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# Control of BLDC Motor Air Cooler for Low Voltage DC House

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***Abstract***: ***Recent power sector targets on cleaner and sustainable generation and distribution system. This can be done by improving DC based applications for low voltage DC residential homes. During summer air cooling systems are very much useful in reducing the room temperature. Brushless-DC (BLDC) motors are best suited these days as electric motors of fans and air cooling systems with very low power utilization and many other reasons like lesser maintenance, compact and huge gain of torque to volume ratio etc., the control of BLDC motor classified mainly of two types sensor scheme and sensor-less schemes. This paper presents simulation and analysis of two control schemes for BLDC motor drive for air cooling system. The BLDC drive system was developed in MATLAB for both sensor and sensor-less schemes and simulated for different loading conditions.***

***Keywords***: ***DC House, BLDC, Sensor-less, Air Cooler, Low voltage.***

## I. INTRODUCTION

The Global energy demand increasing tremendously with faster pace, need of renewable and sustainable energy resources became important. In view of this efficient electrical systems needed with greater reliability. Though we have many types of AC electrical motors as prime drive mechanism in domestic appliances the impact of Brushless DC (BLDC) motor drives increasing day-by-day because of its sophisticated features. BLDC motor drives became popular because of their numerous advantages like high torque to weight ratio, high efficiency, more compact and high power density of the drive system. DC micro gird and Low voltage and low cost DC house concept will be introduced in near future in all the remote rural areas where availability and accessibility of electricity is a dream for many people. This dream comes true through the concept of DC micro grid and DC house using renewable and sustainable sources of power generation [1].

One needs an inverter system for driving BLDC motor, also position sensor to continuously monitor the shaft position. However having position sensor is dis-advantageous to most of the applications since the motors need to operate continuously at high temperature zones during summer. Hence research going on off sensor schemes for controlling the BLDC drive which can be operated without mounted sensors [2]. Sensor-less control schemes are again classified into different categories based on their estimation techniques. Some of the reported schemes are phase current sensing scheme [3] in which conduction period of free-wheeling diode is detected which are connected as anti-parallel diodes across power switches. Though it has advantages like high performance even at low speeds it needs supply for op-amps to compare to detect the conduction periods. One more method of implementing sensor-less control scheme is observing 1/3 frequency component back-EMF and performing integration to remove all fundamental and other frequency components. One advantage of this scheme is filter size reduction for integration function which has a frequency of thrice the fundamental frequency. Solar based stand alone BLDC motor for air conditioning systems is discusses in [4]-[5]. For solar PV system with low cost devices and their key drivers are discussed in [6]. Digital control based solutions for BLDC motor is presented in [7]. Torque ripple minimization and better dynamic response are the key features of any drive system these importance are highlighted in [8]. Comparison with traditional induction motor with BLDC motor is done in [9]-[10] for chiller applications like cooler and air conditioner. The back-EMF integrating method present in [11] applies the concept that integration process is not varying from cross over point of back-EMF to $30^0$. The benefits are main processor operation decreases, but this method doesn't have synchronization between phase current and back-EMF. One more way of sensor-less scheme is using un-energized phase voltage for detecting the cross over point of motional EMF [12]-[14]. It is also called indirect estimation of back-EMF which is most commonly implemented sensor-less control scheme. In [15] phase free delay scheme is proposed which helps to reduce the delay and improves drive accuracy. In-direct back emf estimation scheme is first discussed in [16]. Classification chart of different schemes of brushless DC motor control is presented in figure-1.

In this paper back EMF detection using line voltages difference has taken into account for the analysis and validation.this scheme is simple and allows complete information of back emf zero crossings which enable gating sequence generation easy. This paper presented as section-II describes the analysis of brushless DC motor and section-III describes simulation and results analysis of sensor and sensor-less schemes.

