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D E C I S I O N
of 10 December 2003

Case Number: T 0637/01 - 3.5.2

Application Number: 92904583.9

Publication Number: 0577611

IPC: H02J 5/00

Language of the proceedings: EN

Title of invention:
Inductive power distribution system

Patentee:
Auckland UniServices Limited

Opponent:
DaimlerChrysler AG

Headword:
-

Relevant legal provisions:
EPC Art. 54, 56, 84

Keyword:
"Novelty and inventive step - yes"
"Clarity of claims - yes"

Decisions cited:
-

Catchword:
-

Case Number: T 0637/01 **-** 3.5.2

D E C I S I O N
of the Technical Board of Appeal 3.5.2
of 10 December 2003

Appellant: (Opponent)
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Representative: -

Respondent: (Proprietor of the patent)
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Decision under appeal: **Interlocutory decision of the Opposition Division of the European Patent Office posted 7 May 2001 concerning maintenance of European patent No. 0577611 in amended form.**

Composition of the Board:

Chairman: W. J. L. Wheeler
Members: F. Edlinger
P. Mühlens

Summary of Facts and Submissions

I. The opponent filed this appeal against the interlocutory decision of the opposition division concerning maintenance of the European patent No. 577 611 in amended form.

II. The independent claims 1, 47 and 49 of the patent as approved by the contested decision have the following wording:

Claim 1:

"An inductive power distribution system comprising:

an electric power supply (2402);

a primary conductive path (2405) connected to said electric power supply (2402);

one or more electrical devices (2101, 2102, 2401) for use in conjunction with said primary conductive path (2405);

the or each device (2401) capable of deriving at least some power from a magnetic field associated with said primary conductive path (2405);

the or each device (2401) having at least one inductive pick-up means (23103, 24103, 2501) and at least one output load capable of being driven by electric power induced in the inductive pick-up means;

wherein:

said at least one inductive pick-up means (23103, 24103, 2501) includes a resonant component having a pick-up resonant frequency;

and there are provided:

control means to control the power applied to said output load;

characterised in that:

there is mechanical or electrical decoupling means actuable by said control means to inhibit the transfer of power from said primary conductive path to said device during operation of said device by preventing resonant current from flowing in the inductive pick-up means whilst the primary conductive path remains on, thereby to substantially completely disengage said at least one inductive pick-up means from the primary conductive path (2405)."

Claim 47:

"A vehicle capable of deriving some of its power from a magnetic field associated with a primary conductive path (2405) supplied by a varying electric current, said vehicle having at least one inductive pick-up means (23103, 24103, 2501) and at least one output load (2503) capable of being driven by electric power induced in the inductive pick-up means (23103, 24103, 2501),

wherein:

said at least one inductive pick-up means (23103, 24103, 2501) comprises a resonant component having a pick-up resonant frequency;

and there are provided:

control means to control the power applied to said output load;

characterised in that:

there is mechanical or electrical decoupling means actuable by said control means to inhibit the transfer of power from said primary conductive path to said device during operation of said device by preventing resonant current from flowing in the inductive pick-up means whilst the primary conductive path remains on, thereby to substantially completely disengage said at least one inductive pick-up means from the primary conductive path (2405)."

Claim 49:

"An inductive power distribution system comprising:

an electric power supply (2402);

a primary conductive path (2405) connected to said electric power supply (2402);

a plurality of electrical devices (2101, 2102) for use in conjunction with said primary conductive path (2405);

each device (2101) capable of deriving at least some power from a magnetic field associated with said primary conductive path (2405);

each device (2101) having at least one inductive pick-up means (23103, 24103, 2501) and at least one output load capable of being driven by electric power induced in the inductive pick-up means (23103, 24103, 2501);

wherein:

said at least one inductive pick-up means (23103, 24103, 2501) comprises a resonant component (23102, 23103) having a pick-up resonant frequency;

and there are provided:

control means to control the power applied to said output load;

characterised in that each device (2101) has decoupling means actuable by said control means to inhibit the transfer of power from said primary conductive path to said device during operation of said device by preventing resonant current from flowing in the inductive pick-up means whilst the primary conductive path remains on, thereby to substantially completely disengage said at least one inductive pick-up means (23103, 24103, 2501) from the primary conductive path (2405)."

Claims 2 to 46 and 50 are dependent on claim 1 and claim 48 is dependent on claim 47.

III. The following documents cited in the opposition proceedings will be referred to below:

D1: 40th IEEE Vehicular Technology Conference 6 to 9 May 1990, Orlando, Florida; pages 100 to 104; Manochehr Eghtesadi: "Inductive Power Transfer to an Electric Vehicle - Analytical Model"

D2: US-A-4 914 539

E3: US-A-4 800 328 and

E4: US-A-4 007 817.

IV. According to the decision under appeal, D2 disclosed the features of the preambles of claims 1 and 49, and E3 disclosed a vehicle comprising the features of the preamble of claim 47. The shunting action provided by FET 96 in the circuit of Figure 2 of D2 only operated during a portion of each waveform and merely prevented the resonant current from reaching the output of the pick-up circuit. The resonant tank circuit of D2 only stopped resonating under a fault condition when current delivered to the load exceeded a predetermined limit.

E4 was not submitted in due time and, since it was not considered as relevant for the decision, was not taken into consideration by the opposition division (Article 114(2) EPC).

