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Implementation of NI-Labview based BLDC Motor Drive Controller for Electric Vehicle

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Abstract: Nowadays electric vehicles are replacing conventional vehicles because of their environment friendly operation and less maintenance. It also has several advantages, such as the reduced greenhouse emissions, fuel savings and its ease of use. The increase of the electric vehicles in the roads raises issues about their impact on the grid, in terms of power quality. Most of the electric vehicles use three phase induction motors. In this project BLDC motor drive is proposed as it exhibit high torque, high efficiency, easy speed control, reduced noise and longer life time. Retrofitting conventional vehicles to electric vehicles by replacing a brushless dc motor will have a great scope in future as it is economical.
Keywords: Brushless DC Motor, CUK Converter, LabVIEW, MultiSIM, and Co-Simulation.

I. INTRODUCTION

Electric vehicles are mostly used because of their environment friendly operation and less maintenance. It also has several advantages, such as the reduced greenhouse emissions, fuel savings and its ease of use. The increase of the electric vehicles in the roads raises issues about their impact on the grid, in terms of power quality. Most of the electric vehicles use three phase induction motors. In this project BLDC motor drive is proposed as it exhibit high torque, high efficiency, easy speed control, reduced noise and longer life time. Retrofitting conventional vehicles to electric vehicles by replacing a brushless dc motor will have a great scope in future as it is economical. The PMBLDC motor requires an inverter and a position sensor that exposes rotor position for appropriate alternation of current. The rotation of the PMBLDC motor is built on the feedback of rotor position that is gained from the hall sensors. PMBLDC motor generally utilizes three hall sensors for deciding the commutation sequence. In our proposed work, the control in the chopper and inverter circuit can be achieved using MYRIO. The pulses can be generated from PWM pins of MyRIO in a sequence and that can be used to control power devices of the inverter circuit. Generate the PWM pulses in the required sequence and there by achieve the speed control of the BLDC motor with MyRIO. Aim of our project is to design and develop the co-simulation approach for embedded control of electrical drive system based on NI-LabVIEW and Ni-MultiSIM for low-power applications like electric vehicle.

II. PROPOSED SYSTEM

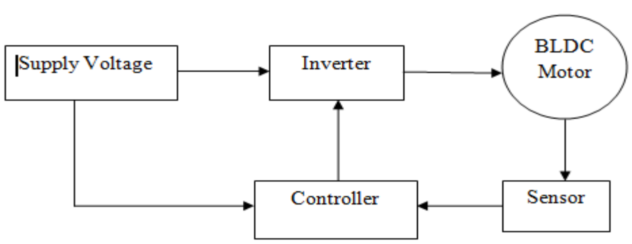

Fig. 1 Block Diagram of the Proposed System

Undoubtedly, the DC machine fulfils these aim of this paper is to measure and test the performance of Brushless DC Motor. In modern era, at every major electrical machine application, a wide range of speed and torque control of the electric motor is required. One key element behind the success of the virtual instrumentation approach is LabVIEW, a software development tool originally developed to support the requirements of virtual instrumentation. The principle of BLDC motor is same as that of the brushed DC motor but, in case of brushed motor the mechanical commutator and brushes is implemented as the feedback whereas, BLDC motors uses multiple sensors as the feedback. The most commonly used feedback sensors are hall sensors and optical sensors .this project deals with the usage of Hall Effect sensors. Hall Effect sensors works on the principle that when the current carrying conductor is exposed to the magnetic field, charge carriers experiences a force based on the voltage developed across the two sides of the conductors. If the direction of the magnetic field is reversed for the Hall sensor used, the voltage developed is reversed. For the Hall Effect sensor used in the BLDC motors, whenever the magnetic poles pass near the hall sensor, they generate a HIGH or LOW level signal which is used to determine the position of the shaft. In the commutation system the motor position is identified using Hall sensors.

III. DESIGN AND WORKING

A. Brushless DC Motor

Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors) are synchronous motors that are powered by a DC electric source via an integrated inverter/switching power supply, which produces an AC electric signal to drive the motor. In this context, AC, alternating current, does not imply a sinusoidal waveform, but rather a bi-directional current with no restriction on waveform. Additional sensors and electronics control the inverter output amplitude and waveform (and therefore percent of DC bus usage/efficiency) and frequency (i.e. rotor speed).

