

# Performance Analysis of Modified Landsman Converter-Fed BLDC Motor

<sup>1</sup>Lakitha V, <sup>2</sup>Vedhavalli G, <sup>3</sup>Roja P, <sup>4</sup>Dr S Saravanan

<sup>1</sup>Student, <sup>2</sup>Student, <sup>3</sup>Student, <sup>4</sup>Assistant professor

<sup>1</sup>Department of Electrical and Electronics Engineering,

<sup>1</sup>SRM Institute of Science and Technology, Chennai, India

<sup>1</sup>[vl2545@srmist.edu.in](mailto:vl2545@srmist.edu.in), <sup>2</sup>[vg8664@srmist.edu.in](mailto:vg8664@srmist.edu.in), <sup>3</sup>[rp0392@srmist.edu.in](mailto:rp0392@srmist.edu.in), <sup>4</sup>[saravans13@srmist.edu.in](mailto:saravans13@srmist.edu.in)

**Abstract**— A PFC in a bridge-less converter topology (Landsman converter) connected to a brushless DC motor (BLDCM) drive for low power applications is detailed. The diode switching losses are reduced by adopting the BL topology and the switching losses of the voltage source inverter solid state switches are reduced by using low frequency switching signals for electronic commutation of BLDCM motor. The landsman converter with BL PFC at the front-end and operating with DICM topology is used to control the DC bus voltage and the PFC is naturally achieved with low losses. Only one voltage sensor is used to regulate the DC bus voltage. A test bed was developed to test the BLDCM. Here the operation of BLDCM is shown with respect to its performance for different AC supply voltages (90V-265 V).

**Index Terms**— Discontinuous inductor current mode, PFC, Landsman Converter, BLDC Motor, VSI Introduction

## I. INTRODUCTION

In recent years, the need for efficient and power-quality-compatible motor drives has prompted the design of efficient power electronic converters. The modified bridgeless Landsman converter has emerged as a promising candidate to enhance efficiency and power factor in Brushless DC (BLDC) motor drives. Traditional AC - DC conversion with diode bridge rectifiers leads to large conduction losses and degrades system efficiency. The bridgeless Landsman converter removes the diode bridge, resulting in lower losses, better thermal management, and improved efficiency. Traditionally, DC-DC converters like buck, boost and Ćuk converters have been used, but they have poor power factor correction (PFC) and efficiency. The Landsman converter, which is derived from canonical switching converters, provides inherent PFC and better current shaping. The latest research involves incorporating bridgeless topologies and discontinuous conduction mode (DCM) to improve its performance, making it suitable for BLDC motor drives.

There are a number of research papers in the literature on Landsman converter-fed BLDC motor drives. Earlier research has shown the benefits of single-sensor-based bridgeless Landsman converters in power factor correction and motor drive efficiencies [1], [5]. Variants of the converter have been reported to achieve improvements in power factor correction at the source and lower harmonic distortion [2], [13]. Other studies have proposed using Landsman converters for solar PV-fed BLDC drives, electric vehicle drives, and exhaust fan drives [3], [4], [8]. Research has demonstrated that these converters can achieve unity power factor, low switching losses and enhanced dynamic response [6], [9]. Further studies on PFC converters and BLDC motor drives underline the significance of efficient power conversion, stress reduction on the components, and enhanced reliability for industrial applications [11], [14].

While progress has been made, there are still some limitations in the existing work. Numerous systems use multiple sensors, which adds to the complexity and cost of the system. Certain converter topologies have high switching stresses, large number of components and low efficiency over a wide input voltage range. Further, simultaneous high power factor and low total harmonic distortion (THD) is often difficult to achieve in practice. There is also a need to enhance thermal considerations and reliability under dynamic load conditions. Furthermore, control techniques with low hardware requirements yet high performance need to be improved.

This paper proposes an improved version of a bridgeless Landsman converter-fed BLDC motor drive to overcome these issues. The system adopts a single voltage sensor for control, operates in discontinuous conduction mode to achieve inherent power factor correction and employs a bridgeless design to minimise conduction and switching losses. This approach offers high efficiency, lower component stresses, and better power quality. This paper is further organized as follows: Section II discusses the working principle and methodology of the proposed system, Section III shows the simulation and experimental results, and Section IV concludes the performance of the system.

