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An Adjustable-Speed BLDC Motor Drive with fuzzy controller

Dr.K.Bhaskar, P.Pavani

Associate Professor, Dept. of Electrical and Electronics Engineering , JNTUH College of Engineering, Hyderabad-500085,Telangana, INDIA.
M.Tech in Power Electronics, JNTU-HYD

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ABSTRACT: Brushless Direct Current (BLDC) Motor Drive As A Cost-Effective Solution For Low-Power Applications. An Approach Of Speed Control Of The BLDC Motor By Controlling The Dc Link Voltage Of The Voltage Source Inverter (VSI) Is Utilize With A Single Voltage Sensor . BLDC Motor is analyzed, and the simulation is performed through the MATLAB software. The obtained power quality indices are within the acceptable limits of international power quality standards such as the IEC 61000-3-2. In this paper we presented a strategy for control using modern fuzzy logic speed controller.

Key words :—Bridgeless (BL) buck–boost converter, brushless direct current (BLDC) motor, discontinuous inductor current mode (DICM), power factor corrected (PFC), power quality.

I. INTRODUCTION

The Efficiency and cost are the major concerns in the development of low-power motor drives targeting household applications such as fans, water pumps, blowers, mixers, etc. The use of the brushless direct current (BLDC) motor in these applications is becoming very common due to features of high efficiency, high flux density per unit volume, low maintenance requirements, and low electromagnetic –interference problems .

Power quality problems have become important issues to be considered due to the recommended limits of harmonics in supply current by various international power quality standards such as the International Electro technical Commission. For class-A equipment (< 600 W, 16 A per phase) which includes household equipment, IEC 61000-3-2restricts the harmonic current of different order such that the total harmonic distortion (THD) of the supply current should be below 19% [7]. A BLDC motor when fed by a diode bridge rectifier (DBR) with a high value of dc link capacitor draws peaky current which can lead to a THD of supply current of the order of 65% and power factor as low as 0.8 [8]. So, a DBR followed by a power factor corrected (PFC) converter is utilized for improving the power quality at ac mains.

Many topologies of the single-stage PFC converter are reported in the literature which has gained importance because of high efficiency as compared to two-stage PFC converters due to low component count and a single switch for dc link voltage control and PFC operation. The choice of mode of operation of a PFC converter is a critical issue because it directly affects the cost and rating of the components utilize in the PFC converter. The continuous conduction mode (CCM) and discontinuous conduction mode (DCM) are the two modes of operation in which a PFC converter is designed to operate. In CCM, the current in the inductor or the voltage across the intermediate capacitor remains continuous, but it requires the sensing of two voltages (dc link voltage and supply voltage) and input side current for PFC operation, which is not cost-effective. On the other hand, DCM requires a single voltage sensor for dc link voltage control, and inherent PFC is achieved at the ac mains, but at the cost of higher stresses on the PFC converter switch; so, DCM is preferred for low-power applications. The conventional PFC scheme of the BLDC motor drive utilizes a pulse width-modulated voltage source inverter (PWM-VSI) for speed control with a constant dc link voltage. This offers higher switching losses in VSI as the switching losses increase as a square function of switching frequency. As the speed of the BLDC motor is directly proportional to the applied dc link voltage, so, the speed control is achieved by the variable dc link voltage of VSI.

The proposed model contains a BL buck–boost converter-fed BLDC motor drive with fuzzy controller and variable dc link voltage of VSI for improved power quality at ac mains with minimised components.

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PFC BASED BL BUCK-BOOST CONVERTER

The implementation of the propound drive is evaluated for a wide range of speed control with improved power quality at ac mains.