The rotor part of a brushless motor is often a permanent magnet synchronous motor, but can also be a switched reluctance motor, or induction motor. Brushless motors may be described as stepper motors; however, the term stepper motor tends to be used for motors that are designed specifically to be operated in a mode where they are frequently stopped with the rotor in a defined angular position. Brushless motors fulfil many functions originally performed by brushed DC motors, but cost and control complexity prevents brushless motors from replacing brushed motors completely in the lowest-cost areas. Nevertheless, brushless motors have come to dominate many applications particularly devices such as computer hard drives and CD/DVD players. Small cooling fans in electronic equipment are powered exclusively by brushless motors. They can be found in cordless power tools where the increased efficiency of the motor leads to longer periods of use before the battery needs to be charged. Low speed, low power brushless motors are used in turntables for gramophone records. Feedback from the hall sensor by BLDC motor is used to design the control algorithm to generate gate signal for Dc-Dc converters.

1) Mathematical Model Of PMBLDC Motor

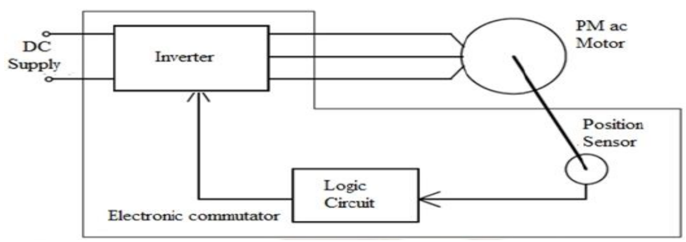

Fig. 2 Permanent Magnet BLDC motor

Mathematical Modelling Brushless DC Motors are permanent magnet motors where the function of commutator and brushes were implemented by solid state switches. BLDC motors come in single-phase, 2-phase and 3-phase configurations. Corresponding to its type, the stator has the same number of windings. Out of these, 3-phase motors are the most popular and widely used. Because of the special structure of the motor, it produces a trapezoidal back electromotive force (EMF) and motor current generate a pulsating torque. Three phase BLDC motor equations: -

$$Va = iaRa+La\,diadt+Mab\,dibdt+Mac\,dicdt+ea \text{ ----1}$$

$$Vb = ibRb+Lb\,dibdt+Mba\,diadt+Mbc\,dicdt+eb \text{ ----2}$$

$$Vc = ICRC+Lc\,dicdt+Mcb\,dibdt+Mca\,diadt+ec \text{ ----3}$$

R: Stator resistance per phase, assumed to be equal for all phases

L: Stator inductance per phase, assumed to be equal for all phases.

M: Mutual inductance between the phases.

ia,ib,ic: Stator current/phase.

2) Equivalent Circuit of 3-phase PM BLDC Motor: Va, Vb, Vc: are the respective phase voltage of the winding

The stator self-inductances are independent of the rotor position, hence:

$$La=Lb=Lc=L$$

And the mutual inductances will have the form:

$$Mab=Mac=Mbc=Mba=Mca=Mcb=M$$

Assuming three phase balanced system, all the phase resistances are equal:

$$Ra=Rb=Rc=R$$

Rearranging the above equations

$$Va = iaR+Ldiadt+Mdibdt+Mdicdt+ea \text{ ----4}$$

$$Vb = ibR+Ldibdt+Mdiadt+Mdicdt+eb \text{ ----5}$$

$$Vc = icR+Ldicdt+Mdibdt+Mdiadt+ ec \text{ ----6}$$

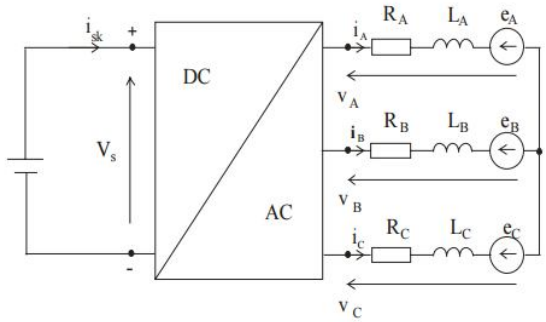

Fig. 3 Equivalent circuit of BLDC motor

Neglecting mutual inductance

$$Va = iaR+Ldiadt+ea \text{ ----7}$$

$$Vb = ibR+Ldibdt+eb \text{ ----8}$$

$$Vc = icR+Ldicdt+ec \text{ ----9}$$

B. CUK Converter

Cuk converter is a type of DC/DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is essentially a boost converter followed by a buck converter with a capacitor to couple the energy. Similar to the buck–boost converter with inverting topology, the output voltage of non-isolated cuk is typically also inverting, and can be lower or higher than the input. It uses a capacitor as its main energy-storage component, unlike most other types of converters which use an inductor.

