midpoint of capacitors C1 and C2 and diode Dx1 conducts and helps to transfer the energy stored in the boost inductor Lin to the dcbus capacitor. Diode Dx3 bypasses Dx2 and makes a path for circulating current. Although there is only a single converter, it is operated with two independent

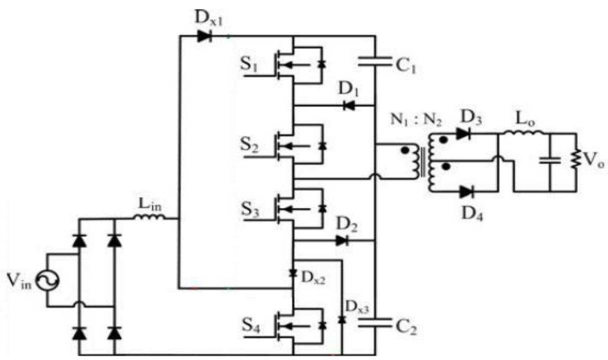


Fig. 2. Circuit diagram of the integrated drive

One controller is used to perform PFC and regulate the voltage across the primary side dc-bus capacitors by sending appropriate gating signals to S4 . The other controller is used to regulate the output voltage by sending appropriate gating signals to S1 to S4 .

It should be noted that the control of the input section is decouple from the control of the dc–dc section and thus can be designed separately. The gating signal of S1 , however, is dependent on that of S4 , which is the output of the input controller; The gating signals for S2 and S3 are easier to generate as both switches are each ON for half a switching cycle, but arenever ON at the same time. Typical converter waveforms are shown in Fig. 3, and equivalent circuit diagrams that show the converter's modes of operation are shown in Fig. 4 with the diode rectifier bridge output replaced by a rectified sinusoidal source. As the input line frequency is much lower than the switching frequency, it is assumed that the supply voltage is constant within a switching cycle. It is also assumed that the input current is discontinuous, although there is no reason why the input current cannot be made to be continuous if this is what is desired. The converter has the following modes of operation:

The proposed converter has the following features:
3.1. Reduced cost compared to two-stage converters: Although the converter may seem expensive, the reality is that it can be cheaper than a conventional two-stage converter. This is because replacing a switch and its associated gate drive circuitry with four diodes reduces cost considerably even though the component count seems to be increased—this is especially true if the diodes are ordered in bulk numbers.

TABLE 1
OPERATING MODES OF THE DRIVE

MODE	OPERATING SWITCHES	LOAD Power transfer by
• MODE 1	• S1 and S2 IS ON	• C1 energy is transferred
• MODE 2	• S1,S2 & S4 IS ON	• C1 and Lin
• MODE 3	• S2 & S4 IS ON	• C1 and Lin with raising Current • Supressed voltage
• MODE 4	• S4 IS ON	• C2 gets charge with S4 on
• MODE 5	• S4 & S3 IS ON	• C2 is discharged with Lin raise
• MODE 6	• S3 & DX1 IS ON	• C1 and C2 is ON, inductor current reduces to Zero
• MODE 7	• S3 IS ON	• Load inductor current freewheels
• MODE 8	• ALL SWITCHES OFF	• C1 charges

3.2 Better performance than a single-stage converter: The proposed single-stage converter can operate with a better input power factor for universal input line applications than a single controller, single-stage because it does have a dedicated controller for its input section that can perform PFC and regulate the dc-bus voltage. The presence of a second controller also allows the converter to operate with better efficiency and with less output ripple as each section of the converter can be made to operate in an optimal manner.

3.3. Improved light-load efficiency: The proposed converter can be designed so that it has a conventional dc-bus voltage of 400 V. Since the converter is a multilevel converter, a 400 V dc bus means that each switch will be exposed to a maximum voltage of 200 V. Having 200 V across a MOSFET device instead of 400 V (as is the case with two-level converters) results in a 75% reduction in turn on losses when the converter is operating under light-load conditions and there is an insufficient amount to current available to discharge the switch output capacitances before the switches are turned on.