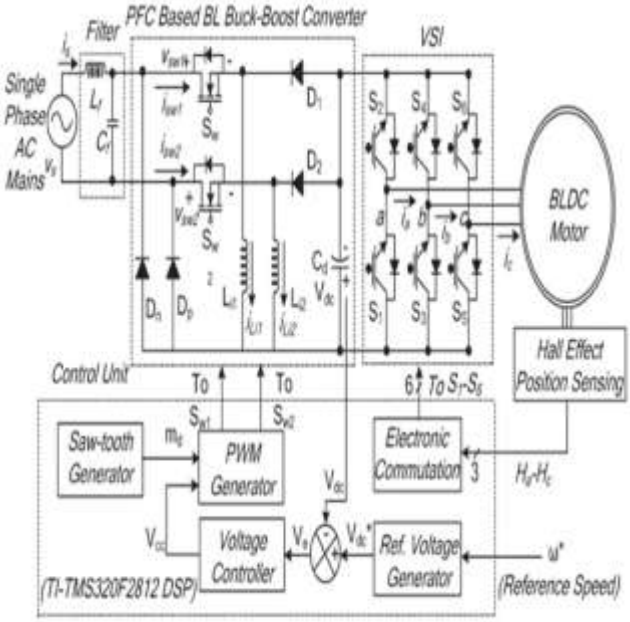

Fig.1.Block diagram

Figure 1.1 shows The propound configuration of the BL buck–boost converter

The propound configuration of the BL buck–boost converter has the minimum number of components and least number of conduction devices during each half cycle of supply voltage which governs the choice of the BL buck–boost converter

Conventional Buck-Boost DC-DC converter

It is a type of DC to DC converter and it has a magnitude of output voltage. It may be more or less than equal to the input voltage magnitude. The buck boost converter is equal to the fly back circuit and single inductor is utilize in the place of the transformer. There are two types of converters in the buck boost converter that are buck converter and the other one is boost converter. These converters can produce the range of output voltage than the input voltage. The performance of the proposed drive is evaluated for a wide range of speed control with improved power quality at ac mains.Moreover, the effect of supply voltage variation at universal ac mains is also studied to demonstrate the performance of the drive in practical supply conditions. Voltage and current stresses on the PFC converter switch are also evaluated for determining the switch rating and heat sink design. Finally, a hardware implementation of the proposed BLDC motor drive is carried out to demonstrate the feasibility of the proposed drive over a wide range of speed control with improved power quality at ac mains.

Table 1 -COMPARITIVE ANALSIS OF PROPOSED CONVERTER

configuration	No. of Devices					½ period cond.	Suitability
	Switch	D	L	C	Total		
Buck[13]	2	4	2	2	10	5	No
Boost[14]	2	2	1	1	6	4	No
BL –Cuk [19]	2	3	3	2	10	8	Yes
BL-SEPIC[20]	2	2	1	3	9	7	Yes

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BL-Buck-Boost [16]	3	4	1	3	11	8	Yes
Proposed	2	4	2	1	9	5	Yes

Table 1 shows the comparison is carried out on the basis of the total number of components (switch—Sw, diode—D, inductor—L, and capacitor—C) and total number of components conducting during each half cycle of supply voltage. The BL buck and boost converter configurations are not suitable for the required application due to the requirement of high voltage conversion ratio.

The propound configuration of the BL buck–boost converter has the minimum number of components and least number of conduction devices during each half cycle of supply voltage which governs the choice of the BL buck–boost converter for this application.

II OPERATING PRINCIPLE OF PFC BL BUCK -BOOST CONVERTER

The operation of the PFC BL buck–boost converter is classified into two parts which include the operation during the positive and negative half cycles of supply voltage and during the complete switching cycle

The proposed configuration of the BL buck–boost converter has the minimum number of components and least number of conduction devices during each half cycle of supply voltage which governs the choice of the BL buck–boost converter for this application.

Operation during Positive and Negative Half Cycles of Supply Voltage:

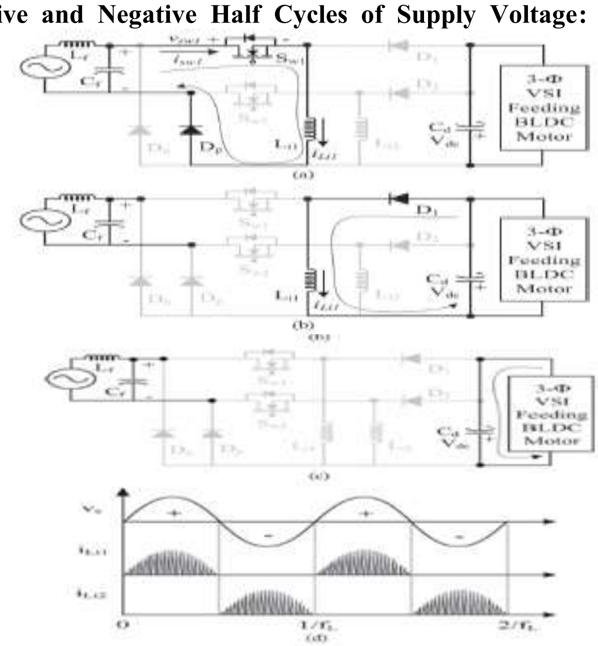

Fig.2.Operation of proposed converter in modeI modeII modeIII

Three modes of operation during a complete switching cycle are discussed for the positive half cycle of supply voltage as shown hereinafter.

