International journal of basic and applied research
www.pragatipublication.com
ISSN 2249-3352 (P) 2278-0505 (E)
Cosmos Impact Factor-5.86

A New Approach of BLDC Motor Using Fuzzy Fractional Order PID

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ABSTRACT:

Thispaperprovidesanovelhybridcontroltechniqueforbrushless DC(BLDC)motorspeedmanagement that controls both the BLDC motor reference current and the inverter DC busvoltageatthesametime.TheBLDCmotorreferencecurrentiscontrolledbyafractional-orderPID (FOPID) controller, while the inverter DC bus voltage is controlled by a fuzzy logiccontroller. For tweaking FOPID controller parameters, a modified harmony search (HS)metaheuristic technique is devised. The motor is put through its paces in three differentoperatingconditions:noload,varyingload,andvaryingspeed.Totesttheeffectivenessoftheproposed controller, run it at a high pace. In addition, the proposed hybrid control techniquehas been evaluated. compared to FOPID and Fuzzy-based speed control methods The resultsshow that the proposed control is effective. method allows for more precise speed controlacrossalarge area.

1.INTRODUCTION

Because of their high efficiency, silent operation, compact size, reliability, and littlemaintenance, brushless dc (BLDC) motors are favoured as small horsepower control motors.However,overthelastfewdecades,continuingtechnologicaladvancementsinpowersemiconductors, microprocessors, adjustable speed driver control schemes, and permanent-magnet brushless electric motor production have been combined to provide a reliable, cost-effective solution for a wide range of adjustable speed applications. Over the next five years,household appliances are predicted to be one of the fastest-growing ends-product markets forelectronic motor drivers. Clothing washers, room air conditioners, refrigerators, vacuumcleaners, freezers, and other big equipment are included. Traditional household applianceshavereliedonsinglephaseACinduction,includingsplitphase,capacitor-start,capacitor–runkinds, and universal motors. These traditional motors are often run at constant speed frommain AC power without care for efficiency. Lower energy costs, improved performance,decreased acoustic noise, and more convenience features are increasingly top priorities forconsumers. Traditional technology are incapable of providing solutions. BLDC motors areused in almost every market category. Appliances, industrial control, automation, and aircraftarejust afew examples.

• ConstantloadBLDCmotor

• Differentialloads

• Applicationsforpositioning

These are the kinds of applications where having a variable speed is more critical thanmaintaining a set speed's accuracy. The load is directly linked to the motor shaft in theseapplications. Fans, pumps, and blowers are examples of these types of applications. These applications necessitate low-cost controllers that are essentially open-loop. These are the applications in which the motor's load varies over a speed range. These applications may necessitate high speedcontrolaccuracyandresponsiveness.Washers,dryers,andcompressorsare examples of home appliances. Fuel pump control, electronic steering control, enginecontrol, and electric vehicle control are all instances of this in the automotive industry. Thereare a variety of applications in aerospace, such as centrifuges, pumps, robotic arm controls,gyroscope controls, and so on. These applications may make use of speed feedback devices and operate in either as closedlooporacompletelyclosedloop.Theseapplicationsmakeuseofcomplexcontroltechniques, whichmakesthecontrollermoredifficulttouse.Thisalsoraisesthe overall cost of the system.

BLDCmotors haveanumberof advantagesoverDC motors.

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- Highdynamicresponse.
- Highefficiency
- Longoperatinglife
- Operationislow.
- Higherrangeofspeed

The main disadvantage of BLDC is its higher cost, which comes from two disadvantages.To start with, BLDC motors requires complex electronic speed controllers to operate. Acomparablysimplevariableresistor(potentiometerorrheostat)canbeusedtoregulatebrushedDC motors, which is inefficientbut suitableforcost-sensitive applications.

PrincipleoperationofBrushlessDC(BLDC)Motor

Apermanentsynchronousmachinewithrotorpositionfeedbackisreferredtoasabrushlessdc motor. A three-phase power semiconductor bridge is commonly used to control brushlessmotors. For beginning and delivering suitable commutation sequence to turn on the powerdevices in the inverter bridge, the motor requires a rotor position sensor. The power devicesare commutated every 60 degrees according to the rotor position. Electronic commutation isutilisedinsteadofbrushestocommutatethearmaturecurrent,whichiswhyitisanelectronicmotor. Thisremovesdifficultiesconnectedwiththebrushandcommutatorarrangement,suchassparkingan dthecommutatorbrusharrangementwearingout,makingaBLDCmotormoredurable thanadcmotor.