## II. LITERATURE REVIEW

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### III.METHODOLOGY

The bridgeless Landsman Power Factor Correction (PFC) converter does not include a diode bridge rectifier. The AC source can be directly connected to the PFC converter and hence the efficiency of the conversion process can be enhanced and the number of conversion steps can be reduced. The PFC converter operates on the input AC voltage during each half cycle by switching (with different switching paths for the positive and negative half cycles). The conduction paths are separated for the half cycles of conduction, thus giving the optimum current flow. The number of semiconductor devices conducting during the conversion process for each half cycle is reduced, thus resulting in lower conduction losses than those observed in systems with bridge rectifiers (and lower efficiency). Efficient rectification and energy transfer will enhance the input power efficiency. This in turn leads to an improvement in system efficiency and improvement in the grid interface power quality.

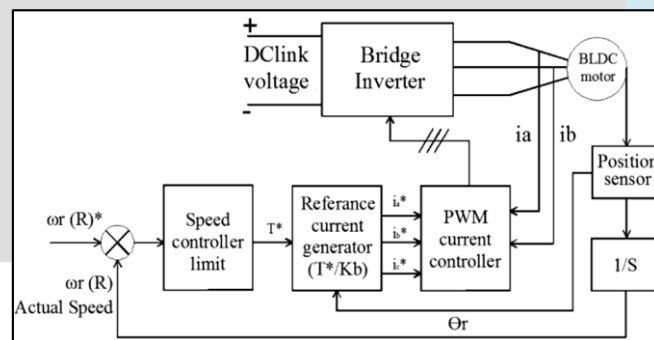


Fig 1. Block diagram

Typical AC/DC conversion systems (using a diode bridge) suffer from high conduction losses as a result of the extra serial connected diodes in the bridge. By implementing a bridgeless converter (eliminating the full bridge rectifier at the input) the number of power side current paths has been minimised which results in a reduction in voltage drop and conduction losses per switching cycle by almost 50%. With reduced power losses, the system's thermal performance increases. Better thermal performance also means a less fatigued environment; thus, increasing the reliability and eliminating the need for bulky heat sinks. All of this allows for an improvement in efficiencies at low line voltages. Therefore, the removal of the full-bridge rectifier will improve system performance.

The Landsman converter is the semiconductor device that exhibits the best PFC characteristics due to its inherent current-shaping ability. It is a canonical switching converter with an output inductor that will provide continuous current characteristics and reduced ripple in the input current. This will allow the input current to follow the input voltage's sine wave and the input current will be in phase with the input voltage, thus allowing for a near-unity power factor at the AC mains. The total harmonic distortion of the input current will be kept low. Furthermore, this topology will enable boosting of the DC-link voltage for regulation. As such, the Landsman converter will provide both power quality and voltage regulation.

The system is using a single voltage sensor for feedback control. The voltage sensor is used to sense the DC-link voltage of the converter. This voltage is compared with a reference voltage; the error signal (difference) between the two will be applied to the PI controller. The benefits of using this approach are that the hardware is less complex, and with fewer sensors, there is a reduction in the system cost. Also, it is easier to condition and isolate the sensor signals due to the reduction in the number of sensors. Lastly, using discontinuous conduction mode of the converter allows for inherent power factor correction (PFC) without the need for current sensing - thus ensuring more cost effective and reliable operation.

PWM is used to regulate the DC link voltage through duty cycle control of the switch based on the PI Controller output and in turn regulate the DC output from the converter to a constant level by varying the duty cycle. The PWM signal is generated by comparing the control signal with a high frequency waveform (carrier) which will ensure accurate switching. The DC link voltage is maintained constant despite variations in the magnitude of input voltage (due to low to high mains). So, PWM control should allow better operation with regard to the voltage regulation.

A well-regulated DC-link voltage will be provided to the VSI that drives the BLDC motor. The DC link capacitor stores the energy from the PFC stage to the inverter stage. DC regulation ensures the inverter switching operation is stable. The role of inverters is to convert DC to three-phase AC supply required for the motor. DC stability will ensure that there is no torque ripple and/or speed variation of the motor. In terms of response, the stability in voltage provides better response for load variations. Power flow from the PFC stage to the inverter is seamless and so that there is no interruption in power being delivered to the motor.