3.4 Increased design flexibility: Since the converter is a multilevel converter, it can be operated with high dc-bus voltage (800 V), standard dc-bus voltage (400 V), or any dc-bus voltage 400 V <Vbus < 800 V. There are advantages to operating with high dc-bus voltage or with standard dc bus voltage. The fact there is flexibility in the level that the dc-bus voltage is set means that there is considerable flexibility in the design of the converter. This gives the designer options as to how to optimize the design of the converter for other factors such as efficiency profile and cost (i.e. cost of switches based on voltage rating considerations and availability). It should be noted that this design flexibility makes the design of the three-level converter to be much simpler than that of a single-stage two-level converter or that of a single-controller three-level single-stage converter as the dc-bus voltage can be fixed to a desired level that is considered

4 ADVANCED FUZZY SYSTEM

Fuzzy rules are applied to convert crisp sets to fuzzy sets .

Mandoni rules are applied for control. Seven linguistic variables for each input variable are used. These are NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZR (Zero), PS (Positive Small), PM (Positive Medium), and PB(Positive Big). There are alsoseven linguistic variables for output variable, namely, IB (Increase Big), IM (Increase Medium), IS (Increase Small), KV (Keep Value), DS (Decrease Small), DM (Decrease Medium), and DB (Decrease Big). The control rules subject to the two input signals and the output signal are listed in Rule Table. A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1.The number of fuzzy levels is not fixed and it depends on the input resolution needed in an application. The larger the number of fuzzy levels, the higher is the input resolution. The fuzzy control implemented here uses sinusoidal fuzzy-set values Decision making: The control rules that associate the fuzzy output to the fuzzyinputs are derived from general knowledge of the system behaviour. However, some of the control actions in the rule table are also developed using –error and change in error‖ and from an –output‖ feel of the process to be controlled.

TABLE 2
FUZZY CONTOL RULES CONSOLIDATED

Ch Er \ Er	NB	NM	NS	ZR	PS	PM	PB
PB	KV	IS	IM	IB	IB	IB	IB
PM	DS	KV	IS	IM	IB	IB	IB
PS	DM	DS	KV	IS	IM	IB	IB
ZR	DB	DM	DS	KV	IS	IM	IB
NS	DB	DB	DM	DS	KV	IS	IM
NM	DB	DB	DB	DM	DS	KV	IS
NB	DB	DB	DB	DB	DM	DS	KV

5 FAULT MITIGATION SYSTEM

The Fault recovery system consists of a recovery diode and recovery capacitor. During the absence operation the charged capacitor and the diode supplies the voltage for the load and this avoids the abrupt reduction in voltage levels to very low level

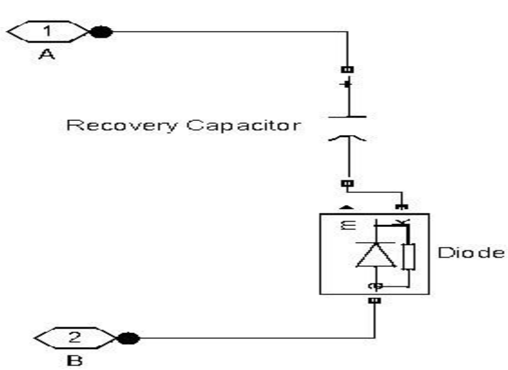
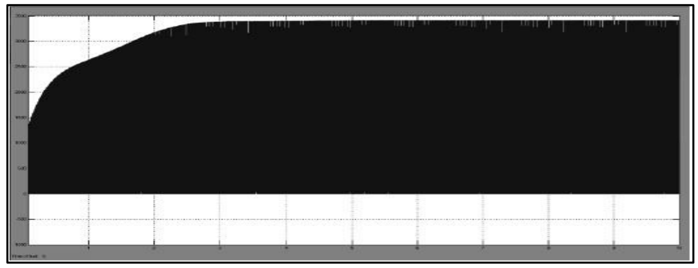


Fig. 3 . Fault mitigation system diagram

6 PERFORMANCE AND RESULTS

6.1 Rectified Boost Voltage

Fig 4 Rectified Boost Voltage



The above simulation plot illustrates the output of the boost – rectification module, the input voltage is 250 V peak voltage and the output voltage after the process is 3400 V as pictured above and this remains constant over the period of stable operation