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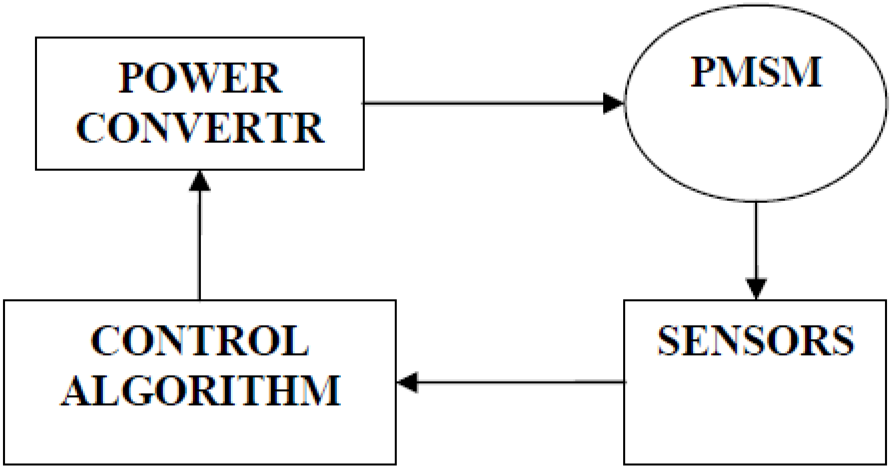

Fig.2.2Basicblock diagramofBLDCmotor

Figure 2.1 shows the fundamental block diagram of a brushless dc motor. The brushless dcmotorhasfourmajorcomponents:apowerconverter,permanentmagnet-synchronousmachine (PMSM) sensors, and a control algorithm. The power converter transfers electricalenergy into mechanical energy by converting power from the source to the PMSM. The rotorposition sensors are one of the most notable features of the brushless dc motor. The controlalgorithms determine the gate signal to each semiconductor in the power electronic converterbased on the rotor position and command signals, which may be a torque command, voltagecommand,speedcommand,andsoon.Permanentmagnetsynchronousmachineswithsinus oidal or non-sinusoidal back emf waveforms can utilise both voltage and current sourcebased drives. The torque of a machine with a sinusoidal back emf (Fig.2.3) can be regulatedtobevirtuallyconstant.Forthesamepoweroutput,however,amachinewithanonsinusoida lbackemf(Fig.2.4) offerssmallerinverter sizes and lower losses.