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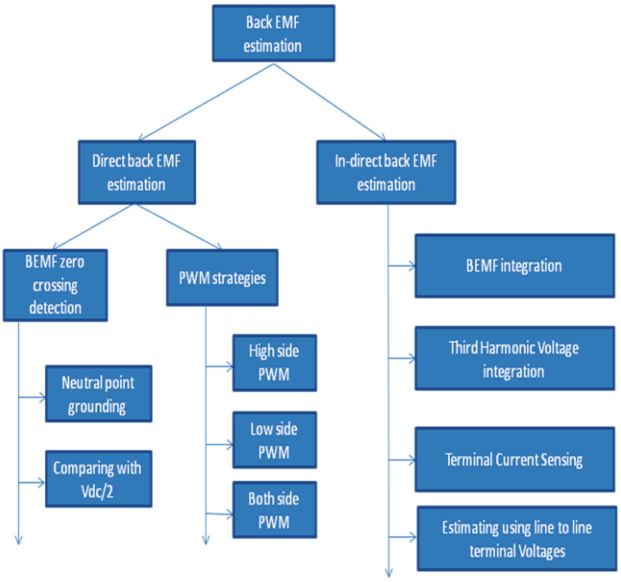


**Fig 1. Classification of different Back EMF estimation schemes**

## II. ANALYSIS OF BRUSHLESS DC MOTOR CONTROL

The modeling of the BLDC motor is done using the machine steady-state equations which represented in state-space form. Assumptions taken into account while modeling the motor are

- Stator winding impedances of all phases are same
- Self and coupled inductance of the machine is constant

The basic block schematic of BLDC drive system is shown in figure-2. The machine voltage equations are represented by the following equations 1 & 2. The first equation represents voltage difference of phases A and B and second equation represents voltage changes of B&C phases based on the above considered assumptions.

$$V_{ab} = R(i_a - i_b) + (L - M)P(i_a - i_b) + E_{ab}(1)$$
$$V_{bc} = R(i_b - i_c) + (L - M)P(i_b - i_c) + E_{bc}(2)$$

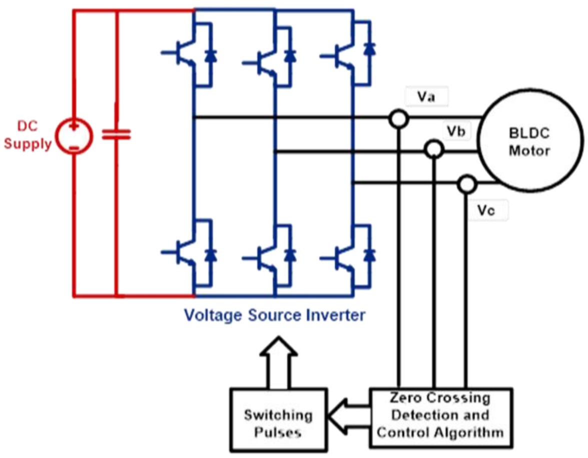


**Fig 2. Basic block schematic BLDCM drive with indirect back emf estimation**

In this paper supply potential difference is calculated and used for the cross over point identification of back EMF. This technique, the cross over points of motional EMF is evaluated from the terminal potential difference estimated with respect to negative dc bus. The integration process not involved in this scheme. Further, since supply potential is used, eliminating neutral point is not a problem. Hence common mode noise is negligible. No derivative operations are involved. Line voltages can be determined using voltage divider networks which can easily fed as inputs to estimation circuit [15] which as shown in figure 2.
From the equations 1 & 2 the difference between line voltages $V_{ab}$ and $V_{bc}$ represents the phase'b' motional emf likewise the difference between line voltages of $V_{bc}$ and $V_{ca}$ represents phase'c' motional emf and the difference between line voltages of $V_{ca}$ and $V_{ab}$ represents phase-A back-EMF. Hence cross over points can be detected identified by terminal potential difference of the brushless dc motor.

## III. SIMULINK RESULTS OF THE PROPOSED SCHEME

This Simulation of the BLDC motor is done in two cases, in the first case using sensor based and gating signals generated for the voltage source inverter. In this case both open loop and closed loop simulations are done. For the closed loop control PI regulator is used for speed regulation. The below table-I shows the simulation parameters taken for the BLDC machine.

**Table-I : ratings of the system.**

| S. No | Parameter | Rating |
|---|---|---|
| 1. | Phase resistance (Rs) | 2.8750 Ohms |
| 2. | Phase inductance (Ls) | 8.5 milli Henry |
| 3. | Torque constant (Kt) | 1.4 N-m/A |
| 4. | Speed (N) | 2100 R.P.M |
| 5. | Supply to inverter (DC) | 310 Volts |
| 6. | Moment of inertia (J) | 0.0008 kg-m2 |
| 7. | No. of Poles | 4 |
| 8. | Voltage Constant | 146.607 Peak (L-L)/ krpm |

For the simulation with sensor feedback taking hall sensors input for pulse generation the hall to virtual EMF subsystem and virtual EMF to pulse generation subsystem are employed to get the firing instants to voltage source inverter. These two subsystems are shown in figures 3.1 and 3.2 the subsystem.
The results of MATLAB/SIMULINK are shown in figures 3.3 to 3.5 under different loads. Similarly the result of closed loop speed control system shown in fig 3.6. The second case of simulation is done using line voltages for estimating back EMF's zero crossing detection and there by pulse generation using the subsystems shown in figures 3.1 and 3.2. Since most of the sensor-less schemes need a pre-defined start-up procedure initially the motor start with predefined starting at stand-still condition, after few cycles switching to sensor-less loop.