6.2 Transformer input voltage

The below simulation plot illustrates the Transformer input voltage which is of pulsating DC and its measured in the scope 3 simulation terminal its illustrated in the simulation diagram. The Voltage levels are measure to be in the range of 2000V both in the positive and negative side. The Transformer output is the main source of drive out put

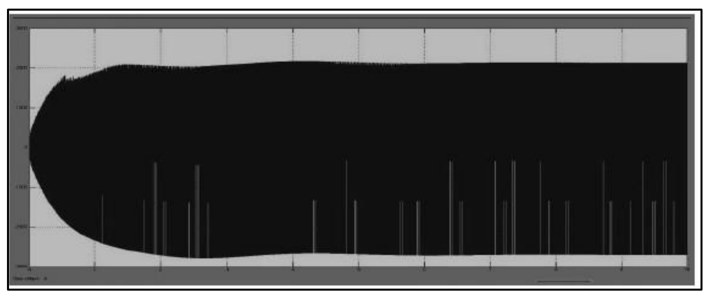


Fig 5 Transformer Input voltage

6.3 Output voltage

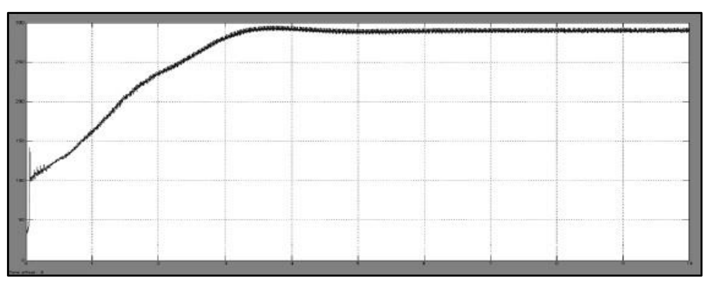


Fig 6 Output voltage of the load

The above simulation plot illustrates the output voltage. The Value of output voltage meets close to the range below 300V which is sufficient to drive applications on the voltage range. This voltage seems to attain steady state at certain level and its characteristics are exponentially rising to a certain level

6.4 Torque and Speed waveforms

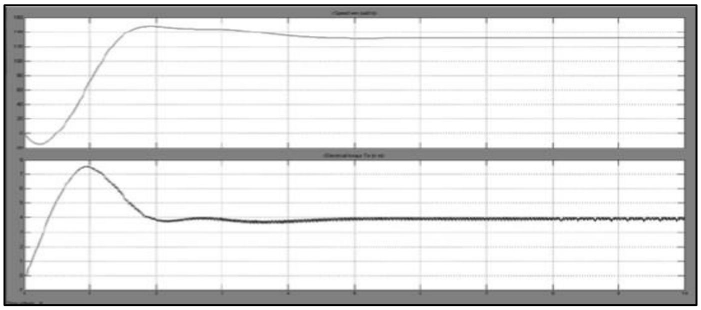


Fig 7 Torque and speed waveforms of the motor

The above simulation plot illustrates the Torque and speed waveforms of the Motor block. The torque seems to have a steep rise in its operation with rise in speeds and the rated torque is achieved after certain interval of time .The constant torque operation is achieved at 4 Nm at the average speed of 140 radians per sec.

To convert Radians to RPM: [(1Rad/sec)/2 pi] *(60sec/min) = (140/2*3.14)*60 = 1337 RPM

6.5 Output Voltage during Fault Condition

Fault mitigation system has been designed to ensure the continuity and reliability of the drive operation. The fault condition considered here is to in absence of triggering pulse to switch 3 or Switch S3 remains off due to certain fault conditions fault recovery system has been designed for the same