Mode I: In this mode, switch Sw1 conducts to charge the inductor Li1; so, an inductor current iLi1 increases in this mode as shown in Fig. 2(a). Diode Dp completes the input side circuitry, whereas the dc link capacitor Cd is discharged by the VSI-fed BLDC motor.

Mode II: As shown in Fig. 2(b), in this mode of operation, switch Sw1 is turned off, and the stored energy in inductor Li1 is transferred to dc link capacitor Cd until the inductor is completely discharged. The current in inductor Li1 reduces and reaches zero.

Mode III: In this mode, inductor Li1 enters discontinuous conduction, i.e., no energy is left in the inductor; so, current iLi1 becomes zero for the rest of the switching period. As shown in Fig. 2(c), none of the switch or diode is conducting in this mode, and dc link capacitor Cd supplies energy to the load; so, voltage Vdc across dc link capacitor Cd starts decreasing. The operation is repeated when switch Sw1 is turned on again after a complete switching cycle.

III CONTROL OF PFC BL BUCK–BOOST CONVERTER-FED BLDC MOTOR DRIVE

Pi Speed Controller :

A proportional integral-derivative is control loop feedback mechanism used in industrial control system. In industrial process a PI controller attempts to correct that error between a measured process variable and desired set point by calculating and then outputting corrective action that can adjust the process accordingly. The PI controller calculation involves two separate modes the proportional mode, integral mode. The proportional mode determine the reaction to the current error, integral mode determines th e reaction based recent error. The weighted sum of the two modes output as corrective action to the control element. PI controller is widely used in industry due to its ease in design and simple structure. fuzzy logic techniques have gained much interest in the application of control system. They have a real time basis as a human type operator, which makes decisionon its own basis.We presentthe controller whichincludes three dual inputs butsingle rule for the fuzzy logic and three PI controllers in different sampling time The fuzzifying, control rule and defuzzification are based on the rotor speed. The major work of the fuzzy logic is scaling speederror for PI controller.

fuzzy controller:

There are specific components characteristic of a fuzzy controller to support a design procedure.

The point of fuzzy good judgment is to map an enter area to an output space, and the primary mechanism for doing that is a listing of if-then statements known as regulations. All policies are evaluated in parallel, and the order of the policies is unimportant. The policies themselves are useful because they seek advice from variables and the adjectives that describe the ones variables. earlier than you may construct a device that interprets rules, you ought to outline all of the terms you propose on using and the adjectives that describe them. to mention that the water is hot, you need to outline the range that the water's temperature can be expected to vary as well as what we mean by way of the word warm. the following diagram affords a roadmap for the bushy inference manner. It shows the overall description of a fuzzy machine on the left and a particular fuzzy system on the right.

Fuzzification: The fuzzification block matches the input data with the conditions of the rules to determine. There is degree of membership for each linguistic term that applies to the input variable. The three fuzzy logic are based on rotor speed, andthe speed isdefinedonthe universeof discourse 0 to 3000rpm.The inputmembershipfunctions ofthe fuzzy sets are trapezoidal and triangular exception.

Defuzzification: Defuzzification is when all the actions that have been activated are combined and converted into a single non-fuzzy output signal which is the control signal of the system. The output levels are depending on the rules that the systems have and the positions depending on the non -linearities existing to the systems. To achieve the result, develop the control curve of the system representing the I/O relation of the systems and based on the information; define the output degree of the membership function with the aim to minimize the effect of the non-linearity.

Fuzzy Logic Control Of The Bldc Motor

The input variable is speed error (E), and change in speed error (CE) is calculated by the controller

with E .The output variable is the torque component of the reference (iref) where iref is obtained at the output of the controller by using the change in the reference current.The controller observes the pattern of the speed loop error signal and correspondingly updates the output DU and so that the actual speed ωm matches the command speed ωref.There are two inputs signals to the fuzzy controller, the error E =ωref −ωm and the change in error CE.

Membership Functions :

The triangular shaped functions are chosen as the membership functions due to the resulting best control performance and simplicity. The membership function for the speed error and the change in speed error and the change in torque reference current are shown in Fig. For all variables seven levels of fuzzy membership function are used .Table show the 7 *7 rule base table that was used in the system. Seven membership function has used, functions defined as: Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM), and Positive Big (PB).

