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D E C I S I O N
of 14 June 1996

Case Number: T 0684/94 - 3.5.2

Application Number: 84904177.7

Publication Number: 0163746

IPC: H02M 7/48

Language of the proceedings: EN

Title of invention:
PWM inverter apparatus

Applicant:
MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD., et al

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step - yes (after amendment)"

Decisions cited:
-

Catchword:
-

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Case Number: T 0684/94 - 3.5.2

D E C I S I O N
of the Technical Board of Appeal 3.5.2
of 14 June 1996

Appellant 01: MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 24 March 1994 refusing European patent application No. 84 904 177.7 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: W. J. L. Wheeler
Members: R. G. O'Connell
M. Lewenton

Summary of Facts and Submissions

I. The appellant contests the decision of the examining division refusing European patent application No. 84 904 177.7. The reason given for the refusal was that the subject-matter of independent claim 4 then on file did not involve an inventive step, having regard to the prior art known from the following documents:

D1: US-A-4 020 361

D2: "A new high-quality PWM ac drive", IEEE Transactions on Industry Applications, vol. IA-19, No. 2, March/April 1983, pp. 211-216.

II. Following a communication from the board and discussion of the case at oral proceedings held on 14 June 1996 the appellant requested (main request) that a patent be granted on the basis of the application in its amended form, that is:

Claims: 1 to 6, as submitted in oral proceedings 14 June 1996;

Description: pages 2, and 4 to 11, as originally filed,
pages 1, 1a, 3, 3a, as submitted in oral proceedings 14 June 1996;

Drawings: sheets 1 to 5, as originally filed.

The appellant also submitted an auxiliary request which specified a different wording for claim 4 but was otherwise identical to the main request.

III. Independent claims 1 and 4 (main request) are worded as follows:

"1. A pulse width modulation inverter apparatus comprising:
a frequency setting part (1) for setting the frequency of the fundamental wave of an output voltage to be supplied to a load (9);
a control circuit part (2) generating a pulse width modulation signal on the basis of the fundamental wave and a carrier wave in response to the signal from said frequency setting part (1);
a phase drive part (3) receiving the pulse width modulation signal from said control circuit part (2); and
a DC power source part (8) connected to said phase drive part (3);
characterized in that said control circuit part (2) is responsive to the signal from said frequency setting part (1) to increase the carrier frequency of said pulse width modulation signal when said setting frequency is decreased and vice versa, whereby the frequency range lies between 8 kHz and 24 kHz.

4. A variable speed drive DC/AC converter for an induction motor including a pulse width modulation inverter apparatus comprising:

a frequency setting part (1) for setting the frequency of the fundamental wave of an output voltage to be supplied to the motor (9) as the driving voltage thereof;

a control circuit part (2) generating a pulse width modulation signal on the basis of the fundamental wave and a carrier wave in response to the signal from said frequency setting part (1);

a phase drive part (3) receiving the pulse width modulation signal from said control circuit part (2); and

a DC power source part (8) connected to said phase drive part (3);

characterized in that the carrier frequency of said pulse width modulation signal from said control circuit part (2) is selected to have a predetermined value in the range of 8 kHz to 16 kHz."

Claims 2 to 3 and 5 to 6 are dependent on claims 1 and 4 respectively.

IV. The appellant argued essentially as follows:

Independent claim 4 was now explicitly directed to a variable speed drive DC/AC converter for an induction motor; it specified a frequency-setting part for setting the frequency of the fundamental wave to be supplied to the motor and a phase drive part. Hence the terms of the claim now implied structure and design constraints which distinguished it from converters for use in music/voice synthesisers or amplifiers involving an external reference signal such as referred to in D1, column 1, lines 22 to 31.

D2 represented the closest prior art. It addressed the problem of designing variable speed drives for induction motors using pulse width modulation (PWM) converters and referred to the problem of audible acoustic noise. In contrast, D1 (loc cit) specifically addressed the problem of designing PWM converters for extended dynamic range in voice and music reproduction; it contained no reference to the problem of noise arising in magnetic loads as occurred in induction motors.

D2, at page 211, taught that the ratio of the carrier frequency to the modulating frequency in a variable speed drive DC/AC PWM converter for an induction motor should be as high as possible in order to increase the frequency of unwanted harmonics in the output waveform, thus reducing the ripple current in an inductive load such as an induction motor. It further explained, at page 212, that the use of power field effect transistors made it possible for PWM converters to operate "at much higher carrier frequencies eg 20 kHz", and set out five advantages which result from the use of carrier frequencies of this order, of which the fifth was:

"Raising the switching frequency to above the audible range would allow ac variable speed drives to be used in office and domestic equipment where the acoustic noise associated with currently available drives would make them unacceptable".

In essence the teaching of D2 was that the carrier frequency should be as high as possible and, in particular, should be above the audible range. In contrast the present invention as defined by independent claim 4 was based on the insight explained in the description relating to Figures 6 and 7, which identified a significant drop in magnetic acoustic noise while the carrier frequency remained in the audible range. This drop resulted from the combined effect of magnetic acoustic noise at the carrier frequency and magnetic acoustic noise having a frequency two times the carrier frequency. The range of 8 kHz to 16 kHz for the carrier frequency represented a surprisingly good trade-off between magnetic acoustic noise and switching power loss. There was no suggestion whatsoever in D2 of this advantageous range.

