BESCHWERDEKAMMERN DES EUROPÄISCHEN PATENTAMTS | BOARDS OF APPEAL OF THE EUROPEAN PATENT OFFICE | CHAMBRES DE RECOURS DE L'OFFICE EUROPEEN DES BREVETS

Publication in the Official Journal ~~Yes~~ / No

File Number: T 549/90 - 3.5.2

Application No.: 83 109 859.5

Publication No.: 0 105 511

Title of invention: Control method for induction motors

Classification: H02P 5/40

D E C I S I O N
of 12 March 1991

Applicant:

Proprietor of the patent: Hitachi Ltd.

Opponent: Siemens AG

Headword:

EPC Art. 56, 83

Keyword: "Sufficient disclosure (yes)"
"Inventive step (yes)"

Headnote

Europäisches Patentamt | European Patent Office | Office européen des brevets

Beschwerdekammern | Boards of Appeal | Chambres de recours

Case Number : T 549/90 - 3.5.2

D E C I S I O N
of the Technical Board of Appeal 3.5.2
of 12 March 1991

Appellant : (Opponent)	Siemens Aktiengesellschaft Berlin und München Postfach 22 16 34 D-8000 München 22 (DE)
Representative :	Dr. Kübel Siemens AG Paul-Gossen-Straße 100 D-8520 Erlangen (DE)
Respondent : (Proprietor of the patent)	Hitachi Ltd. 6, Kanda Surugadai 4-chome Chiyoda-ku Tokyo 100 (JP)
Representative :	Patentanwälte Beetz sen. Beetz jun., Timpe, Siegfried, Schmitt-Fumian Steinsdorfstraße 10 D-8000 München 22 (DE)
Decision under appeal :	**Decision of Opposition Division of the European Patent Office dated 10 May 1990 rejecting the opposition filed against European patent No. 0 105 511 pursuant to Article 102(2) EPC.**

Composition of the Board :

Chairman : E. Persson
Members : W. Riewald
W.J.L. Wheeler

Summary of Facts and Submissions

I. European patent No. 0 105 511, was opposed by the Appellant on the grounds of lack of sufficient disclosure and lack of inventive step.

II. Independent Claim 1 as granted, reads as follows:

"1. A vector control method for induction motor (2) independently controlling a torque current component and an exciting current component of the primary current supplied to an induction motor through the control of an amplitude and a frequency of the primary current, including the steps of:

detecting (6) a motor voltage of said induction motor (2); characterised by

resolving (7,8) said motor voltage into a vector component e_d parallel with an exciting current component of the primary current and a vector component e_q orthogonal to said exciting current component vector; and

controlling (5,9,10,12,13,15) the frequency of said primary current so that said vector component e_d of said motor voltage is zeroed, while at the same time controlling said primary current corresponding to a difference (5) between said vector component e_q and a speed command signal (3), thereby to control the speed of said induction motor."

III. The Opponent cited in the opposition proceedings the following documents:

D1: "Siemens-Zeitschrift" 45 (1971), p. 761-764
D2: "Siemens-Forschungs und Entwicklungs-Berichte" 3 (1974), No. 5, p. 327-332
D3: "Siemens-Zeitschrift" 45 (1971), p. 195-197
D4: DE-A-2 919 852

IV. The opposition was rejected by the Opposition Division.

V. The Opponent lodged an appeal against this decision and made reference to the following further documents as evidence of the general background knowledge in the relevant technical field:

D5: D. Ernst, D. Ströle: "Industrieelektronik", Berlin, Heidelberg, New York, 1973, pp. 15-17 and 195-210,

D6: E. Eder: "Stromrichter zur Drehzahlsteuerung von Drehfeldmaschinen" Part 1, Siemens AG, 1974, pp. 47-51, and

D7: Heumann, Stumpe: "Thyristoren, Eigenschaften und Anwendungen", Edition, Stuttgart 1974, pp. 247-251.

VI. The Appellant (Opponent) argued that the description of the contested patent was partly deficient and that there were doubts, that a normally skilled person would be able to carry out the claimed invention as required under Art. 83 or 100(b) EPC. Particular attention was in this context drawn to the fact that an explanatory vector diagram, which had been presented by the Respondent (Patentee) with a letter dated 14 July 1989, was not disclosed in the original documents. Without help from this explanatory diagram, the Appellant derived from the description of the patent in suit that a d-q co-ordinate system with its d-axis being oriented on the field axis, necessarily would mean that the d-axis current component i_1d was identical with the exciting current component i_m and that the q-axis current component i_1q was identical with the torque current component i_t. The Appellant concluded that, therefore, the equation (2) of the patent, relating to the dependence of the slip frequency ω_s on the ratio of the two current components, would necessarily be fulfilled because of the physical laws of an induction motor. Following this line of argument, the Appellant took

the view that the diagrams of Figure 2 of the patent representing a dependence of orthogonal flux components ϕ_d and ϕ_q on slip frequencies deviating from said value

$$\omega_s = \frac{1}{T_2} \frac{i_1q}{i_1d}$$

were not clear.