Compared to motors that use brushes (commutation): BLDC's use electronics (electronic commutation) to accomplish this task. Using Hall-effect sensors, a BLDC can sense the position of its rotor to know which switches on the inverter should be switched on and off. This removes the issues of sparking and sparking and wear of brushes. Electronic commutation makes the system more efficient. There is no mechanical wear out of any parts, maintenance costs for a BLDC are much lower. The speed of a BLDC is controlled by modulating the inverter switching signals. These characteristics of BLDC offer high reliability, efficiency and maintenance-free operation.

By using the appropriate topology (converter structure), it is possible to minimise the levels of voltage and current stress seen by semiconductor devices. A design that is both Interleaved and Bridgeless distributes the current across multiple channels, which further reduces the stress level and the peak voltage created from switching transitions; as such, reducing the stress levels allows for devices to be pushed to their limits and therefore increases their lifetime. Further, thermal performance is improved from a lower amount of power losses across the components due to the lower stress; thusly, it is possible to use lower rated devices, and hence save on system costs. Finally, with a reduction of stress levels, it makes the entire motor drive more reliable.

The system is designed in a suitable simulation software such as MATLAB/Simulink. Simulations will be done from the bridgeless landsman PFC stage, through the DC link capacitor, to the inverter and a BLDC motor. The simulation will show key performance parameters (i.e. power factor, total harmonic distortion and stresses on devices). Motor speed and torque characteristics will be determined at various motor load levels. Input current waveform will be analysed to ensure that the input to the AC motor is sinusoidal. DC link regulation will be verified to be regulated properly for different DC input voltages. The overall configuration and control structure of the proposed system are illustrated in Fig. 2.

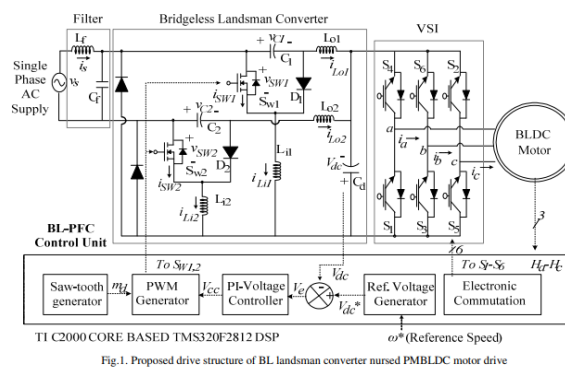


Fig.2. Circuit diagram for Bridgeless landsman converter-Fed BLDCM.

#### IV. ANALYTICAL STUDY AND SIMULATION DIAGRAM

A MATLAB/Simulink-based simulation model of the proposed system is created to study the performance of the bridgeless Landsman converter-fed BLDC motor drive. It includes a single-phase AC input source, a bridgeless Landsman power factor correction (PFC) converter, a DC-link capacitor, a three-phase voltage source inverter (VSI), and an electronically commutated BLDC motor, as indicated in Fig. 3. This model combines both the power and control circuits for the steady-state and dynamic analysis under different operating conditions.

The power factor correction (PFC) stage is a bridgeless Landsman converter, which directly converts the AC input, bypassing the traditional diode bridge rectifier. This eliminates conduction losses and enhances efficiency. For each half-cycle of the AC input, one of the switches is turned on to store energy in the inductors and transfer it to the DC-link capacitor. This converter works in discontinuous conduction mode (DCM), which inherently provides power factor correction by making the input current to follow the input voltage (see Fig. 3). The control signals are aligned with the input voltage using a Phase-Locked Loop (PLL) block. The control of the switches is achieved by generating PWM pulses using a control circuit with a PI voltage controller. The DC-link voltage is measured and compared against a desired reference and the controller acts on the error to modulate the switches' duty cycles. This helps to maintain the DC-link voltage at a desired level, regardless of input voltage source or load changes, as shown in Fig. 3.

The DC-link stage is a capacitor that serves as a buffer between the converter and the inverter. The DC-link voltage is regulated (to about 523 V as seen in the simulation), which allows the flow of power to the inverter. There are voltage and current measurement blocks to observe system performance variables such as output voltage, output current and power factor (as shown in Fig.3). The three-phase VSI is responsible for converting the DC voltage into the AC supply needed for the BLDC motor. Electronic commutation is applied to the inverter switches by considering the rotor position information from Hall sensors and a decoder. This guarantees the correct switching sequence of the motor phases to produce torque and smooth operation. The BLDC motor provides important variables like stator current, back EMF, rotor speed, and electromagnetic torque as illustrated in Fig. 3.