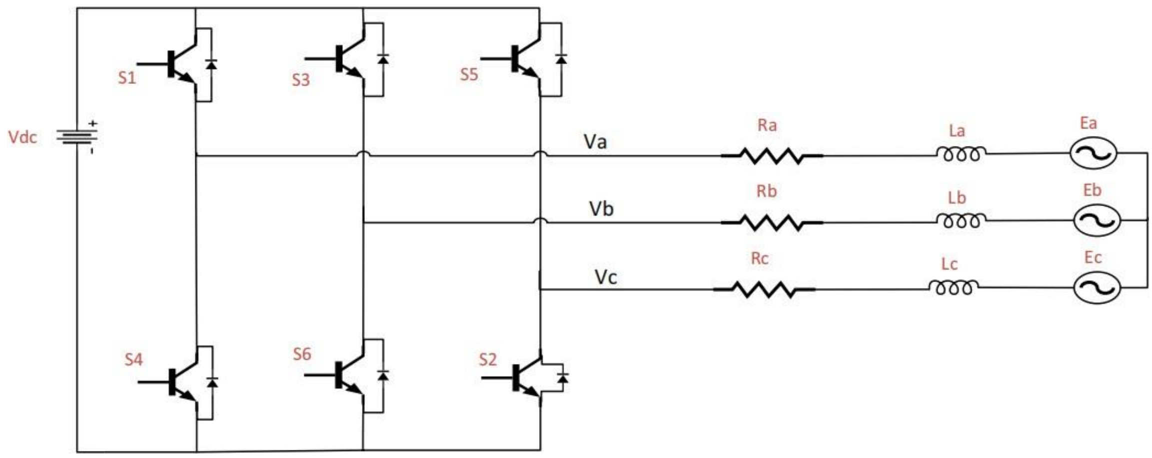

Fig.4.BLDC motordrivesystemequivalentcircuit

Drive Operation Principle

In the BLDC motor drive shown in Fig. 1, the motor is driven at each time by energizingtwo phases of the motor based on the rotor position information obtained from the rotorposition information obtained from the rotor position information obtained from the rotorposition information obtained from the rotor position information obtained from the rotorposition information obtained from the rotor position information obtained three 120 voltsdifferent from hall-effect sensors, each of which gives When it is close to the north and southpoles,itemitsa1or0signal.rotorsofmotors,respectivelyDependingontheeffectofthehallMOSFETgatesignalsarecreatedasaresultofsensors.S1-S6areeitherONorOFFswitches.Table2showstheresults.thephasecurrentstatusandthegateswitchingsignalsbasedontherotor'slocation.

2.SPEEDCONTROLLERDESIGN

2.1 FuzzyController

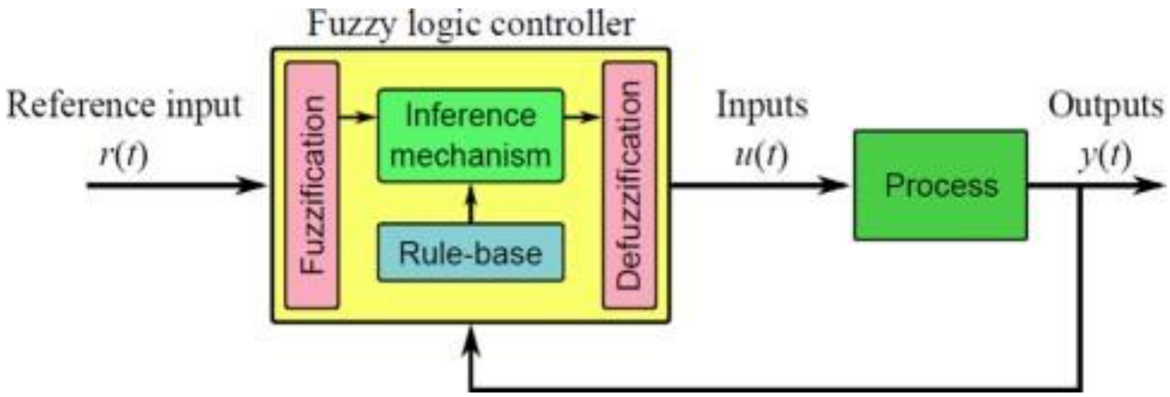

Fig.3 Fuzzylogiccontrolsystemstructure

Figure 3 depicts the usual architecture of a fuzzy control system, which is made up of fourbasicbuilding blocks:

(1) Fuzzification,whichtransformstheinputvaluesintoafuzzy set of values. Expression inthelanguage

(2) Therulebasis, whichismadeupofIF–THEN rules.

(3) A fuzzy control action is inferred using an inference technique. from linguistic variablesand controlknowledge rules.

(4) Defuzzification, which converts the output of the inference mechanism into a numericalvaluein order tocontrol theprocess[16].

The proposed fuzzy controller was created to manage the amplitude of the inverter DC busvoltage. The controller is in charge. The difference between the desired and actual motor isknown as inputs. the error's pace and rate of change, whereas the the controller output isrepresentedby theDC bus voltagereferencevalue.