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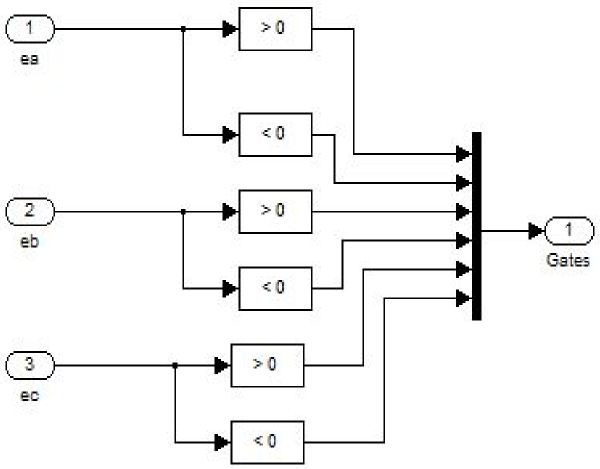



**Fig. 3.1 Subsystem represents virtual back emf to pulses conversion block**

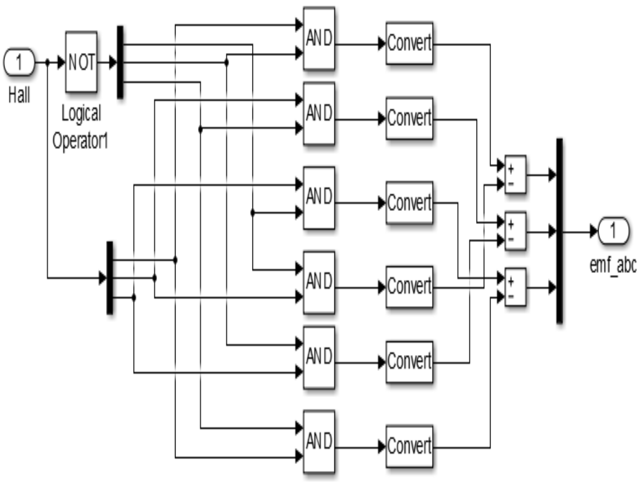
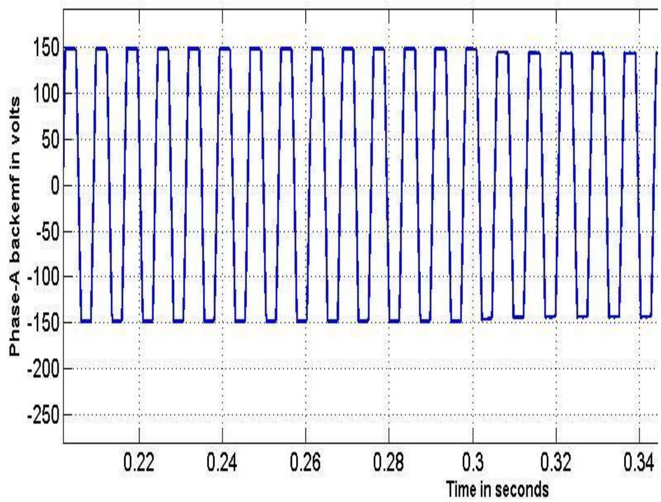



