Global Warming Mitigation Utilizing the Invention Entitled "A Self Starting Method And An Apparatus For Sensorless Commutation of Brushless DC Motors" WIPO International Publication Number WO 2006/073378 A1
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Introduction

Since the beginning of the industrial revolution, atmospheric concentrations of carbon dioxide have increased nearly 30%, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15%. Carbon dioxide is the key greenhouse gas which is responsible for global warming concerns, and the overwhelming share of world carbon dioxide emissions comes from burning fossil fuels, such as coal, oil and gas – our main sources of energy.

The increased industrial activities occurring in traditional industrialised countries, together with the rapid industrialisation taking place in China and India, have increased the global demand for energy. The negative effect of this growth in industrialisation is to increase the percentage of greenhouse gases in the atmosphere, thereby enhancing its heat-trapping capability. The changing climatic conditions caused by greenhouse gases could alter forests, crop yield and water supplies, which in turn would affect human health, animals and many types of ecosystems.

The negative impact of industrialisation on the environment could be reduced through the use of Energy Efficient Systems and Clean Alternative Sources of Energy. Energy Efficiency allows more work to be done per KWh of electricity, thereby reducing the percentage of greenhouse gases which is delivered to the atmosphere, for the same level of industrial activity; while, Clean Alternative Sources of Energy are not fossil based, and would not contribute to the rise in carbon dioxide levels in the atmosphere.

Hence, the way forward is to focus on research activities and develop innovative techniques, to bring High-Performance Energy Efficient Systems and Clean Alternative Energy Systems to the marketplace. These efforts would ensure that we maintain an environment which is capable of sustaining human and animal life.

Role and Environmental Impact of Motors in Industrialised States and the Present State of the Art

Induction motors are widely used in the manufacturing sector and are called the workhorse of industry. These motors consume between 60-70 % of the electrical energy generated in industrialised countries, where in most cases, this electrical energy is generated using oil and gas. With the increasing demand for oil and gas, the depletion of these resources, the rising price of Brent North Sea Crude Oil (reaching an all time high of US $75 a barrel), the instabilities in the Persian Gulf and the negative effects of fossil fuel to the environment, the need for research and development in Efficient Energy Systems and Alternative Sources of Energy has become mandatory, especially for industrialized states utilizing inefficient induction motors in their manufacturing processes.

Many other types of motors are available for industrial applications. They include: the synchronous motor, the brush dc motor, the reluctance motor and the brushless dc motor. The Brushless DC (BLDC) Motor has been gaining popularity in the Appliance, Automotive, Aerospace, Consumer, Medical, Computer and Industrial Automation industries and possesses many advantages over the other motors. Some of these advantages are:

(a) High power density, low inertia and high torque to inertia ratio and high dynamic response due to the small size, low weight and high flux density neodymium-iron-boron permanent magnet rotor.
(b) High efficiency due to the low rotor losses as a result of the absence of current carrying conductors on the rotor and reduced friction and windage losses in the rotor.
(c) Long operating life and high reliability due to the absence of brushes and metallic commutators.
(d) Clean operation due to the absence of brushes, resulting in no brush dust during operation and allowing for clean room applications.
(e) Low audible noise operation due to the absence of brushes, commutators and smooth low air resistance rotor.
(f) High speed operation in excess of 80,000 rpm is possible, since these motors are electronically commutated and are not subjected to the limitations of conventional commutations.
(g) Low thermal resistance since most of the machine losses occur in the stationary stator, thereby allowing heat dissipation by the process of direst conduction. In addition, since the rotor losses are small, heat transfer to machine tools and work pieces when these motors are utilized in machine tools is minimal, thereby reducing the effects of heat on the machining operation.
(h) Low EMI/RFI due to the absence of brushes and metallic commutators.

The advantages of BLDC motors stated above, provides an attractive solution to energy efficiency and environmental pollution, resulting in the motor doing more work per KWh of electricity and bringing industrialised states in alignment with the specifications of the Kyoto Protocol. However, BLDC motors have some disadvantages over the traditional AC Induction and Brush DC motors. These disadvantages are the need for an inverter switch unit, a Digital Signal Processor (DSP) and rotor position sensors to provide rotor position information to commutate and drive the motor, thereby adding increased cost and complexity, and resulting in decreased overall system efficiency and reliability.

The rapid advancements in the power semiconductor and DSP technologies over the last ten years have reduced the cost, complexity and size of electronic drives for BLDC motors, thereby making them competitive with the traditional motors. This leaves the BLDC motor with one disadvantage, the need for rotor position sensors to provide rotor position information to commutate and drive the motor. BLDC motors have been traditionally commutated with Hall sensor devices. This sensored commutation technique employs a sensing magnet of same polarity as that of the rotor magnet and is attached to the rotor in close proximity to the Hall sensors. Three-phase BLDC motors require three Hall sensors and an external dc power supply, resulting in five motor connected wires for the purpose of commutation, together with the three power wires which are necessary for the electromechanical energy conversion process.