3.2.Fractional-OrderPID(FOPID)Controller

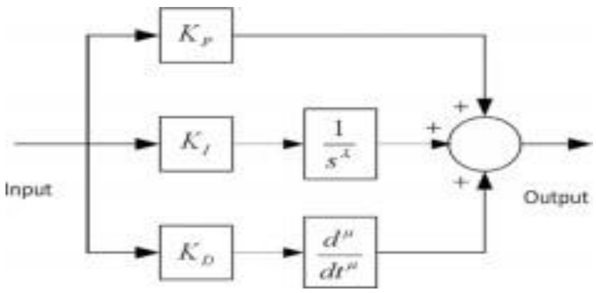

Fig.5 FOPIDcontrollerblock diagram

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The FOPID controller adjusts the magnitude of the three-phase reference currents of thehysteresiscurrentcontrollertocontrolthespeedofBLDCmotors.Themotoristhendrivenusinginvertergatepulses.InTheharmonysearchoptimizationtechniqueisdiscussedinthisstudy.used to figureouttheFOPIDcontroller's parameters' thebest values.

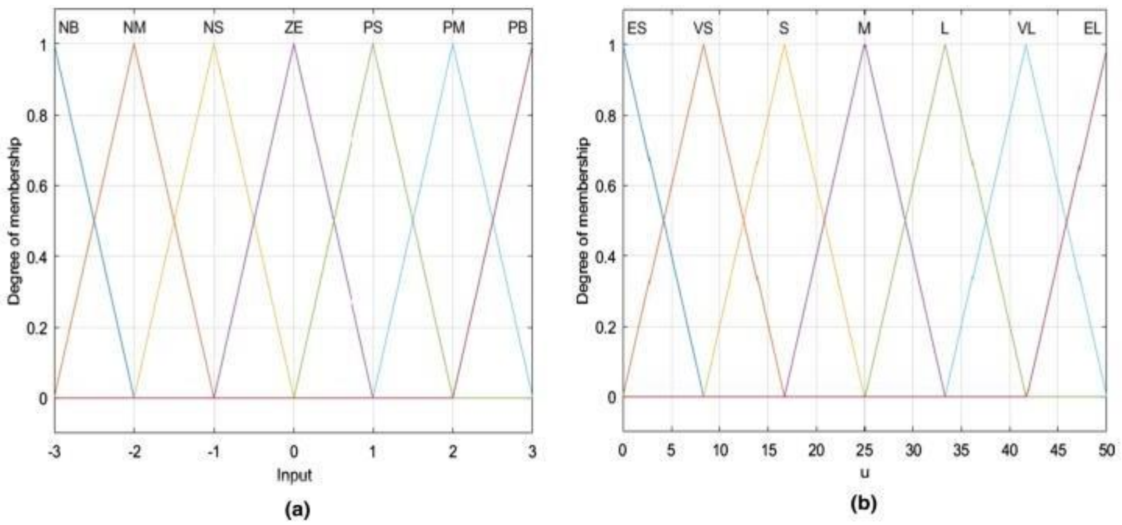

Fig.4a Inputsmembershipfunction,**b**Outputsmembershipfunction

6. SimulationResults

Figure 8 shows the proposed hybrid-Fuzzy-FOPID controlled systems, which manage boththeDC bus voltageand theinvertergatecircuit's referencecurrentat the same time.

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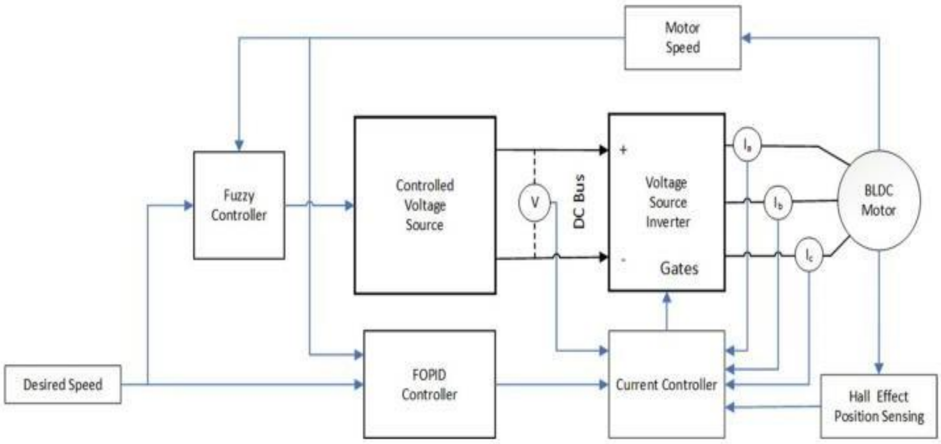