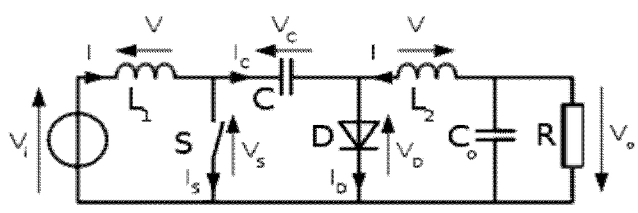

Fig. 4 Cuk Converter

1) *Operating Principle:* A non-isolated cuk converter comprises two inductors, two capacitors, a switch (usually a transistor), and a diode. Its schematic can be seen in figure 4. It is an inverting converter, so the output voltage is negative with respect to the input voltage. The capacitor C is used to transfer energy and is connected alternately to the input and to the output of the converter via the commutation of the transistor and the diode. The two inductors L1 and L2 are used to convert respectively the input voltage source (V_i) and the output voltage source (C_o) into current sources. At a short time scale an inductor can be considered as a current source as it maintains a constant current. This conversion is necessary because if the capacitor were connected directly to the voltage source, the current would be limited only by the parasitic resistance, resulting in high energy loss. Charging a capacitor with a current source (inductor) prevents resistive current limiting and its associated energy loss. As with other converters (buck converter, boost converter, buck–boost converter) the cuk converter can either operate in continuous or discontinuous current mode. However, unlike these converters, it can also operate in discontinuous voltage mode (the voltage across the capacitor drops to zero during the commutation cycle).

2) *Operation:* It is a type of DC-DC converter that has on output voltage magnitude that is either greater than or less than input voltage magnitude. Boost converter followed by buck converter with capacitor to couple the energy. It allows energy to flow bidirectional by using diode and switch. It uses a capacitor as its main energy storage component unlinks other types of converter which use an inductor.

There are two types of cuk converter

a) *Non Isolated Cuk Converter*

i) Continuous mode.

ii) Discontinuous mode

b) *Isolated CUK Converter*

3) *Design of CUK Converter:* A PFC based cuk converter fed BLDC motor drive is designed for DC link voltage control of VSI with power factor correction circuit. The cuk converter is designed for is designed for a CCM and three different DCMs. In DCM, any one of the energy storing elements Li, L_O or C_1 is allowed to operate in discontinuous mode whereas in CCM, all the three parameters operate in continuous conduction.

The output voltage, V_{dc} of cuk converter is given as

$$V_{dc} = \frac{D}{(1-D)} V_{in}$$

The cuk converter is design to operate from a minimum DC voltage of 24V (V_{dc} min) to maximum DC link voltage of 30V (V_{dc}max). The PFC converter of maximum power rating of 100 W (P_{max}) is BLDC motor of (53 w). The switching frequency (f_s) is taken as 20 kHz. Since the speed of the BLDC motor is controlled by varying the DC link voltage of the VSI, hence the instantaneous power, p_i at any DC link voltage (V_{dc}) can take as linear function of V_{dc}. Hence for a minimum value of dc link voltage as 24V, the minimum power is calculated as 53W.

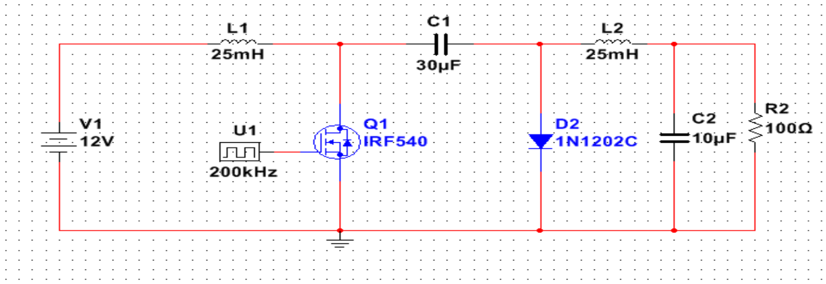

Fig. 5 Design of Cuk Converter in NI-MultiSIM

IV. SIMULATION

One key element behind the success of the virtual instrumentation approach is LabVIEW, a software development tool originally developed to support the requirements of virtual instrumentation. Researchers can use LabVIEW to design (modelling and simulation), prototype (proof of concept), and deploy (field implementation) new technologies that result from R&D activities. Researchers can implement these activities with a highly interactive process known as graphical system design, an approach that leverages virtual instrumentation (modular, customizable, software-defined instrumentation).

The graphical system design approach can improve the productivity of experimental research. To understand how, consider that researchers often have hundreds or thousands of measurements that they use to "feed" their mathematical models. Often, researchers implement data analysis, data visualization, and data mining tasks offline (post processing) using different software tools.

