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Datasheet for the decision of 27 February 2008

Case Number: T 0965/06 - 3.2.01

Application Number: 95112311.6

Publication Number: 0710599

IPC: B62D 6/00

Language of the proceedings: EN

Title of invention:
Method and apparatus for controlling an electric assist steering system using two-dimensional interpolation for current commands

Patentee:
TRW INC.

Opponent:
Switched Reluctance Drives Limited

Headword:
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Relevant legal provisions:
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Relevant legal provisions (EPC 1973):
EPC Art. 56

Keyword:
"Inventive step (no)"

Decisions cited:
-

Catchword:
-

Case Number: T 0965/06 - 3.2.01

D E C I S I O N
of the Technical Board of Appeal 3.2.01
of 27 February 2008

Appellant: (Opponent)	Switched Reluctance Drives Limited East Park House Otley Road Harrogate North Yorkshire HG3 1PR (GB)
Representative:	Hibbert, Juliet Jane Grace Kilburn & Strode 20 Red Lion Street London WC1R 4PJ (GB)
Respondent: (Patent Proprietor)	TRW INC. 1900 Richmond Road Lyndhurst Ohio 44124 (US)
Representative:	Wagner, Karl H. et al WAGNER & GEYER Patentanwälte Gewürzmühlstrasse 5 D-80538 München (DE)

Decision under appeal: **Decision of the Opposition Division of the European Patent Office posted 12 April 2006 rejecting the opposition filed against European patent No. 0710599 pursuant to Article 102(2) EPC 1973.**

Composition of the Board:

Chairman: S. Crane
Members: C. Narcisi
G. Weiss

Summary of Facts and Submissions

I. The Opposition Division rejected the opposition against European patent No. 710 599 with its decision posted on 12 April 2006. Against this decision an appeal was filed by the Opponent on 16 June 2006 and the appeal fee was paid on 19 June 2006. The statement of grounds of appeal was filed on 8 August 2006.

II. Oral proceedings took place on 27 February 2008. The Appellant requested that the decision be set aside in its entirety and that the patent be revoked. The Respondent requested that the appeal be dismissed.

Granted claim 1 reads as follows:

"An apparatus for controlling a steering assist system (10), said steering assist system providing steering assist in response to a steering control signal, said steering assist system including a variable reluctance motor (26), said apparatus comprising:
motor position sensing means (54) for sensing the relative position between the rotor's motor and stator;
first and second torque look-up tables (T1,T2), each of said first and second torque look-up tables having motor current values that vary as a function of motor position;
control means (150) operatively connected to said motor position sensing means (54), characterized in that
said control means (i) determine (310) a first motor current value (I1) by interpolating between two current values corresponding to the two motor positions stored in the first look-up table (T1) closest to the sensed motor position, (ii) determine (312) a second motor

current value (I2) by interpolating between two current values corresponding to the two motor positions stored in the second look-up table (T2) closest to the sensed motor position, and (iii) determine (314) a final motor current value (ICMD) by interpolating between the first and second determined motor current values; and provide (316) a motor control signal in response to said determined final motor current value (ICMD)."

III. The Appellant's arguments may be summarized as follows:

Document D1 (US-A-5 257 828), which incorporates document D2 (US-A-4 868 477) disclosing a control method for a switched variable reluctance motor (see D1, column 4, lines 59-63), represents the closest prior art and has the features of the preamble of claim 1. In particular D2 mentions first and second look-up tables, for a first and second torque value, having motor current values that vary as a function of motor position (D2, column 4, lines 22-31). The technical problem to be solved by the invention may be seen in providing a way of accessing the values on the matrix formed by said tables in order to derive from said matrix an appropriate electrical current value, given that the sensed position and the desired torque value will in almost every case in practice not correspond to any pair of stored rotor position and torque value. In the alternative, the technical problem may also be formulated as finding a way of increasing the degree of resolution, i.e. reducing the discretisation error, without adding storage capacity, this last possibility being already mentioned in D2 (column 5, lines 8-13). In fact, the two problems are equivalent, and the solution leads to a reduction of torque ripple, as stated in D2 (column 1, lines 39-51). From the further available prior art, e.g. A1 ("Numerical recipes in C", second edition, by William H. Press et al., Cambridge University Press, 1992, Chapter 3), A2 ("The Characteristics, Design and Applications of Switched Reluctance Motors and Drives", by Dr. J M Stephenson et al., PCIM 1993) and D3 (JP-A-62 255 277 including patent abstract) it is clear that using two dimensional linear, i.e. bilinear, interpolation in order to solve the mentioned technical problem, as is implied by claim 1, would be obvious for the skilled person. In fact, these documents demonstrate that this interpolation method forms part of the mental tool kit of the person skilled in the art, and moreover that it was already applied in the same technical field for the same purpose (see D3). Hence the subject-matter of claim 1 lacks an inventive step with respect to D1 taking into account the general knowledge of the skilled person.