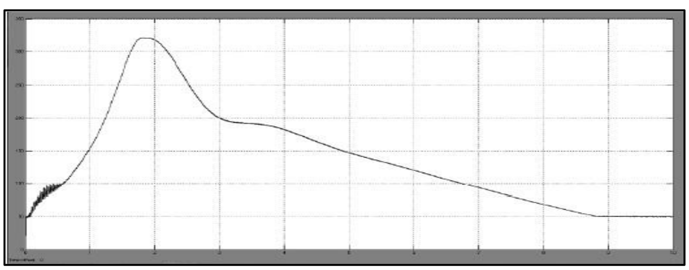


Fig 8 Torque and speed waveforms of the motor

The above plot illustrates the output voltage operation when the Switch S3 is removed the graph shows the devastating decrease in voltage levels due to absence of main operating switch S3. This Fault can be recovered by the design of fault recovery plan designed.

6.6 Fault Recovery system

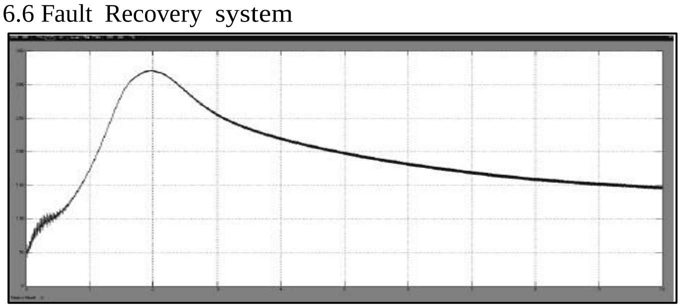


Fig 9 Output voltage with fault recovery system

Fig 9 illustrates the output voltage on with fault recovery system in place. The recovery diode and capacitor supplies for the missing band of Switch S3 operation and hence forth there is no reduction is voltage levels. This fault mitigation plans improves the reliability and continuity in drive operation without any discrepencies

7 ADVANTAGES

7.1 The Fuzzy logic controller:

The Fuzzy logic controller deployed effects a better accuracy in the operation due to its accurate fuzzy rules framed in the system. Fuzzy rules are the set of rules which is used in control to convert the crisp set to fuzzy set. There are many approaches in the fuzzy logic and Mamdani approach is followed to frame the fuzzy set operation. it contains varied rules operating to get the right reference and control which in turn triggers the switches in the require sequence

7.2. High efficiency

The overall operation efficiency is increased due to the improved control strategy and complex algorithms implemented in the system The flexibility of the system is improved due to the improvisations provided get us a reliable operation without increasing the switches used and staging of the drive

7.3. Load Variance

Whatever may be the advantages of drive the application in which it is employed marks the significance of the drive. Just a drive designed with Resistive load does not provide any significance as the loads and applications are majorly inductive. The proposed system is designed for universal motor load, where the performance is determined with respect to changing load.

7.4. Increased Output voltage

Due to the advanced control strategies as discussed above is implemented in the system. The output is increased incrementally to an extent. The improved quality helps in improvement of life of the whole system. Operating efficiency with respect to load is increased.

7.5. Fault recovery system

Fault Control strategy is designed and system performance remains undisturbed even at faulty conditions as even mitigation plan is also implemented. Fault mitigation system has been designed to ensure the continuity and reliability of the drive operation. The fault condition considered here is to in absence of triggering pulse to base switch remains off due to certain fault conditions fault recovery system has been designed for the same

8 CONCLUSION

The Multilevel AC- DC convertor drive with Fuzzy control mechanism has been proposed in this paper. In order to analyze the maximum system performance the operating parameters, both operations under faulty and normal conditions are studied. In order to maintain the stable operation. Fault analysis and mitigation scheme also been provided.

The proposed Drive strategy with both Control and protection technique is applied to achieve the maximum performance in varied load ranges under various conditions of operations. Compared to the conventional methods, the proposed circuit

REFERENCES

[1] M. Pahlevaninezhad, P. Das, P. Jain, A. Bakhshai, and G. Moschopoulos, A self sustained oscillation controlled three level AC/DC single stageconverter,‖ Proc. IEEE APEC, pp. 1172–1178, 2012.