Fig.8 Theproposedhybridfuzzy-FOPIDspeed controller

Threescenarioswereinvestigatedtovalidatetheefficacyoftheproposedcontrolapproach.The system is first simulated at a constant speed with no load, and then the BLDC motor isloaded with a constant load while the speed is varied. Finally, the motor is held at a constantspeed. The motor load has been varied in a specific pattern, while the voltage has remainedconstant.Tosimulate,MATLAB2019bwasutilised.theframeworkFurthermore,theoutcomeshavebeencompared.withFOPID-basedfuzzyspeedcontroltechniquesforany situationTheBLDCiscontrolledbyafuzzycontroller.ByadjustingtheDCbusvoltage,youcan control the motor speed, while The inverter gate signals are produced based on the toaccomplish rotor position acquired from hall-effect sensors Electronic commutation is a termthat refers to the use of electronic devices to The FOPID control mechanism entails The DCbus voltage is maintained at a consistent level, and the speed is controlled. Controlling theBLDCmotor referencedoes this.

6.1 NoLoad Operation

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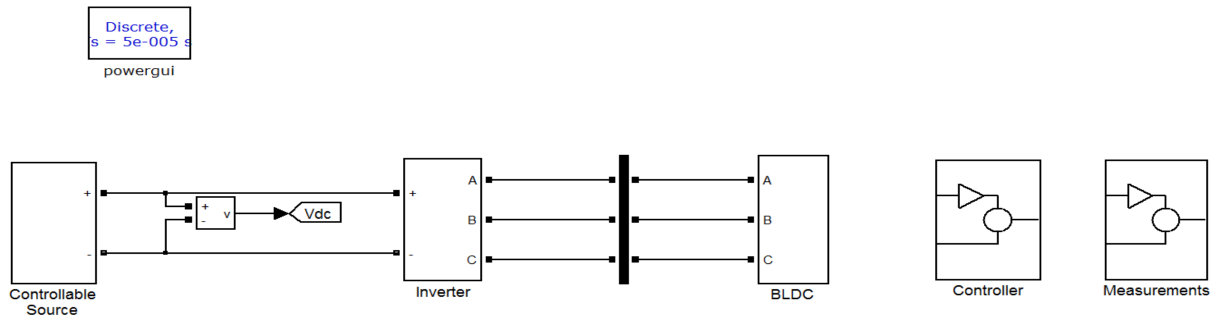

