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Comparative Analysis of BLDC motor for different control topology

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Abstract

This paper presents comparative analysis of trapezoidal shaped back emf Brushless DC motor (BLDCM) for different control topology. The power Quality (PQ) indices like Total Harmonic Distortion (THD), Crest Factor (CF), Power Factor (PF) across the supply mains are to be analyzed and to ensure within the limits prescribed by International standards. To combat PQ menace, the performances of three controllers. Viz., PI, Fuzzy, and Hybrid are to be compared with respect to the following parameters maximum overshoot (Mp), setting time (Ts), Rise time (Tr) and steady state error (Ess) Hence it is a novel attempt because motor parameters speed and torque ripple, PQ indices and controller parameters are analyzed simultaneously. This Proposed technique is executed in simulink of MATLab software of a BLDC Motor.

Keywords: Brushless DC motor; THD; Speed & torque ripple; PI; FLC and Hybrid Controller.

1. Introduction:

A motor that retains the characteristics of DC machine by replacing the mechanical commutator and the brushes with solid state switches and there is no electrical connection between stator and rotor is called Brushes DC Motor. It can be used for wide array of applications from hard disk drives to hybrid electric vehicle. It is a strong contender and has many advantages compared to other motors for the same power ratings some are high speed, efficiency, dynamic response, tenacious, better speed vs. torque characteristics, no slip etc. The main drawback is the power electronic converter associated in the control circuitry [1].

Theoretically it is a constant torque machine but torque ripple exists practically due to current ripple, emf waveform imperfections and phase current commutation. The effects of torque pulsation in BLDCM are audible noise and visible vibration in the high precision application. To improve the performance CUK or SEPIC converter [2], [3] is suggested but results in 4th order system. Instead of analyzing Buck converter [4] or Boost converter [5] individually Buck-Boost converter is preferred. The ill effects of power electronic component are more harmonic content (ie high THD) and results in poor power factor. As per International standards IEC -61000-3-2, P.F should be close to UPF [6]. Usually BLDCMs are fed from I phase AC with Diode Bridge Rectifier (DBR) and results in a pulsed current from supply mains having poor Power Factor (PF), high Crest Factor (CF) and increased Total Harmonic Distortion (THD) of AC current [7], [8]. The reason is uncontrolled charging of DC capacitor leading to a peak value more than the magnitude of the fundamental input current at AC supply main. Hence Bridge less rectifier at the front end is proposed [9], [10] instead of DBR thereby conduction & switching losses are reduced subsequently PF is increased & THD is reduced. A variable output voltage is obtained by varying the DC input voltage & maintaining the gain of the inverter constant [11] - [14].

Over decades of year experts prefer conventional PI controller as shown in Fig.1 due to facile, robust performance etc but it has the disadvantages of mathematical complications, and accurate controller design. To solve these issues like complex, nonlinear, higher order and time delayed systems, technical experts suggest Fuzzy Logic System (FLS) [15] or in combination with PI [16]. FLS is an extension to conventional Boolean logic and concerns about “degree of truth” which lies between zero to one for decision making. Earlier PWM based VSI was used resulted higher switching losses (proportional to square of switching frequency) and for speed control with a constant DC link voltage later the concept of variable dc link voltage was introduced. In which the switching losses are reduced in BLDCM. There are 2 modes of operation viz.

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1. Continuous Conduction Mode (CCM)
2. Discontinuous Condition Mode (DCM) because it is the deciding factor for the cost and rating of components associated in the PFC converter. In this paper DCM is preferred because it requires a single voltage sensor viable for low power applications.

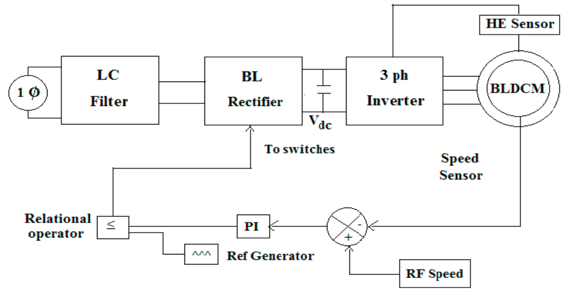

Fig.1 Block Diagram for Existing method (only PI)

2.Controller analysis for BL-buck boost converter fed BLDC drive

Though PI controller as shown in Fig.1 eliminates forced oscillations and minimizes steady state error but integral mode has a negative effect on speed of the response and overall stability of the system. Moreover PI fails when the controlled object is highly nonlinear and uncertain but it can solved through Fuzzy Logic (FL) because FL adopts the logic of reasoning, provides an inexpensive solutions for controlling ill-known complex systems.

To have fine tuning in the controller Hybrid (PI + Fuzzy) logic controller can be used as shown in Fig.2

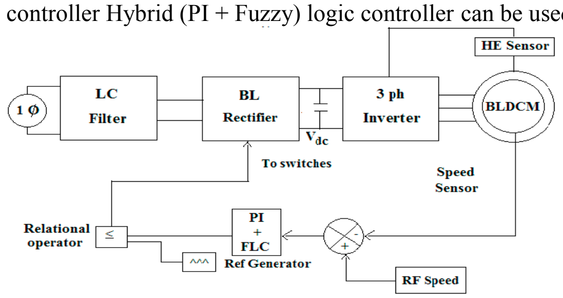

Fig.2 Block Diagram for Hybrid (PI+FLS)

3. Design of buck–boost (bb) converter for VSI FED BLDCM

Let the power rating of BLDCM be P_m=170 watts and BB converter be P_c=300 watts is to be designed.

$$P_m = \frac{2\pi NT}{60} \tag{1}$$

Where N = 1620 rpm (2)

$$T=1\text{Kg.m},\ V_{av} = \frac{2\sqrt{2}V_s}{\pi},\ d = \frac{V_{dc}}{V_{dc}+V_{av}} \tag{3}$$

For Ac supply voltage of 100V, f=50Hz DC link voltage from $V_{dc\,min}$=50V to $V_{dc\,max}$=250 V with an operating value $V_{dc\,req}$ =200V, the Corresponding duty cycle d for d_{min} =0.333 and d_{max} =0.714 respectively. Switching frequency f_{sw} =20KHZ, input inductor value is equal to 1/10th of critical inductance,L_{1I} =L_{2I} and displacement angle,θ =1, source inductance =4% of base inductance and cut off frequency of the supply side is chosen as

$$f<f_{co}<f_{sw}\ ,\ \text{ie}\ \ f_c = \frac{1}{10} f_{sw} \tag{4}$$

3.1. Design of input inductors (L_{1i} & L_{2i})

The formula for critical inductance is

$$L_{ci} = \frac{R(1-d)^2}{} \tag{5}$$