The design of a fuzzy controller for electric drives control requires the choice of the following parameters:

- Choice of language variables
- Choice of the membership functions
- Choice of inference method
- Choice of strategy of defuzzification

Table 2-RULE BASE FOR FUZZY LOGIC CONTROLLER

EW / CEW	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Mechanism of inference: From the basis of rules and the sub fuzzy sets corresponding to the fuzzification, fuzzy inference mechanism allows the determination of the fuzzy output variables. Indeed ,translation of operators "and","or" and "then" by functions ,and the combination of these different functions give the fuzzy output of the regulator .As mentioned previously , several inference methods have been developed to realize fuzzy operators.In our work ,we adopted the the method of inference "product –sum ".In this method the "and" operator is represented by the product ,the "or "by the function sum or average operator function and for the conclution, the "then" operator is represented by the product function . then the resulting fuzzy output of the regulator is the contribution of the 49 fuzzy rules of inference matrix.

The variables and their contemporary values are displayed on top of the columns. in the decrease left, there may be a text subject enter wherein you can input precise input values. For the two-enter device, you will enter an enter vector, [9 8], for example, and then press input. you can also modify these input values through clicking on any of the 3 plots for every enter. this may pass the red index line horizontally, to the factor wherein you have got clicked. rather, you may also click on and drag this line as a way to change the input values. while you launch the road, (or after manually specifying the enter), a new calculation is performed, and you can see the complete fuzzy inference process take place:

• where the index line representing service crosses the membership function line "carrier is poor" inside the higher-left plot determines the degree to which rule one is activated.

• A yellow patch of coloration beneath the actual membership function curve is used to make the fuzzy membership cost visually apparent.

Every of the characterizations of every of the variables is designated with recognize to the input index line on this manner. if you comply with rule 1 across the top of the diagram, you could see the ensuing "tip is reasonably-priced" has been truncated to exactly the identical diploma as the (composite) antecedent—that is the implication manner in motion. The aggregation occurs down the 0.33 column, and the ensuing mixture plot is proven in the unmarried plot appearing within the decrease proper corner of the plot area. The defuzzified output cost is shown with the aid of the thick line passing via the mixture fuzzy set.

you may shift the plots the usage of left, proper, down, and up. The menu gadgets will let you store, open, or edit a fuzzy machine the use of any of the 5 basic GUI gear.

the rule Viewer allows you to interpret the whole fuzzy inference system without delay. the rule of thumb Viewer also suggests how the shape of certain membership functions influences the general end result. as it plots every part of every rule, it is able to emerge as unwieldy for particularly massive systems, however, for a extraordinarily small wide variety of inputs and outputs, it performs well (relying on how a lot screen space you dedicate to it) with as much as 30 rules and as many as 6 or 7 variables.

Fuzzy good judgment Toolbox software program does not restriction the wide variety of inputs. but, the quantity of inputs can be constrained by means of the to be had memory of your system. If the variety of inputs is too large, or After proper weighting has been assigned to each rule, the implication method is implemented. A consequent is a fuzzy set represented by a membership function, which weights appropriately the linguistic characteristics that are attributed to it. The consequent is reshaped using a function associated with the antecedent (a single number). The input for the implication process is a single number given by the antecedent, and the output is a fuzzy set. Implication is implemented for each rule. Two built-in methods are supported, and they are the same functions that are used by the AND method: min (minimum) the number of club capabilities is just too large, then it can also be difficult to investigate the FIS the usage of the opposite tools.

- membership characteristic Editor to outline the shapes of all the club functions related to every variable
- Rule Editor to edit the listing of rules that defines the conduct of the machine.
- Rule Viewer to view the bushy inference diagram. Use this viewer as a diagnostic to see, as an example, which policies are lively, or how person club function shapes have an impact on the results
- surface Viewer to view the dependency of one of the outputs on anybody or of the inputs—that is, it generates and plots an output surface map for the machine.

These GUIs are dynamically linked, in that changes you make to the FIS the use of one among them, affect what you spot on any of the opposite open GUIs. for example, if you trade the names of the membership capabilities inside the club characteristic Editor, the changes are contemplated inside the policies shown in the rule Editor. you may use the GUIs to read and write variables each to the MATLAB® workspace and to a record (the study-simplest visitors can nonetheless trade plots with the workspace and keep them to a file). you could have any or all of them open for any given gadget or have more than one editors open for any range of FIS structures.