IV. The Respondent's arguments may be summarized as follows:

The actual objective problem of the invention is neither to reduce the discretisation error without increasing the storage capacity of the control unit nor finding a way of addressing the stored data to derive an appropriate current value, as stated by the Appellant, but instead reducing noise produced during the operation of the electric motor. The technical problem mentioned by the Appellant cannot be regarded as the objective technical problem of the invention, since it is not permissible to formulate the technical problem in such specific terms which already hint at a possible solution. Indeed, once the objective technical problem is properly established as being that of reducing noise, it appears that the skilled person would have no plausible reason to consider that any of documents A1, A2 or D3 could possibly furnish the solution. In fact, there appears to be no hint either in closest prior art D1 or in anyone of these documents that interpolation methods might at all play a role in reducing the noise produced by a switched reluctance motor. In particular it is noted that D1 does not mention interpolation at all and D2 only uses interpolation to provide the electrical current values to be stored in the look-up table. A1 is a mathematical handbook which teaches, among other scientific computing methods, linear two dimensional and other interpolation methods, without giving however any suggestion as to possible applications to switched reluctance motors. A2 actually gives on page 37 an indication that a single interpolation step is performed for determining a current level, for a sensed position at a given torque, from two stored current values and corresponding stored angular positions of the motor at the given torque. Therefore, contrary to granted claim 1, no further interpolating step depending on the stored torque values is performed. Document D3 likewise would not lead the skilled person to the claimed invention since it merely addresses the problem of reducing the required memory capacity in a control system. In summary, the skilled person in view of this prior art would not arrive in an obvious manner at the subject-matter of claim 1, since he would have no reasons and no incentive to employ a two dimensional interpolation method in combination with the control method disclosed in D1.

Reasons for the Decision

1. The appeal is admissible.

2. It is undisputed that D1, which incorporates D2 disclosing a control method for a variable reluctance motor (see D1, column 4, lines 58-63), is to be regarded as closest prior art including all of the features of the preamble of claim 1. The objective problem underlying the invention may be deduced from paragraphs [0009] to [0012] of the patent specification and from the characterizing features of claim 1 which determine the differences to D1.

In paragraph [10] it is stated that "the amount of noise and ripple occurring upon energization of the electric assist motor is functionally related to the number of data values stored in the mapping table". In particular, "the larger the "space" between motor position vs. current values in the table, the more noise that occurs upon motor energization". However, "to store enough values in a current map to ensure a quiet motor operation, requires a substantial amount of memory". Thus, a direct relation is clearly established between the torque ripple and noise, on the one hand, and the spacing between electrical current values and rotor position values stored in the table for a predetermined torque, on the other hand.

In conclusion, having regard to the characterizing features of claim 1 and the mentioned passages of the introductory portion of the description of the patent, it is evident that the objective problem of the invention is to reduce torque ripple and noise by finding a way to define and access a larger number of current values corresponding to selected torque values and respective sensed rotor positions.

3. The above facts which are described in paragraphs [0009] to [0012] of the patent specification as forming the background of the invention, are also part of the general knowledge of the person skilled in the art, as is confirmed by the cited prior art. A3 ("Torque ripple minimization in switched reluctance motor drives by PWM current control"; I Husain and M Ehsani, Proc of IEEE 9th Applied power electronics conference, 13-17 Feb 1994) asserts that "the primary disadvantage of an SRM is the higher torque ripple, compared to conventional machines, which results in acoustic noise and vibration" (A3, page 72, left column). Further D2, which aims at smoothing torque ripple (column 1, lines 7-11), achieves a flat torque characteristic by "selecting and controlling the magnitude of the current supplied to the stator windings in accordance with the available torque that can be produced by the motor at each of the rotor positions wherein a value of current is selected at each of the rotor positions to produce a given desired torque" (D2, column 3, lines 40-46). This is accomplished by the use of a matrix stored in a memory device, the rows of the matrix containing current values at a given torque for different incremental rotor position values, whereas the columns of the matrix contain current values at a given rotor position for different incremental torque values (D2, column 4, lines 12-31). Thus, "a storage location defined by the intersection of given torque and rotor position values contains information representative of a predetermined value of current that is to be supplied