The simulation outcomes show that the proposed system has near unity power factor, low harmonic distortion and safe motor operation. The motor operates with a steady-state speed of around 2456 rpm with low variations, suggesting successful speed regulation. The torque is smooth, and the stator currents are balanced, indicating successful operation of the inverter. In summary, the simulation confirms the bridgeless Landsman converter's effectiveness in enhancing efficiency, power quality, and overall performance of the BLDC motor drive system (Fig. 3).

**V.EXPERIMENT RESULTS**

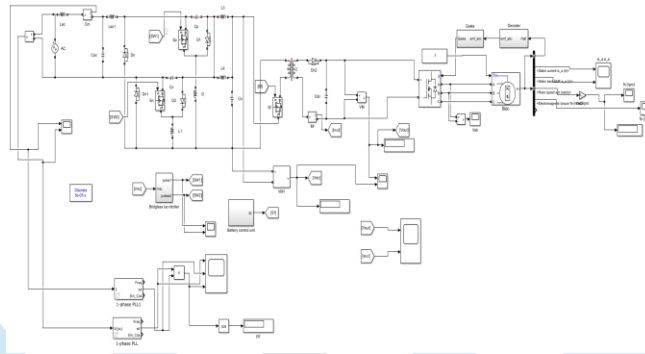


Fig.3. Simulation Diagram

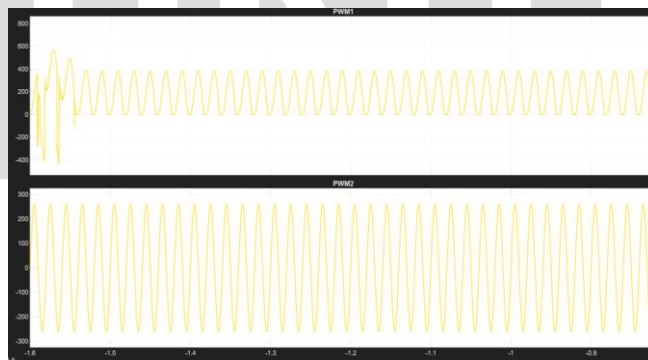


Fig 1. Input Voltage and Current.

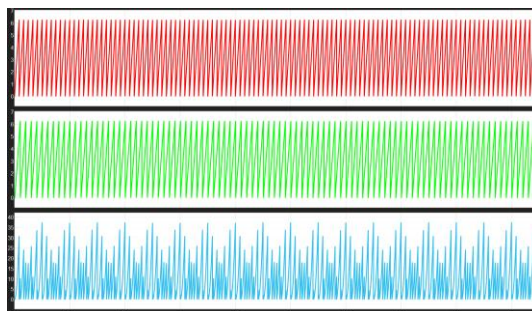


Fig 2. Phase Lock Loop Voltage, current and power.

The Input Current and Voltage Waveforms (PWM1 and PWM2) show the success of the integration of the bridgeless rectification stage into the design of the product. The precision of the bridgeless rectification stage enables the input AC voltage to

be processed at high frequency to give a sine wave envelope that matches the current demand. The bridgeless design allows for low conduction losses and this is shown by the high density switching pulses that are held at peak-to-peak levels.

Besides the Input Current and Input Voltage Waveforms, the Phase Locked Loop (PLL) voltage, current and power levels confirm the phase and frequency matching of the input to the converting logic. The PLL has been developed to lock the input frequency and phase to provide a base for the converter control. This means that there is always high frequency energy flowing from the source to the converter. A very high degree of synchronisation is needed to achieve the Power Factor (0.9811 in the model) of the Landsman converter which shows it is operating at near unity power factor.