A. *Simulation in LabVIEW*

It is the short form for laboratory virtual instrument engineering workbench. Lab view is an engineering software system. Which consist of one or more virtual instrument? Which create graphical notation it is mainly used in industrial field where testing, measurement and control with rapid access to hardware and date insights are required. It a graphical program language which helps to visualize every aspect to the apps also include hardware configuration, measurement of data and debugging. This visualization helps to simplify the integrate measurement hardware from any vendor, represent complex logic on the diagram, develop data analysis algorithms and design for engineering user friendly. It create stand alone executable for distribution and deployment. The main advantage of LabVIEW is object oriented design, graphical user interface, modular and hierarchical design, multiplatform, flexibility, visualization capabilities, image and signal processing, cost reduction.

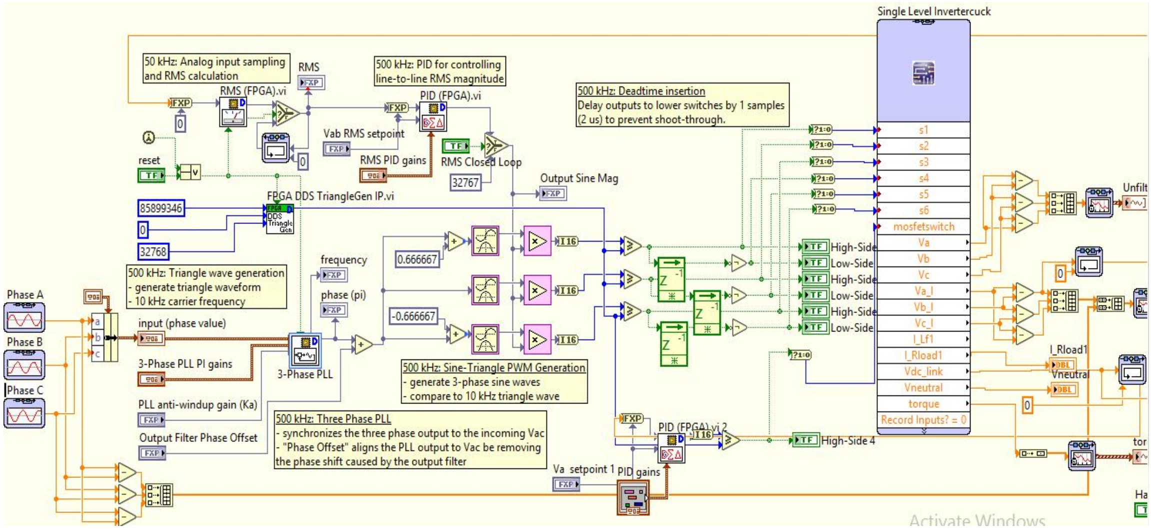

Fig. 6 Block Panel Design in LabView

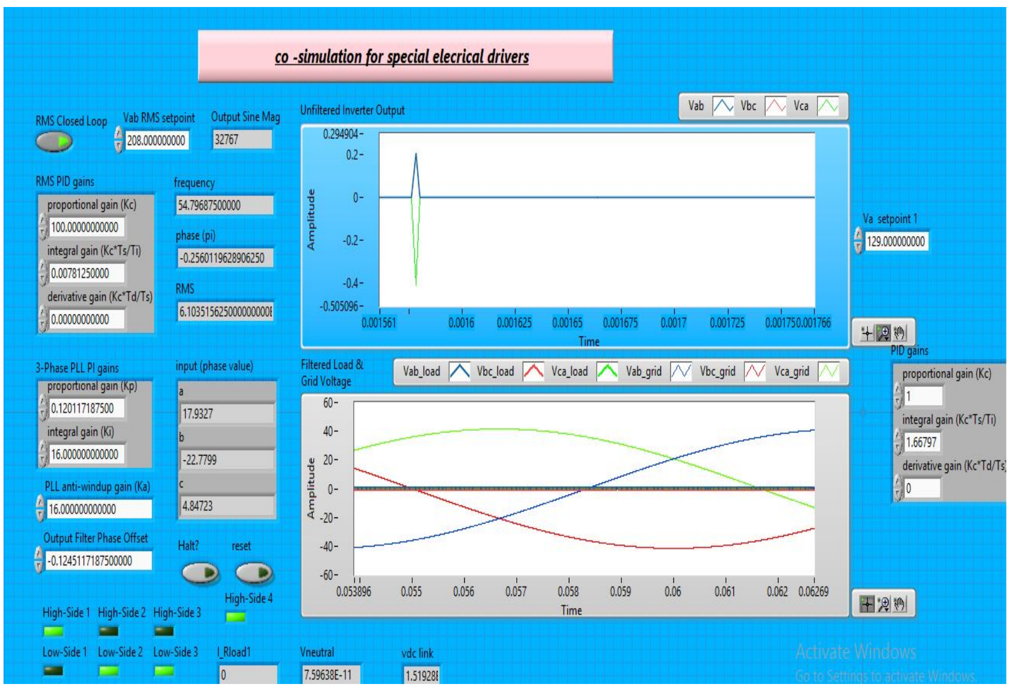

Fig. 7 NI-LabVIEW Front panel

B. Simulation in MultiSIM

It is the short form for multiple simulations. MultiSIM is an industry standard, best in class SPICE simulation environment. It is used for expertise in practical application such as designing, prototype and testing electrical circuits. The MultiSIM design helps to save prototype iteration and optimize printed circuit board (PCB) designs earlier in process. Also it helps to understand circuit behaviour in analog, digital and power class MultiSIM includes analyses from basic transient and AC simulation to advanced parameter sweeps and noise simulation.

The main advantage is