The Appellant further criticised the use of uniform symbols in the drawings for the elements 5,9 and 17, which were drawn as differential amplifiers with a closed loop differential signal at their input. Such an interpretation would make no sense in the case of element 9.

Notwithstanding these points of criticism, the Appellant did not contest that, with appropriate explanation, the circuits disclosed in the patent might be feasible. He argued, however, that only a man with above average skill would be able to understand the disclosure of the patent and that such a skilled man would have had no difficulty in modifying the prior art in the sense of the alleged invention. As for the "person skilled in the art" no lower standard should be applied in respect of Article 56 than in respect of Article 83 EPC.

In the Appellant's view, the closest prior art was represented by the vector control method for an induction motor disclosed in D1 in connection with its Figure 1 (complete circuit diagram, including a vector rotator VD1 and a vector filter VF) and Figure 3 (circuit diagram of the vector filter including a vector rotator VD2, calculator circuit R and oscillator OSZ).

Starting from this prior art, the Appellant argued that Claim 1 solved only the objective problem to simplify the

detection of the flux oriented vector by changing from the flux vector to the voltage vector as a substitution for the flux vector. Such a substitution would only be based on the general background knowledge of the relation between the flux vector and the emf-vector, viz. the proportionality factor ω and the 90° phase difference between the two vectors.

A further subjective problem (mentioned in the patent description, column 1, lines 49 to 55), viz. the frequency control (and therewith the speed control) without the use of a tachometer generator was, in the Appellant's view, not solved with the method of Claim 1. He argued that Claim 1 did not specify that the closed loop differential signal between the vector component u_q and a speed command signal acted on the torque current command signal i_t. The Appellant stressed in particular that, according to Figure 3 of the patent, the said differential signal acted actually on the exciting current command signal i_m*. Otherwise it was, in the Appellant's view, obvious to use the frequency of the primary current or the orthogonal component u_q of the motor voltage as substitute for a speed signal.

VII. The Respondent replied that the explanatory vector diagram presented before the Opposition Division (letter of 14 July 1989) could be easily derived from the disclosures in Fig. 2(a) to (b) and equations (1) to (12) of the original specification in order to support an easy understanding of the invention.

He stressed that it was an essential feature that the error between the d-axis of the reference d-q co-ordinates and the actual flux axis had to be detected, that a q-component of the flux vector would represent such an error, but that this q-component was not directly

detected. Instead, the d-component e_d of the motor voltage vector was detected which was proportional to the q-component of the flux vector.

In the Respondent's view, the present invention could not easily be made on the basis of document D1, because the control principle of D1 was based on the detection of two components of the flux vector of the motor orthogonal to each other, and because none of the other cited references disclosed the idea of detecting the e_d component of the motor voltage in order to control the frequency so as to make e_d equal to zero.

VIII. The Appellant requested a decision according to the state of the file (Entscheidung nach Lage der Akten), if the Respondent should not file amended patent documents, and requested oral proceedings only in the event of the claims being essentially amended.

The Respondent requested that the appeal be rejected.

Reasons for the Decision

1. The appeal is admissible.

2. Sufficient disclosure of the invention.

It may be that part of the description of the disputed patent is difficult to understand. Thus, column 3, lines 8 to 10, read in isolation, may convey the idea that the d-q-reference frame is always oriented on the magnetic field axis. It is however clear from Claim 1, (column 14, lines 60 to 64) that the indices d and q refer to co-ordinates in the direction of the exciting current component and the component orthogonal to the exciting

current component, i.e. the torque current component. Upon reading further in column 3 and 4 of the description, it becomes clear, that the current components referred to there are only to be understood as command values (i_m* and i_t*) and not as the actual values (i_m and i_t); see in particular column 4, lines 57 to 64. It can therefore be understood that the equation (2), determining the slip frequency of the induction motor,

$$\omega_s = \frac{1}{T_2} \cdot \frac{i_1q}{i_1d}$$

cannot be met, if the current components i_1q and i_1d do not correspond to the actual values of the exciting current component i_m and the torque current component i_t, respectively. From Figure 2(a)-(c) one can derive the consequences if the slip frequency does not correspond to the ratio of the two commanded current components: The actual magnetic flux ϕ deviates in its amplitude from its desired value and a ϕ_q-component of the magnetic field indicates that the d-q-reference frame is not oriented with its d-axis on the actual magnetic field axis. The meaning of the diagrams of Fig. 2 is therefore clear.