to the corresponding phase of the motor to cause the motor to develop the desired torque" (D2, column 4, lines 22-27). Therefore, using "memory devices having larger storage capacities can provide a higher degree of resolution since the torque and rotor position magnitudes can be divided into finer increments and accordingly, a larger number of current values may be defined and accessed" (D2, column 5, lines 9-13). This in turn evidently allows a finer tuning of the current at each rotor position thus leading by proper choice of the current in the different stator phases to a flat torque characteristic (D2, figure 4).

In summary, the skilled person would derive from the prior art that reducing the spacing of the stored incremental current values and of the corresponding sensed rotor positions and desired torque values a flat torque characteristic, with minimum torque ripple and noise, may be obtained.
Therefore, contrary to the Respondent's contentions, it would be misleading and erroneous to formulate the objective problem of the invention in such broad terms as being that of reducing noise since in fact a more accurate definition (see point 2) according to the aforesaid is justified and appropriate having regard to the prior art.

4. In view of the objective problem of the invention identified above the skilled person starting from D1 would notice that this document already suggests possible solutions. In fact D2, incorporated in D1, indicates that "larger storage capacities" result in a larger number of current values being defined and accessed (column 5, lines 8-13). Further, D2 also

discloses that interpolation between measured current values, at measured torque and sensed rotor positions, is employed to obtain additional current values, at specific values of torque and position, to be stored in the look-up table, thus increasing its degree of resolution (D2, column 6, lines 55-65; column 7, lines 4-11). Hence the skilled person would learn from D1 that apart from the most obvious solution consisting in increasing memory storage capacity, in the alternative an interpolation between current values stored in the look-up table would provide the corresponding current value at the desired torque and sensed rotor position.

The further cited prior art confirms that interpolation is the most obvious alternative available to the skilled person, if it were by any reason not possible or disadvantageous to increase the memory storage capacity in a specific case. Moreover, interpolation methods form part of the general knowledge of the skilled person, as also follows from the cited prior art. In this respect A2, in the same technical context of the invention (A2, page 58, paragraph 5.8), explicitly mentions that "it is possible to store a sparse matrix and carry out real-time interpolation in the microprocessor" (A2, page 37). Admittedly, A2 does not unambiguously indicate whether one- or two-dimensional interpolation is used. In the first case the current value sought after is determined by choosing the torque value nearest to the desired torque value in the look-up table and extracting from the table the two rotor positions between which the sensed rotor position lies; thereafter linear interpolation is performed between the stored current values at the said two rotor positions at the chosen torque. The skilled person would however recognize that two dimensional linear (bilinear) interpolation is the most suitable tool to be applied in the present case, since the current clearly depends on two variables, rotor position and torque, which is reflected by the stored two dimensional matrix or look-up table. The corresponding elementary formulae are given for instance in the mathematics manual A1 (page 123). Moreover, such bilinear interpolation has already been applied to servo actuators to control steering force in D3 (JP-A-62 255 277 including abstract). In D3 a sought after current value, depending on the steering angle and on vehicle velocity, is determined by bilinear interpolation from the stored look-up table as may be seen from the table together with the corresponding formulae on pages 4 to 5 of D3. The skilled person would understand that in the present case all that has to be done in order to apply these well known formulae is merely to determine four coordinate points, in the two dimensional look-up table, which constitute the square or rectangular grid within which the coordinate point formed by the desired torque and the sensed rotor position falls. The current value at this desired torque and sensed rotor position directly ensues by bilinear interpolation from said four stored coordinate points and their respective stored current values. Obviously, the electric motor is then provided with a signal corresponding to this interpolated current value.

All in all, for the reasons set out above, the skilled person in view of the stated objective problem would arrive at the subject-matter of granted claim 1 starting from D1 and further based on his general technical knowledge without an inventive step being involved (Article 56 EPC 1973).

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The patent is revoked.

The Registrar: The Chairman:

A. Vottner S. Crane