Table 3-DEFINITION OF FUZZY SETS FOR THE FLC

Signification	Symbol	Speed of error EW[rad/s]	Variation of speed error CEW[rad/s]	Change of current Ciqs[A]
Negative big	NB	-400 to -125	-2 to 0.2	-0.5 to -0.1
Negative medium	NM	-250 to -40	-0.8 to -0.1	-0.25 to -0.05
Negative small	NS	-125 to 0	-0.2 to 0	-0.1 to 0
Zero	ZE	-40 to 40	-0.1 to 0.1	-0.05 to 0.05
Positive small	PS	0 to 125	0 to 0.2	0 to 0.1
Positive medium	PM	40 to 250	0.1 to 0.8	0.05 to 0.25
Positive big	PB	125 to 400	0.2 to 2	0.1 to 0.5

Fuzzy controller membership function internal design and those 49 fuzzy rules implementation surface view as shown below

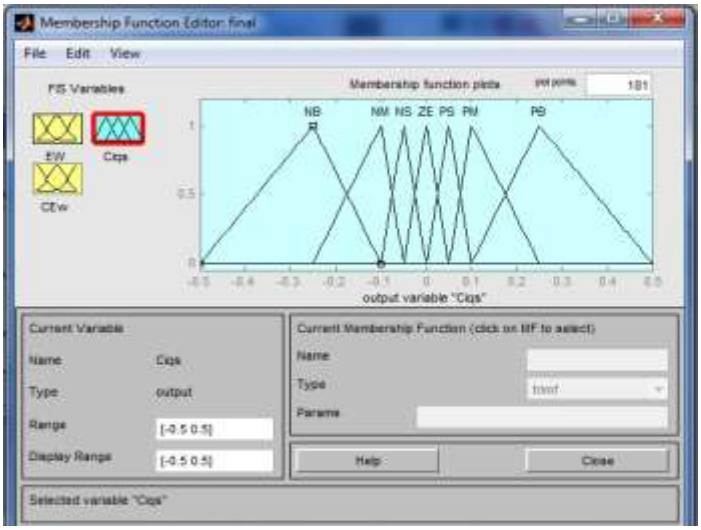

Fig.3. Fuzzy controller membership function internal design

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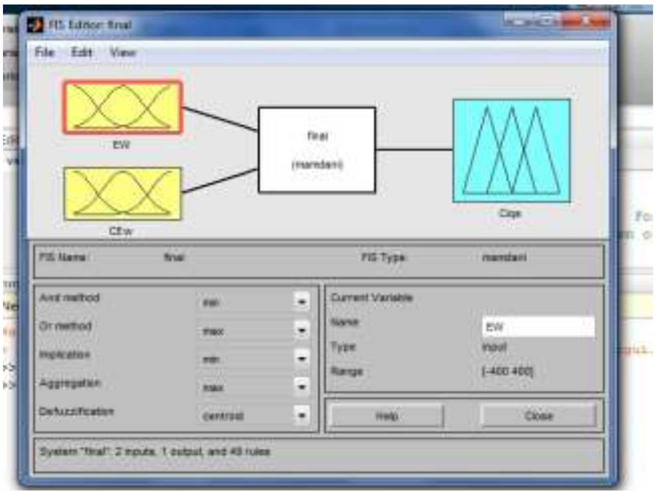