2.1 The Appellant also sees difficulties in understanding the function of the elements 5,9 and 17 (Figures 1 and 3) which, at first sight, appear to be all drawn as differential amplifiers. The elements 5 and 17 are indeed differential amplifiers as can be understood from the description, column 2, line 27 and column 6, lines 62/63. The element 9 is, however, specified as an "adder" adding the output signals of a voltage component detector 8 and a change rate limiter 4 to provide a frequency command signal (column 2, lines 40 to 43). It is clear from Claim 1 that the output signal e_d from the voltage

component detector 8 shall be zeroed by the disclosed control arrangement. This is explained in more detail in the description, column 6, lines 18 to 28 according to which the frequency shall only follow the output of the change rate limiter. Thus, although the function of adder 9 is not directly derivable from the drawing alone, it is explained clearly enough in the description.

The speed control, specified in Claim 1, column 15, lines 3 to 7 is effected according to the examples depicted in Figures 1 and 5 to 7 by action on the torque current component of the primary current. Thus, the Appellant's objection that Claim 1 does not provide a specific control of the torque component (Claim 1 specifies only that the "primary current" is controlled) could at most be taken as a criticism of the clarity of the claim but it does not constitute a valid objection against the sufficient disclosure of the invention.

2.2 The Board is therefore satisfied that the invention is sufficiently disclosed in the patent in suit for it to be carried out by a man of average skill in the art.

3. **Novelty**

3.1 An understanding of the claimed vector control method of Claim 1 can be approached in two different ways.

3.1.1 The motor current is controlled in accordance with a rotating current vector composed of two orthogonal current components i_m* and i_t*. The frequency of the rotating current vector is so controlled that the direction of the resulting field vector, which is deduced from detection of the motor voltage vector, coincides with the direction of the desired exciting current component i_m* of the motor current vector.

This approach corresponds in substance to the explanations in the patent in suit.

3.1.2 The Appellant's line of argument is based on a different approach. According to this approach the voltage vector of the induction motor is detected and the frequency of a vector oscillator (10) is so controlled, that its output vector is in phase with the detected voltage vector (function of a "vector filter", because harmonics in the motor voltage can be eliminated). The output of the vector oscillator provides a reference frame for the separate control of the orthogonal components i_m* and i_t* of the primary current vector.

3.2 The Appellant follows the second line of understanding when referring to D1. This document discloses a vector filter (Figure 3) which comprises a vector oscillator (OSZ) in order to eliminate the harmonics when determining the phase of the flux whose components are detected by Hall probes (Figure 1).

3.2.1 It is, therefore, an essential difference of the claimed vector control method over this prior art, that the detection of the flux vector is replaced by the detection of the voltage vector whose vector component e_d, which is parallel with the exciting current component, is zeroed by the frequency control circuit.

3.2.2 A further essential difference is to be seen in the fact that, according to D1, the speed control requires a tachometer generator (G), whereas the claimed method makes use of one of the voltage vector components, viz. the vector component e_q orthogonal to the (commanded) exciting current component vector, as signal representative of the speed of the induction motor.

3.2.3 Finally, attention is drawn to the fact that, according to D1 (Figure 1), the control of the torque current component (i_2*) and the exciting current component (i_1*) is effected via a cascaded voltage control circuit, and that the frequency is controlled via a vector rotator VD1 in this voltage control circuit. As a consequence, a resolution of the flux vector into vector components parallel with and orthogonal to the exciting current component (similar to the voltage vector resolution as specified in lines 60 to 64 of present Claim 1) is not derivable from D1.

4. **Inventive step**

4.1 The Board cannot follow the Appellant's line of argument that it was obvious to replace the flux detection in the control method disclosed in D1 by a voltage detection in the claimed manner (point 3.2.1 above). D1 does not mention any voltage detection at all. The absolute value (ψ) of the detected flux plays an essential role (ψ-Regler).