fig.6.1fuzzycontrollerforno-loadresponses

fig.6.1 a)fuzzycontrollerno-load speed response

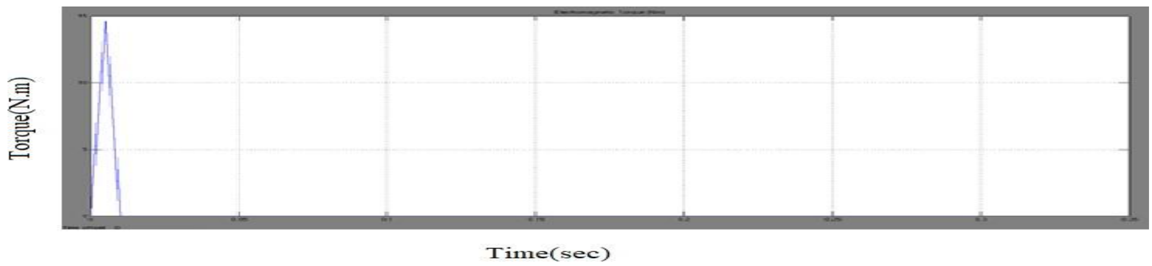

fig.6.1(b)fuzzy controllerno-load torqueresponse

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Apr 2024, Volume 14, ISSUE 2
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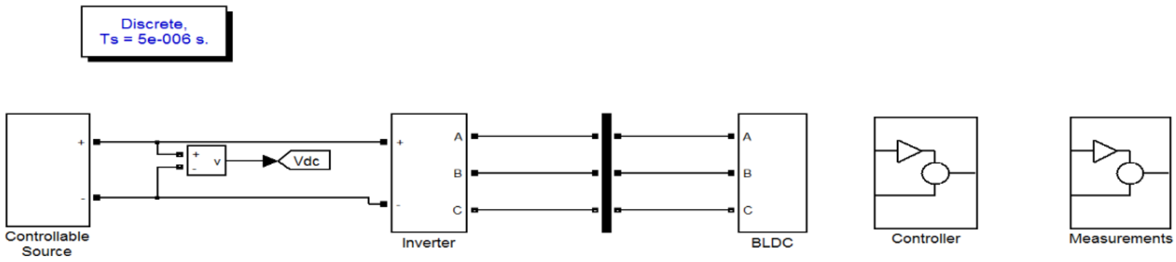
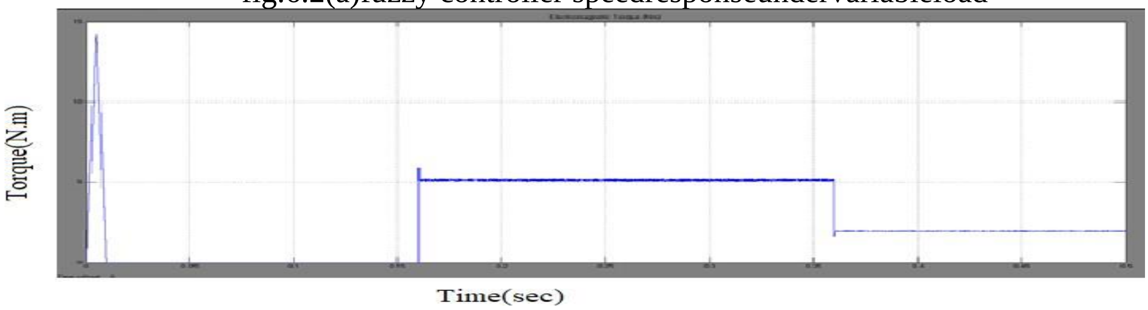


fig.6.2fuzzy controllerforundervariableload responses

fig.6.2(a)fuzzy controller speedresponseundervariableload



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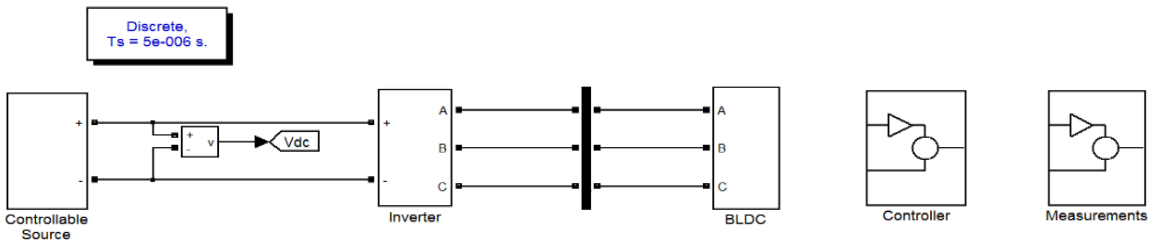

fig.6.2(b)fuzzy controllertorqueresponseundervariableload
fig.6.3fuzzy controllerforundervariablespeed responses