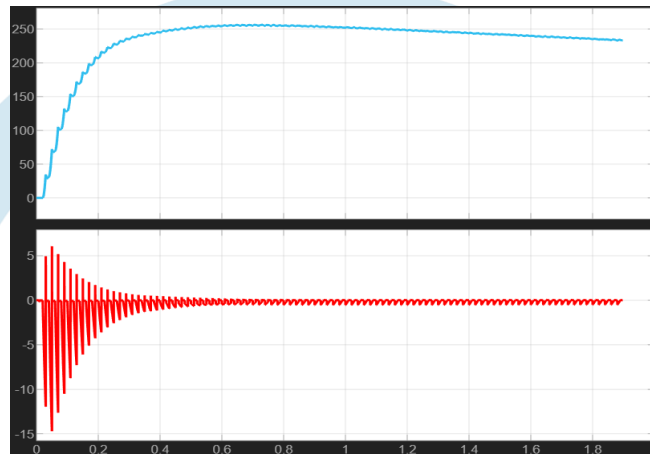


Fig 3. DC Voltage and Current

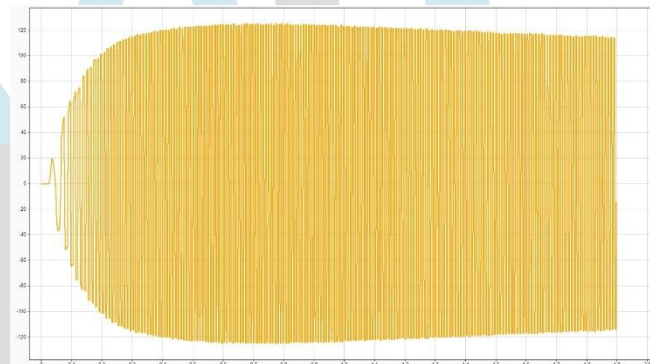


Fig 4. Line to Line Voltage.

In addition to the high gain and commanding stability of the Landsman method, this study shows a smooth rise in the DC link voltage which eventually settles to a steady state DC link voltage level of about 523V (flat). As the DC link is the main energy storage for the BLDC Inverter, its flatness indicates a successful closed-loop voltage regulation. The DC current closely follows the motor’s current during normal operation, it has a smooth behaviour after power up (start) which reduces the ripple current and hence the life of the intermediate energy storage components.

The Line-to-Line Voltage is a proof of successful DC Link to 3-phase AC conversion. The shape is symmetrical and the amplitude has peaks, which are consistent with the 523VDC source (all peaks are high frequency). Therefore, the motor will receive a perfectly balanced supply and a very powerful electrical supply for its lifetime because of the steady state voltage envelope. The buildup of the total voltage envelope during the power on phase shows that soft-starting has successfully contained the inrush current and the motor has not suffered from any mechanical shocks, enabling the long life and reliability of the motor drive system.

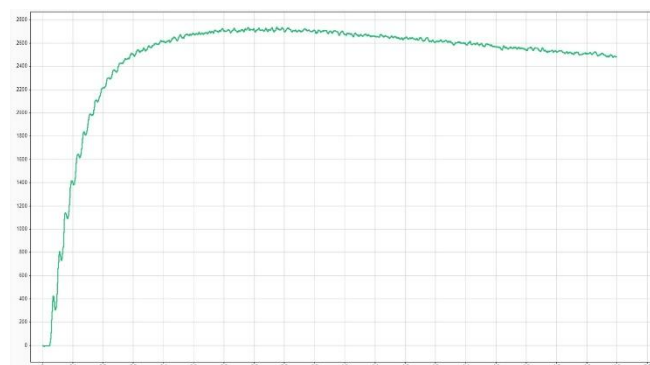


Fig 5. Speed of the Motor.

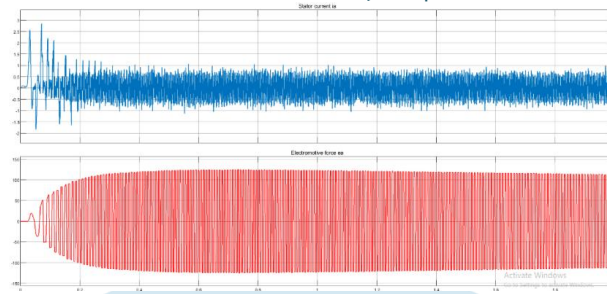


Fig 6. Stator Current and Torque.

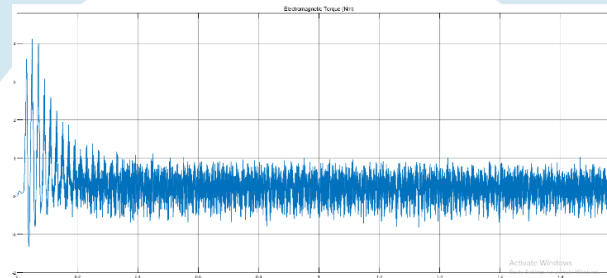


Fig 7. Torque.