[2] M. S. Agamy and P. K. Jain, –An adaptive energy storage technique forefficiency improvement of single-stage three-level resonant AC/DC converters,‖IEEE Trans. Power Electron., vol. 47, no. 1, pp. 176–184, Sep.2011

[3] H. J. Chiu, Y. K. Lo, H. C. Lee, S. J. Cheng, Y. C. Yan, C. Y. Lin, T. H. Wang, and S. C. Mou, –A single-stage soft-switching flyback converterfor power-factor-correction applications,‖ IEEE Trans. Ind. Electron.,vol. 57, no. 6, pp. 2187–2190, Jun. 2011

[4] C. Wu and R. Xinbo, –Zero-voltage-switching PWM hybrid full-bridgethree-level converter with secondary-voltage clamping scheme,‖ IEEE Trans. Ind. Electron., vol. 55, no. 2, pp. 644–654, Feb. 2008.

[5] H.-L. Cheng,Y.-C.Hsieh, and C.-S. Lin, –Anovel single-stage highpowerfactorAC–DC converter featuring high circuit efficiency,‖ IEEE Trans.Ind. Electron., vol. 58, no. 2, pp. 524–532, Feb. 2011.

[6] J.-Y. Lee, –Single-stage AC/DC converter with input-current dead-zonec ontrol for wide input voltage ranges,‖ IEEE Trans. Ind. Electron., vol. 54, no. 2, pp. 724–732, Apr. 2007.

[7] D. D.-C. Lu, H. H.-C. Iu, and V. Pjevalica, –A single-stage AC/DC converterwith high power factor, regulated bus voltage, and output voltage,‖IEEE Trans. Power Electron., vol. 23, no. 1, pp. 218–228, Jan. 2008.

[8] H. Ma, Y. Ji, and Y. Xu, –Design and analysis of single-stage power factor correction converter with a feedback winding,‖ IEEE Trans. PowerElectron., vol. 25, no. 6, pp. 1460–1470, Jun. 2010.

[9] H. S. Athab and D. D.-C. Lu, –A high-efficiency ac/dc converter withquasi-active power factor correction,‖ IEEE Trans. Power Electron., vol. 25, no. 5, p. 1103-1109, May 2010.

[10] J. M. Kwon, W. Y. Choi, and B. H. Kwon, –Single-stage quasi-resonantflyback converter for a cost-effective PDP sustain power module,‖ IEEETrans. Ind. Electron., vol. 58, no. 6, pp. 2372–2377, Jun. 2011.

[11] H. Athab and D. Lu, –A single-switch ac/dc flyback converter using a CCM/DCM quasi-active power factor correction front-end,‖ IEEE Trans.Ind. Electron., vol. 59, no. 3, pp. 1517–1526, Mar. 2012.

[12] Y. Gu, Z. Lu, and Z. Qian, –Three level LLC series resonant DC/DC converter,‖ Proc. IEEE APEC, pp. 1647–1652, 2004.

[13] P. Barbosa, F. Canales, J. Burdio, and F. Lee, –A three level converter andits application to power factor correction,‖ IEEE Trans. Power Electron.,vol. 20, no. 6, pp. 1319–1327, Nov. 2005.

[14] G. Moschopoulos, Q. Mei, H. Pinheiro, and P. Jain, –PWM full-bridge converter with natural input power factor correction,‖ IEEE Trans. Aerosp.Electron. Syst., vol. 39, no. 2, pp. 660–674, Apr. 2003.

[15] P. Das, S. Li, and G. Moschopoulos, –An improved AC–DC single-stagefull-bridge converter with reduced DC bus voltage,‖ IEEE Trans. Ind.Electron., vol. 56, no. 12, pp. 4882–4893, Dec. 2009.

Kirubakaran G has obtained his B.E degree in Electrical and Electronics Engineering from Anna university , Chennai in the year 2010 and pursuing his M.E., degree in Power electronics and Drives engineering from Gnanamani college of engineering. His area of interest includes Power Electronics and Control of Drives.

Sundaraperumal M received B.E Degree in Electrical and Electronics Engineering & M.E Degree in Power Electronics and Drives. He is currently working as an Assistant Professor at Gnanamani College of Engineering & the area of interest includes ANN , matrix converter & hybrid power generation.