Fig.3.1. Fuzzy controller membership function internal design

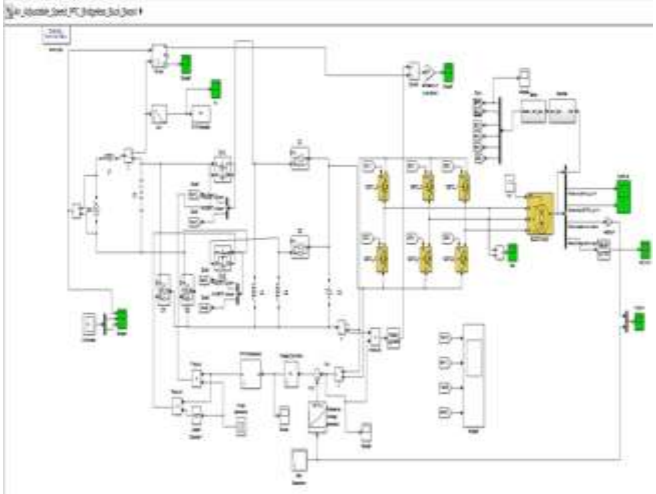

Fig.4.simulation diagram of proposed converter with pi controller

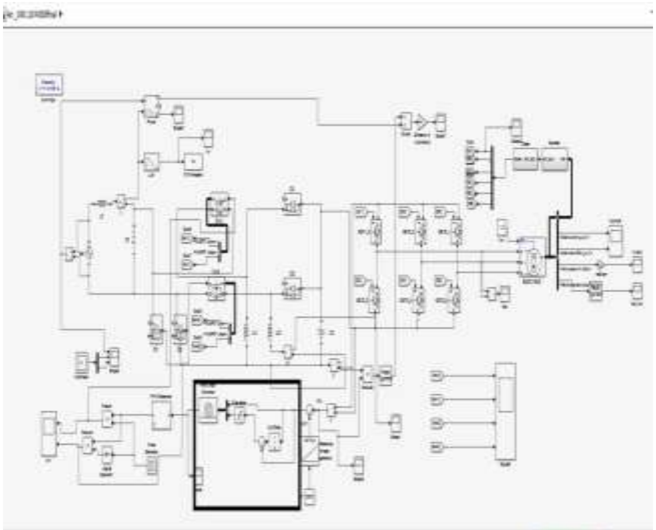

Fig.5.simulation diagram of proposed converter with fuzzy controller

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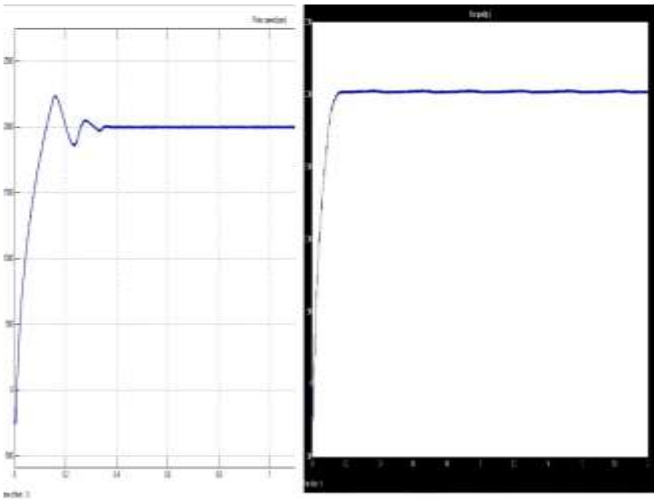

Fig.6. comparative speed response wave form output after simulation

IV.RESULTS AND DISCUSSION:

Various simulation results are analyzed and presented on BLDC motor drive for different conditions in order to demonstrate the satisfactory performance. From the simulation results of BLDC using PI and fuzzy control technique . it can be observed that the simulation results are improved with the FLC. The BLDC Motor is simulated and compared with two different controllers in MATLAB Simulink

Fig.3 shows that the internal design of fuzzy controller and membership function and rules to displace the values of fuzzy controller .

Fig.4 and 5 show that MATLAB simulink with PI and fuzzy logic controller respectively.

Fig.6 shows that speed response comparison between PI and Fuzzy controllers .

The behavior of the two regulators is identical during the permanent regiments, but the fuzzy controller has a clear advantage in transient mode**:**

-No overrun at start-up and at setpoint changes.

-The disturbance peaks are much less important.

- The correction is slightly slower, which is necessarily due to the fuzzy processing.

V.CONCLUSION

In this paper ,fuzzy logic controller (FLC) for the BLDC has been presented . It combines the capability of fuzzy reasoning in handling uncertain information .The classical control is based on PI ,These lasts need the adjustment of controller gains . The determination of gains is not easy and needs to be adjusted If the operating conditions change. This drawback cn be overcome using the presented FLC in regulation loop of BLDC . The FLC CAN BE VIEWED AS A NON LINEAR pi controller with an adaptive parameters which are automatically tuned according to the operating point . To improve the dynamic performance of BLDC drive , an controller based on fuzzy logic control has been studied and given a good agreement between different types of BLDC profile reference . The FLC can be dedicated entirely to control of dynamic system and it offers a robust and a realizable controller acting as a non linear PID . The result of simulation have shown that the BLDC drive with proposed FLC has the merits of simple structure , robustness and accurate tracking performance.

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