**Fig. 3.2 Subsystem represents hall signal to virtual back emf conversion block**




'**Fig. 3.3 Back EMF of phase-A under different loads**

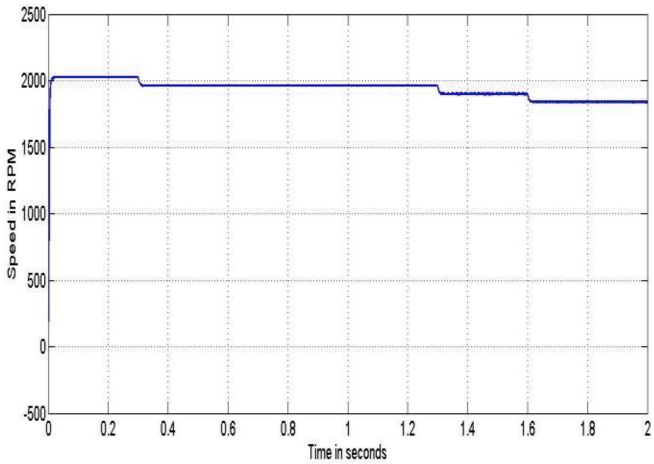



**Fig. 3.4 Speed under different loads**

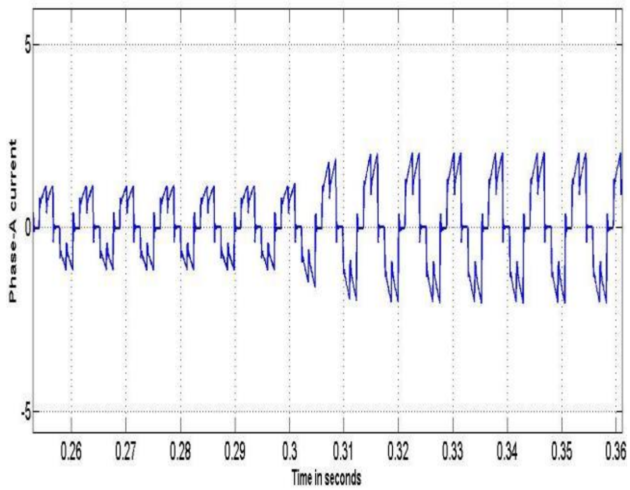



**Fig 3.5 Phase-A Current under different loads**

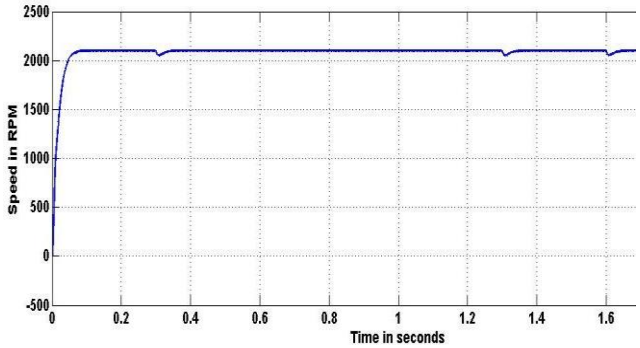



**Fig 3.6 Speed under different load conditions in closed loop**

Figure 3.7 displays under different loads speed of motor and figure 3.8 shows the 'A' phase current under different loads. At 0.17 seconds where phase back EMF's reached to maximum values using manual switch in MATLAB switching over to sensor-less loop even after switching over to sensor-less loop speed doesn't changed up-to the time load didn't disturbed. There is no change in current also after switching over to sensor-less loop.

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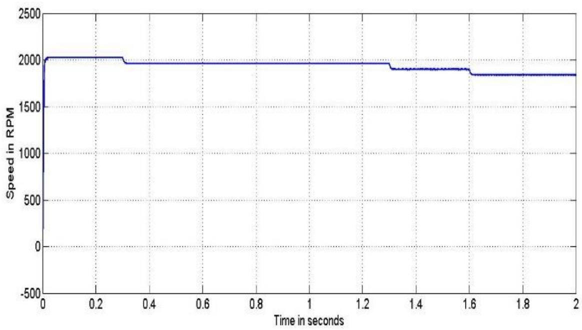