The most impressive graph is Rotor Speed, where the motor reaches a steady state value of 2456 RPM in speed. The curve exhibits a very rapid linear acceleration, followed by a very stable overshoot around the desired speed. As a result of this fast response speed curve, driven by a PI based speed control loop, the Bridgeless Landsman converter has been shown to be capable of operating at high power levels, and providing very accurate speed control. With the stable output of 2456 RPM, this motor drive system is suitable for use in high performance industrial systems where constant speed is important regardless of load.

Lastly, The Stator Current, Back EMF and Torque waveforms all offer further evidence of the electrical and mechanical health of the motor. The Stator Current is evenly distributed between the three phases, and has a consistent AC waveform that corresponds with the trapezoidal Back EMF waveform that is produced by the permanent magnets on the Rotor. The Electromagnetic Torque has a large peak to generate initial motion, and then a stable level to sustain 2456 RPM. The smooth torque and Back EMF waveforms both confirm the electronic commutation has been timed with the rotor to ensure maximum efficiency and minimal operating noise.

**VI.HARDWARE RESULTS**

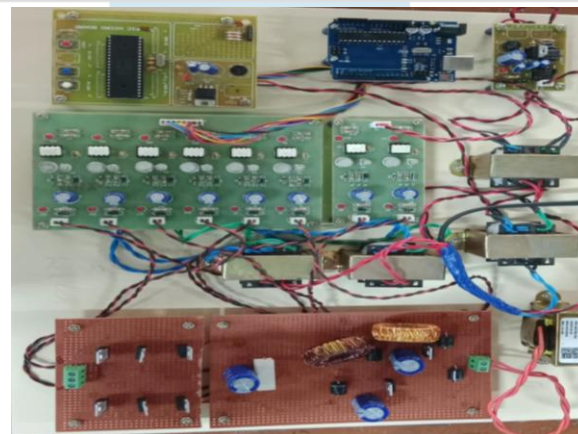


Fig 8. Hardware kit.

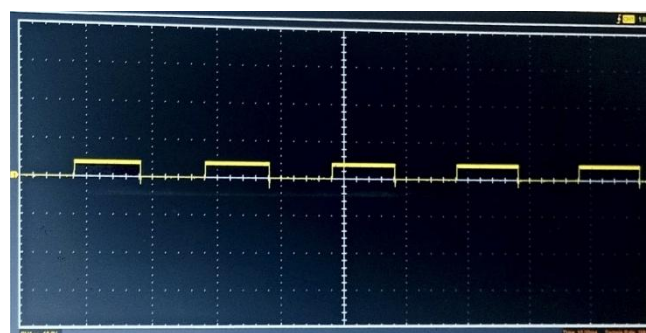


Fig 9. Obtained PWM gate signal waveform.

## VII. CONCLUSION

Design, simulation, and experimentation of a bridgeless landsman topology PFC converter-fed BLDC motor drive to obtain an efficient design for modern industrial motor applications by using a bridgeless rectifier in the front end, and a high gain landsman topology. The proposed project has addressed the major issue of the power factor correction (PFC) and stress on the components due to their high power quality and low conduction losses. The simulation results indicate that the system has unity power factor (PFC) of 0.9811 at input side and guarantees a very high power quality and low cost compared with a bridged rectified design. With such high quality electrical performance, there will be a steady and stable 523V DC bus available which can provide energy for the high speed motor drive.

The motor drive also verifies the performance of the Control Systems as the BLDC motor operates at constant speed of 2456 RPM and the back EMF is trapezoidal with no arcing of the electrical joints. It is clear that the electronic commutator is in sync with the rotor position and the PI speed controller has followed the rotor position accordingly. Hence, it enables the maximum energy transfer efficiency of the drive systems and the lifetime of the power electronics by avoiding electrical stress and thermal cycling of the power electronics. In summary, this project has been developed and verified as a proof of concept of a high power electric motor drive system that is grid compliant and offers high mechanical power of the motor drive.

## VIII. ACKNOWLEDGMENT

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