It is known per se to apply instead of the flux detection by Hall probes (as in D1, Figure 1), a computation of the flux from the detection of the motor voltage, as acknowledged in the patent in suit, column 1, lines 36 to 48 (see also D4, page 8, lines 5 to 22 and D5, Figure 9.45). However, these known control methods are still based on the necessity to determine the complete flux vector (two orthogonal components and/or absolute value and phase), which requires an integrator whose drifts in its characteristic give rise to errors (patent in suit, column 1, lines 40 to 42).

The present invention is, in contrast to this, based on a concept that renounces the determination of the absolute

value of the flux (the maintenance of the exciting current component being regarded as sufficient to maintain the flux value) and makes only use of the direction of the flux in order to control the exciting current component and the orthogonal torque current component in accordance with this direction. In application of this concept, the inventor took the further step of taking into account that any flux detection can be avoided when the voltage vector is detected and use is made of the fact that the voltage vector is, in the stationary state, 90° out of phase from the flux vector, so that the voltage component in the direction of the flux is always zero. A voltage component e_d in the direction of the commanded exciting current component i_m^* can therefore be taken as a signal indicative of a deviation of the actual direction of the flux vector from the desired direction of the flux vector, i.e. the direction of the exciting current component i_m^*.

In spite of the Appellant's comprehensive efforts to explain this method on the basis of principles of vector control, the Board cannot find any passage in the cited prior art documents that would lead the expert to the concept outlined above.

4.2 The concept of detecting the motor voltage vector in order to get a vector component e_d to be zeroed by the frequency control entails the further advantage that the orthogonal vector component e_q is essentially proportional to the frequency and can thus be used as representing an approximate value of the actual speed in a speed control method as recited at the end of Claim 1. Although it is known per se to use a value representing the motor frequency as actual speed value (see D4, page 6, first paragraph) thereby avoiding a separate tachometer generator, the use of e_q for this purpose is not disclosed in any document.

4.3 The fact that the claimed method controls the frequency of the commanded primary current vector components and not, as in D1, the frequency of the commanded primary voltage components in a cascaded voltage control circuit (see point 3.2.3 above), necessitates a considerable difference in the elements of the overall circuitry. Methods for effecting the vector control solely on the level of the current signals are known in the prior art (the proceedings of the IEEE cited in the patent in suit, column 1, lines 28 to 30 show the principal arrangement in Figure 28 on page 129). A corresponding simplification of the principal control method of D1, Figure 1 may, therefore, fall within the range of modifications obvious to a skilled person.

4.4 Summing up the considerations of points 4.1 to 4.3, the Board concludes that, although the feature discussed in paragraph 4.3 considered by itself may have been obvious, the combination of all the features of Claim 1 (taking into account their correct interpretation, set out in section 2 above), is clearly based on an inventive step.

4.5 Claim 1 can, therefore, be maintained as granted.

5. Claim 2, which is appended to Claim 1, specifies further features concerning the control of the exciting current in accordance with respective details disclosed in Figure 3 of the patent: a voltage difference amplifier 17 serves as means to control the exciting current command value in such a way that a signal proportional to a frequency command signal equals the detected voltage component signal e_q. By this method the magnetic flux ϕ_d in the d-axis of the induction motor is kept constant when the slip frequency deviates from its rated value, as depicted in Figure 4 (in contrast to the flux variations shown in Figure 2 for the embodiment of Figure 1).

The Board notes that Figure 3 of the patent in suit, which is the only Figure concerned with the further features of Claim 2, is not consistent with the method of Claim 1, since the speed control is not effected on the basis of a difference between the speed command signal (3) and the said vector component e_q. Inconsistency of a single embodiment with the claims is, however, no reason for opposition under the terms of Article 100 EPC, at least as long as the disclosure of the description as a whole is sufficient for carrying out the invention claimed.

The Board is satisfied that this condition is also satisfied for Claim 2, since a combination of speed control according to Claim 1 (and Figure 1) and exciting current control according to Claim 2 (and Figure 2) appears to be readily feasible. Claim 2 can, therefore, also be maintained as granted, together with the dependent Claims 3 and 4 which specify further embodiments of the invention.

6. As regards the Appellant's remarks on the lack of clarity of Claim 1 of the patent in suit, it is to be noted that a deficiency in this respect is no ground for opposition under the terms of Article 100 EPC.

7. It follows from the reasons set out above, that the Appellant's grounds for opposition cannot prejudice the maintenance of the patent as granted.

Since the Appellant asked for oral proceedings only by way of an auxiliary request conditional upon the filing of essentially amended claims, which is not the case here, the decision is taken without oral proceedings.

Order

For these reasons, it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

M. Kiehl E. Persson