Research in the area of sensorless commutation and control of these motors, to reduce motor complexity, and hence increase the reliability of the system, provide further cost reduction of the motor and maintain system efficiency, has been taking place for over twenty years. Three sensorless commutation techniques have been presented in the prior art. They are: ***the BEMF (Back EMF) Zero Crossing*** by Knight J. H., and presented in "Rotary Machine," US Patent 4,027,215, May 31, 1977; ***the BEMF Integration*** by Lerdman D. M., and presented in "Electronically Commutated Motor," US Patent 4,169,990, Oct. 2, 1979 and ***the BEMF Third Harmonic method*** by Vulosavic S. N., and presented in "Third Harmonic Commutation Control System and Method," US Patent 4,912,378, Mar. 27, 1990. However, these three sensorless commutation techniques ***have proven to decrease the reliability and performance of the motor, and more importantly, these sensorless commutation techniques are not self-starting and must rely on a prescribed starting technique.*** These sensorless commutation techniques employ information from the previous commutation interval in the determination of the new commutation point, resulting in an estimation of the new commutation point. This method is adequate for constant speed, no-load operation, but produces advanced or retarded commutation under load and variable speed conditions, resulting in high motor currents and degraded performance under these operating conditions. Commutation points are also missed in these sensorless commutation techniques and are compensated by the introduction of an estimated commutation point. Some of these sensorless commutation techniques require the use of motor parameters, some of which undergo variations with ambient conditions and motor variables, resulting in incorrect commutation point determination as a result of motor parameter variation. And finally, these sensorless commutation techniques all depend on the magnitude of the detected BEMF, which is a function of the motor speed. Hence, at low speeds when the BEMF is small, incorrect commutation takes place, resulting in stalling of the motor.
The economic and environmental benefits which are possible with the utilization of BLDC motors in industrialised countries has been driving the intense research efforts by the major players in the field like; IBM, Hitachi Ltd, Samsung, Seagate Technology, Inc., Dalkin Industries, Ltd., Daewoo Electronics Co., Ltd., SGS-Thompson Microelectronics, Inc., etc., to develop a robust sensorless commutation technique which would result in a tremendous intellectual property asset. These companies have dominated the International Patent Classification (IPC) categories of H02P and H02K with patents for several years. However, they have not been successful in the production of a robust commutation technique for BLDC motors.

The possibility of the existence of a new commutation technique for BLDC motors, which is superior to the three sensorless techniques presented in the prior art, to derive the energy efficient and environmental advantages of these motors, became visible to this inventor in the time-space transformation theory of electrical variables. This theory presented the possible existence of electrical time dependent variables in the spatial domain, and had been presented by two Hungarian scientists Kovacs and Racz in **"Transient Phenomena in Electrical Machines,"** Verlag der Ungarischen Akademie der Wissenschaften, Budapest, 1959. However, proof of equality of the magnitude of these variables in the time and spatial domains had not been presented, and more so, the referral of scalar electrical quantities in a motor to vector magnetic quantities and vice versa is absent in the literature.

The invention entitled ***"A Self Starting Method and an Apparatus For Sensorless Commutation of Brushless DC Motors" PCT/TT 2005/000001,*** describing the development and application of the ***De Four BEMF Space Vector Resolver*** for the efficient commutation of BLDC motors was examined at the ***Austrian Patent Office under the Patent Cooperation Treaty (PCT) of the World Intellectual Property Organisation (WIPO).*** The results of this examination are presented in the documents dated 19 April 2006, entitled:

(a) PCT Notification of Transmittal of The International Search Report and The Written Opinion of The International Searching Authority, or The declaration
(b) PCT International Search Report
(c) PCT Written Opinion of The International Searching Authority.

These three documents (a), (b) and (c) constitute the ***International Preliminary Examination Report (IPER).***

The five documents cited in the PCT Search Report, two US patents and three refereed publications from prestigious journals were reported to be ***" defining the general state of the art which is not considered to be of particular relevance."*** The Written Opinion of The International Searching Authority reported on the five cited documents by stating ***"the recited components and sequential steps of DC motor control are not disclosed by the cited art."*** The report concluded by making a clear statement of De Four's invention of ***"A Self Starting Method and an Apparatus For Sensorless Commutation of Brushless DC Motors" PCT/TT 2005/000001,*** by stating ***"thus, claimed subject matter can be considered new and inventive. Industrial applicability is given"*** and presented novelty, inventive step and industrial applicability for all 9 claims. Hence, a clean and positive IPER has been given to this invention. In addition, this inventor's departure from the prior art in this invention and extent to which he distanced himself from all the other players in the field occupying IPC categories HO2P and HO2K was realised in the ***new IPC of H02P 6/18 (2006-01)*** which has been given to this invention. Thus, a new pillar has been created in the field by this invention, which increases the energy efficiency of BLDC motors, and when implemented in the marketplace, it shall decrease the greenhouse effect produced by carbon dioxide emissions for the same level of industrialisation. This invention is published on the Internet on WIPO's web site under the International Publication Number of **WO/2006/073378 A1.**

Conclusion

The clean and positive IPER given to this invention entitled: *"A Self Starting Method and an Apparatus For Sensorless Commutation of Brushless DC Motors,"* together with the excellent performance evaluation results produced by the employment of the De Four BEMF Space Vector Resolver, which is utilised in the said invention for the commutation of phase windings of a BLDC motor provides strong and unquestionable justification for the utilization of this invention for motor applications. In addition, due the excellent electrical, energy efficiency and environmental properties of this invention, it is expected to control a significant amount of the market share in the Appliance, Automotive, Aerospace, Consumer, Medical, Computer and Industrial Automation industries.