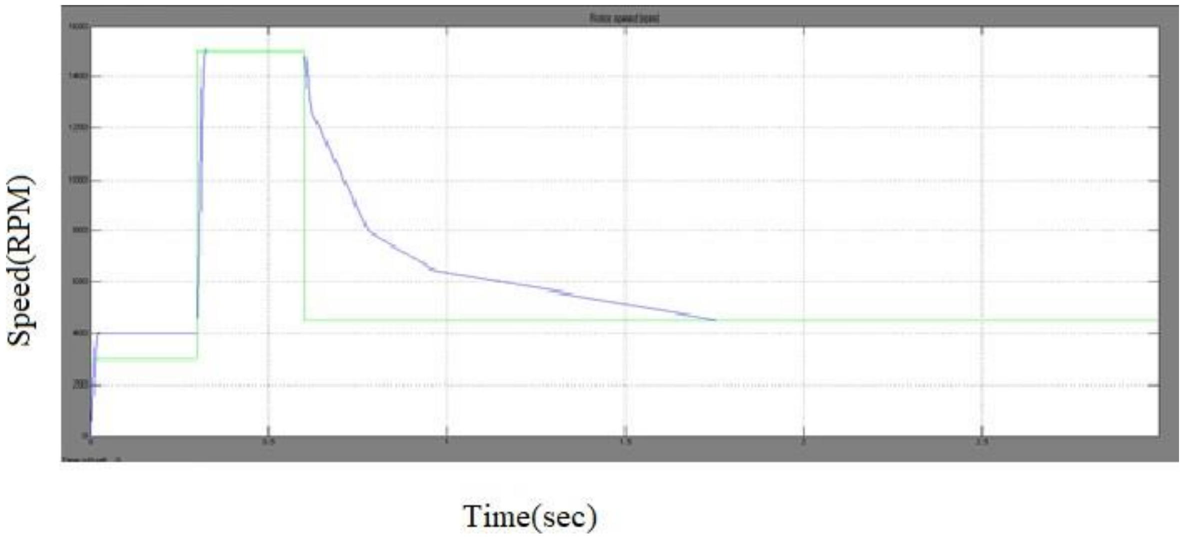

fig.6.3(a)fuzzy controller speedresponseundervariablespeed

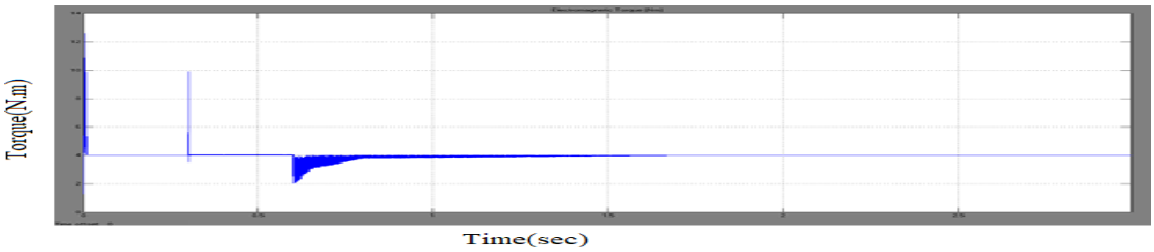

fig.6.3(b)fuzzy controllertorqueresponseunder variablespeed

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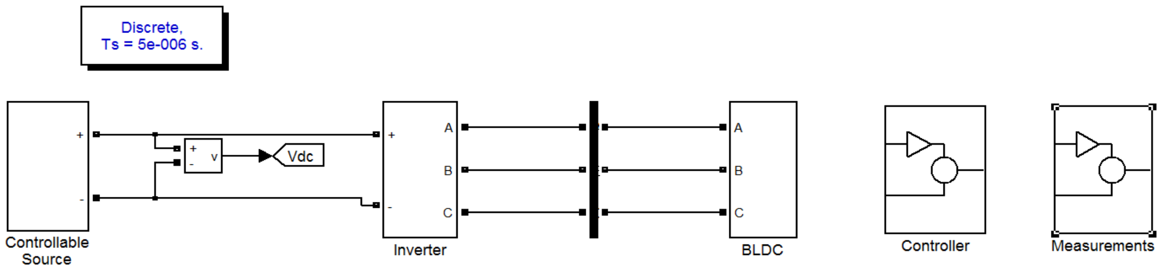