Reasons for the Decision

1. The appeal is admissible.

2. *Amendments (main request)*

2.1 Independent claims 1 and 4 as now worded express the relationship between the PWM signal and the fundamental and carrier waves in terms corresponding to those employed in the originally filed claims. In the judgement of the board no contravention of EPC Article 123(2) is involved.

2.2 In addition claim 4 has been amended to make it clear that the subject-matter of the claim is a variable speed drive DC/AC converter for an induction motor and thus to distinguish the subject-matter claimed from converters for use in music/voice synthesisers or amplifiers involving an external reference signal as referred to in D1, column 1, lines 22 to 31. These amendments also comply with the requirements of EPC Article 123(2).

3. *Inventive step (main request)*

3.1.1 Since there is no disclosure or suggestion in either of the prior art documents of the feature "that said control circuit part (2) is responsive to the signal from said frequency setting part (1) to increase the carrier frequency of said pulse width modulation signal when said setting frequency is decreased and vice versa, whereby the frequency range lies between 8 kHz and 24 kHz.", the board has no reason to review the positive finding of the examining division in relation to independent claim 1.

3.1.2 The main issue to be decided in this appeal is whether the variable speed drive DC/AC converter as claimed in independent claim 4 involves an inventive step within the meaning of Article 56 EPC.

3.2 A prior art variable speed drive DC/AC converter (for an induction motor) according to the preamble of claim 4 of the present application is disclosed in document D2. The board agrees with the appellant that this document represents the closest prior art, since it addresses the same problem of designing a PWM converter of this kind so as to reduce simultaneously the acoustic noise arising in an induction motor controlled by the converter and switching power losses. Cf D2, pages 211 and 212, especially Section I,D, point 5) (cited in the appellant's argument at point IV above), page 214, Section A ("despite the high switching frequency, power losses due to switching are very small"), Section IV ("Audible acoustic noise is also eliminated"). This corresponds closely to the indication in the present application as originally filed, foot of page 6: " ...an efficient PWM inverter apparatus can be provided, by which generation of (the) magnetic noise in the audible range is relatively suppressed".

3.3 This problem is plausibly solved in accordance with the teaching of the present application by choosing the carrier frequency of the PWM converter to lie in the range of 8 kHz to 16 kHz as specified in independent claim 4.

3.4 As illustrated in Figures 6 and 7 of the present application this range is characterised by a sharp drop in acoustic magnetic noise accompanied by a relatively modest increase in switching power loss. The technical phenomenon underlying this effect is the generation in the magnetic materials of the motor of acoustic noise

having a frequency twice the carrier frequency as well as acoustic noise having a frequency equal to the carrier frequency; cf page 6, lines 11 to 20 of the application as originally filed.

3.5 The board agrees with the appellant that the prior art documents D1 and D2 cited in the decision under appeal do not suggest the invention claimed in claim 4 of the present application. D2 is closest prior art and consistently teaches that the design aim should be to raise the carrier (ie switching) frequency "above the audible range". At page 212, Section D, it states: "...the switching speeds of power FETs make it possible for FET inverters to operate at much higher carrier frequencies, eg 20 kHz. The use of carrier frequencies of this order has a number of important consequences...5) Raising the switching frequency to above the audible range would allow ac variable speed drives to be used in office and domestic equipment where the acoustic noise associated with currently available drives would make them unacceptable".

3.6 Against the background of these statements the sentence in Section A of D2 :"Therefore despite the high switching frequency, power losses due to switching are very small and a carrier frequency of 18 kHz is entirely reasonable." is interpreted by the board to mean that switching power losses were quite tolerable at this frequency, but that to the extent that power losses permitted, the frequency should be chosen as high as possible - and preferably above the audible range - in the interests of reduced acoustic noise.

3.7 Nowhere in D2 is there a suggestion of an empirical or theoretical basis for a sharp drop in acoustic noise while the carrier frequency is still well inside the audible range. The assertion in the decision under

appeal at point 3 that "In the light of this disclosure (D2) it is a simple measure of the skilled person to select an appropriate frequency range for the carrier wave for a particular appliance to reduce audible magnetic noise" is, in the judgement of the board, a speculation based on hindsight, since the plain teaching of D2 is that the "appropriate frequency range" for an induction motor variable speed drive is "above the audible range" or as close to that ideal as the efficiency of available switching elements permits. In this respect D2 teaches away from the solution specified in claim 4.

3.8 Prior art document D1 is not relevant to the problem solved by the variable speed drive DC/AC converter for an induction motor specified in independent claim 4. There is no mention of induction motors or magnetic loads in the document and **a fortiori** no teaching in relation to the problem of reducing magnetic acoustic noise arising in such loads. It is therefore irrelevant on inventive step and, as indicated at point 2.2 above, is not novelty-destroying for the amended claim 4.

3.9 The board therefore concludes that the subject-matter of claim 4 involves an inventive step within the meaning of Article 56 EPC. The same is true for the dependent claims 5 and 6. As indicated above the board sees no reason to disagree with the positive opinion of the examining division on the issue of inventive step in relation to independent claim 1, the amendments made thereto being judged neutral on this issue. The same is true for claims 2 and 3, which are dependent on claim 1.

4. In the judgement of the board, the application in accordance with the main request meets the requirements of the EPC. The auxiliary request need not be considered.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the department of first instance with the order to grant a patent on the basis of the main request (see paragraph II above).

The Registrar: The Chairman:

M. Beer W. J. L. Wheeler