**Fig 3.7 Speed under different load conditions with sensor-less scheme**

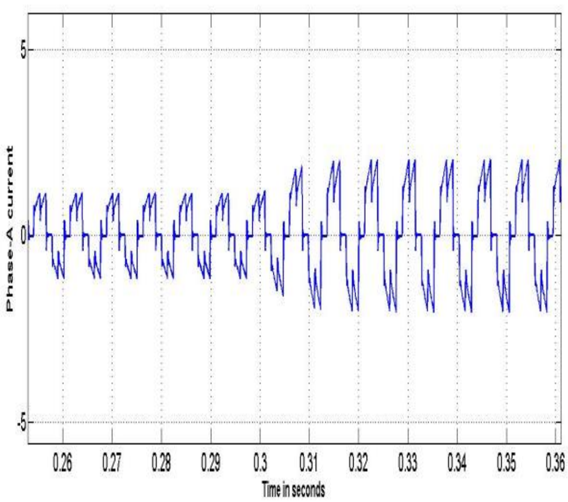


**Fig 3.8 Current under different load conditions with sensor-less scheme**

## IV. CONCLUSION

In this paper literature survey on different position estimation techniques for the shaft position decoding and control of BLDC motor were explained and simulation of employable control schemes including both sensor and sensor-less schemes for brushless motor with Simulink software simulated. Also BLDC motor is modelled from state space equations using abc phase variable model to understand the dynamic model of the system. For the simulation of sensor scheme both with and without feedback done and the results were compared for different load conditions. For the simulation of sensor-less scheme in-direct estimation method called estimating from line voltage differences scheme was developed and implemented in Simulink. Also to verify the scheme under steady state first, motor started with using open loop start-up technique using feed-back signals. Finally the results were analysed after switching over to sensor less scheme and at switch-over period observed the behaviour of motor.

## REFERENCES


1. Naoki ayai, Toshiya hisada, Toshikazu shibata, Hidekazu miyoshi, Takashi iwasaki and Ken-ichi kitayama "DC micro grid System" Electric wire & cable, Energy, SEI Technical review pp 131-136, Number 75, October 2012.
2. T.-J. Yeh, Y.-J. Chen, W.-Y. Hwang and J.-L. Lin, "Incorporating fan control into air-conditioning systems to improve energy efficiency and transient response", Applied Thermal Engineering, Volume 29, Issue 10, Pages 1955-1964, July 2009.
3. J. Ogasawara and H. Akagi, "An approach to position sensorless drive for brushless DC motors," IEEE Trans. on Industry Applications, vol. 27, no. 5, pp. 928-933, 1991.
4. Rajan Kumarand Bhim Singh "BLDC Motor-Driven Solar PV Array-Fed Water Pumping System Employing Zeta Converter" IEEE transactions on industrial applications, volume: 52, issue 3, 2015.
5. L. Deng, P. Liu, Q. Fu, Q, Zheng, H. Liu, Study on commutation for permanent magnet brushless DC motor, Automation Congress, 2008. WAC 2008. World, pp.1, 4, Sept. Oct. 2008.
6. Deepak Pullaguram ; Sukumar Mishra ; Sunanda Banerjee "Standalone BLDC based solar air cooler with MPPT tracking for improved efficiency," IEEE power india international conference , 2016.
7. U. Pillai "Divers of cost reduction in solar photo voltaic," Energy Economics Vol.50. pp 286-293, 2015.
8. Texas Instruments Europe, DSP Solution for BLDC Motors, 2001.
9. G.R. Kumar, K. N V Prasad, M.A.N. Doss, Improve the transient response of speed and torque ripple minimization of the BLDC motor by varies controllers, Computer Communication and Informatics (ICCCI), 2012 International Conference, pp.1, 6, Jan. 2012.
10. Micheal PA, Suji Vinayak Michael, P. A., Suji Vinayak A., Jero Faustin A., Viswa Hariharan A., & Sharon G. "Modeling, simulation and comparison of BLDC motor and induction motor condenser in a chiller cooler system using CFD", 11th international conference on intelligent systems and control, 2017.
11. *M. A. Hassan ; A. R. Abdullah ; N. Bahari ; A. Jidin "In corporating brushless dc motor in outdoor fan control of low voltage air conditioning system"*, IEEE Student Conference on Research and Development, pp: 1-5, Jan 2015.
12. B. J. X. Sen, Z. Q. Zhu, and D. Hwe, "Sensrless flux-weakening control of permanent-magnet brushless machines using thrd harmonic back EMF," IEEE Trans. on Indusry Applicaions, vol. 40, no. 6, pp. 1629-1636, 2004.
13. G. J. Su and J. W. Mckeever, "Low cost sensoless control of brushless DC motors with improved speed range," IEEE Transaction on Power Electronics, volume. 19, pp. 296-302, 2004.
14. Jianwen Shao "An improved microcontroller based sensorless brushless dc motor drive for automotive applications" IEEE transaction on industrial applicationsvol.42 no.5 pp: 1216-1221, 2006.
15. D. jiang, M, C. Bi, K and R. Haung "A new phase delay free method to detect back emf zero crossing points for sensorless of spindle motors" *IEEE Trans.* Magn. Vol. 41, no. 7, pp.2287-2294, 2005.
16. Damodharan and Krishna Vasudevan "sensorless BLDC motor drive based on zero crossing detection of back EMF from the line voltage difference " IEEE transactions on Energy conversion, vol. 25, no-3 September 2003.


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