fig.6.9fuzzy-FOPIDcontrollerforundervariablespeed responses

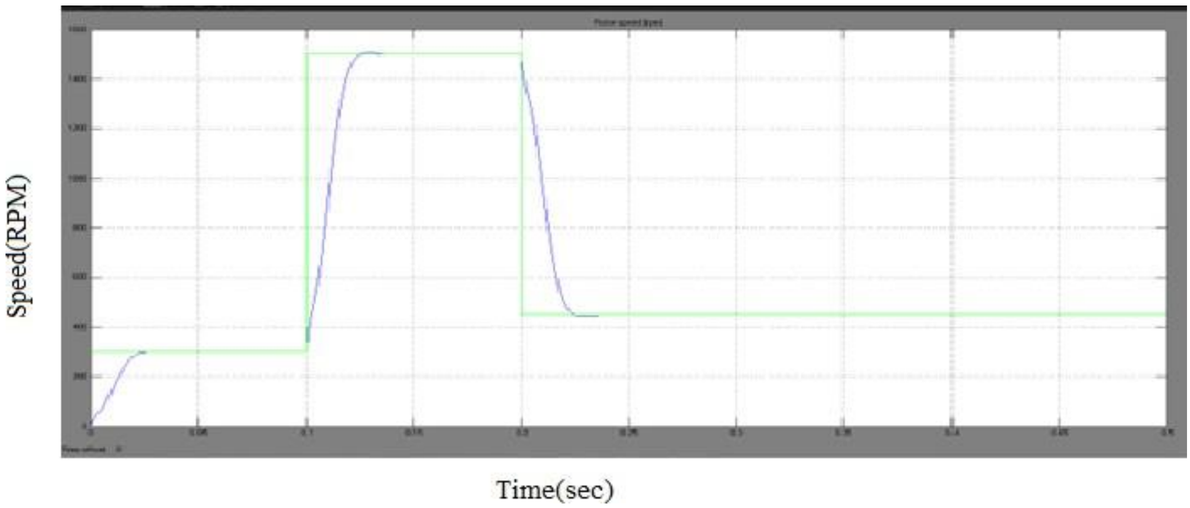

fig.6.9(a)theproposed fuzzy-FOPIDcontrollerspeedresponseundervariablespeed

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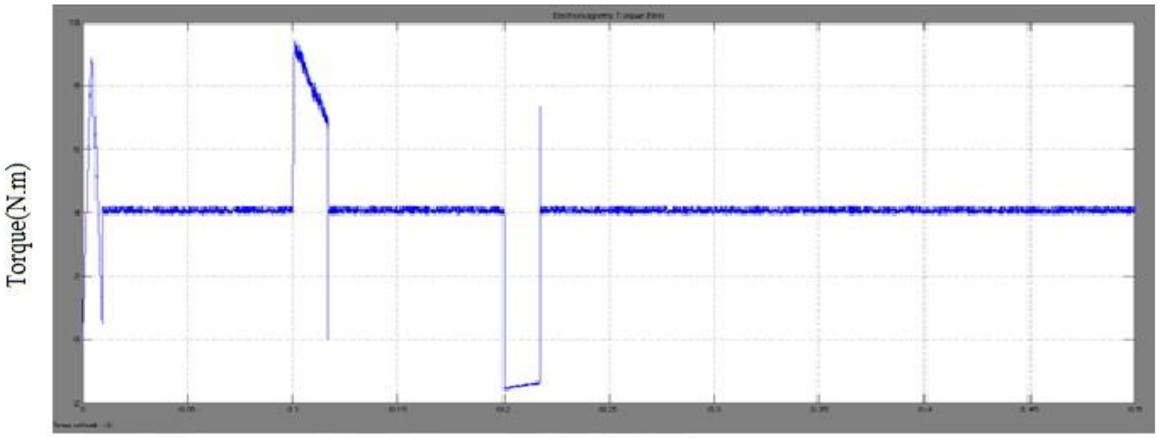

fig.6.9(b)theproposed fuzzy-FOPIDcontroller torqueresponseundervariable speed

Conclusion

This article proposes a hybrid fuzzy FOPID controller for BLDC motors designed tosimultaneously control theinverter DC bus voltage and the hysteresis current regulatorreference current. The modified HSA tuned the proposed hybrid fuzzy FOPID. A hybridcontrol scheme was compared with a standalone purge system and a FOPID -based system.TheproposedfuzzyFOPIDhybridcontrollercombinestheadvantagesofthefuzzycontrolle rwith the adaptability to changing operating conditions and small steady-state errors. variablespeedFIG17aProposedvariablespeedFuzzyFOPIDspeedcurve,bFuzzyFOPIDProposed variable speed torque thirteen FOPID like fast response and inrush current limit function.Considering the simulation results, the implemented fuzzy FOPID hybrid controller showssignificantimprovementsinenginespeedandtorqueresponseindifferentoperatingscenarios

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