1) Used to evaluate transient response
2) Visualize steady state ripples
3) Used to determine power efficiency
4) Review thermal performance
5) It saves PCB layout of development work so it reduces design cost.

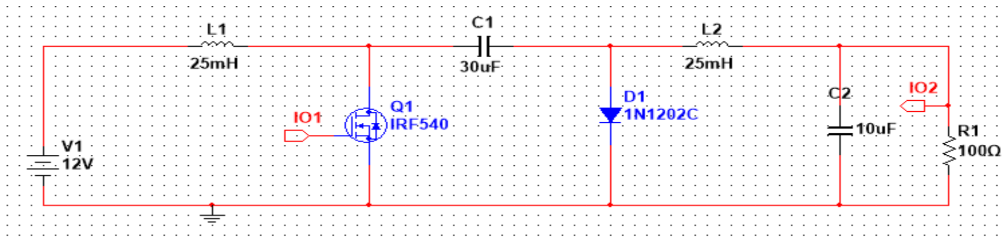

Fig. 8 Block panel of MultiSIM

C. Co-Simulation

In co-simulation the different subsystems which form a coupled problem are modelled and simulated in a distributed manner. Hence, the modelling is done on the subsystem level without having the coupled problem on the subsystem level. The coupled simulation is carried out by running the subsystems in a black-box manner. During the coupled simulation the subsystems data will exchange. Co-simulation is a joint simulation of the already well established tools and semantics; when they are simulated with their suitable solvers.

The main advantage of Co-simulation is validation of multi-domain and cyber physical system by offering a flexible solution which allows consideration of multiple domains with different time steps at the same time. Also enables the possibility of large scale system assessment.

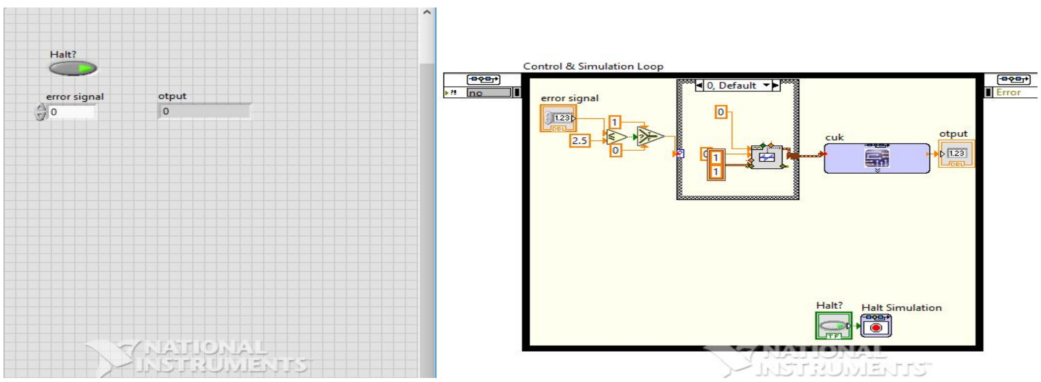

Fig. 9 Co-Simulation of LabVIEW and MultiSIM

V. CONCLUSIONS

Aim of our project is to design and develop the co-simulation approach for embedded control of electrical drive system based on NI-LabVIEW and Ni-MultiSIM for Electric Vehicle. Investigate a bridgeless PFC converter topology suitable for low-power BLDC motor applications. The proposed converter should be able to reduce the switching losses compared to other PFC topologies by minimizing the conducting elements during a cycle, therefore improving the efficiency and the industry standards.

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