V. Oral proceedings were held before the Board on 10 December 2003.

VI. The appellant opponent requested that the decision under appeal be set aside and that the patent be revoked.

VII. The respondent proprietor requested that the appeal be dismissed and that the patent be maintained.

VIII. The appellant opponent essentially argued as follows:

D2 uncontestedly disclosed the features of the preambles of claims 1 and 49. Contrary to the decision of the opposition division, D2 also disclosed decoupling means actuable by control means as specified in the characterising parts. The subject-matter of claims 1 and 49 thus lacked novelty.

D2 (column 9, lines 31 to 34; Figure 2) disclosed a regulator circuit (72) which controlled both the inductive coupling between the primary conductive path and the pick-up coil, and the power applied to a load connected to output terminals. In addition, the regulator was short-circuit protected (D2, column 9, lines 39 to 42). If the load current exceeded a certain limit, resonant current flow within the tank circuit stopped whilst the primary conductive path remained on (see D2, column 7, lines 51 to 58). When FET 96 in Figure 2 of D2 was switched on, the tank circuit was short-circuited and no transfer of power was possible. The short-circuit would almost instantaneously stop resonance in the tank circuit and thus decouple the device from the primary conductive path because the inductor 88 (connected on the load side of the FET 96) could not delay the current decrease and the switching on of FET 96 was synchronised with the resonant frequency.

The shunting function of FET 96 in Figure 2 of D2 was also the same as that of corresponding switches in the embodiments of Figures 12 and 14 of the opposed patent. In both cases, the resonant component of the pick-up means and the load were decoupled by diodes, capacitors, inductors and switches so that the resonant voltages and power supplied to the loads were limited to safe values, and load current would continue to flow for a short time even if the pick-up means was completely decoupled from the primary conductive path. When the voltage across the pick-up coil was short-circuited and thus zero, be it only for a short time, no electrical power was supplied from the primary conductive path even if current continued to flow through the load. In the circuits of Figures 12 and 14 of the opposed patent, a switch (12T1; 14113) effectively shorted the pick-up coil when the load voltage exceeded a reference value. "The result of this action is the power transferred from the pickup coil is virtually zero" (patent specification, column 13, lines 41 to 50). Since an inductor (12L1; 14121) was connected on the power source side of the switch (12T1; 14113) with a preferred rate of switching ("nominally 30Hz") that was much lower than the resonant frequency of the pick-up coil, the current in the resonant circuit would continue for a longer time before decoupling could take place than in the circuit of Figure 2 of D2 (column 14, lines 10 to 18 of the patent specification). Therefore, the electrical decoupling means in Figures 12 and 14 rather did not "substantially completely disengage" the pick-up means from the primary conductive path. These circuits were inconsistent with, and did not constitute embodiments of, claims 1, 47 and 49.

The voltage and current diagrams filed with the statement of grounds of appeal confirmed that a circuit as shown in Figure 2 of D2, simulated under various load conditions, went through phases of complete decoupling between primary conductive path and pick-up coil during each cycle of the resonant frequency when FET 96 short-circuited the pick-up coil. The duration of these phases increased with the output voltage when a light load was connected to the output terminals. The electrical power transferred from the primary path to the pick-up means thus decreased, as did the amplitude of the oscillations of the resonant circuit. It became almost zero when FET 96 was closed during the whole cycle under no-load conditions.

Claim 47 specified a vehicle having the inductive pick-up means. Subject-matter with this sole distinction was obvious because a person skilled in the art understood from the disclosure of a resonantly and inductively coupled vehicle system in D1 that the regulation of power transfer disclosed in D2 could be successfully applied to vehicles. The subject-matter of claim 47 equally lacked an inventive step in view of the prior art disclosed in E4 and D2. E4, like D1, dealt with the Californian bus system which played an important role in the granting procedure of the opposed patent. E4 described vehicles which derived inductively coupled power from a primary conductive path, but did not hint at a pick-up comprising a resonant component. Having knowledge of the regulator circuit for a resonant pick-up with electrical decoupling as disclosed in D2, a person skilled in the art would have arrived at the subject-matter of claim 47 by obvious modification of the inductive coupling in E4.

The extensive discussion about the novelty of claims 1 and 49 and the error in judgement of the opposition division cogently demonstrated that the terms "substantially completely disengage" were unclear. These terms had no generally recognised meaning and were self-contradictory concerning the degree of disengagement. It was thus impossible to determine the extent of protection conferred by these claims. In accordance with consistent jurisprudence of the Boards of Appeal of the EPO, such terms in a claim did not comply with Article 84 EPC.

IX. The respondent proprietor essentially argued as follows:

The claims of the opposed patent clearly defined the differences with respect to the prior art disclosed in D2 in that they specified that transfer of power from the primary conductive path to the device was inhibited by the decoupling means. To achieve this, resonant current was prevented from flowing in the inductive pick-up means whilst the primary conductive path remained on. In this context, the feature "to substantially completely disengage" said at least one inductive pick-up means from the primary conductive path was clear as a statement of effect which was achieved by the decoupling means.

In power distribution systems of the kind described in the opposed patent, problems arose when a plurality of variable loads were coupled to the primary conductive path. High levels of current could then circulate through a lightly loaded pick-up coil and were reflected back into the primary conductive path. A lightly loaded pick-up coil could thus block the power supply to other devices supplied from the same primary conductive path.

The inventors had found that this problem could be solved by controlling the total flux linking the pick-up means (thus the flow of power) in dependence on the actual load and by disengaging the inductive pick-up means under certain load conditions. This could be done in a number of ways, mechanically or electrically, for example by providing an auxiliary winding which reduced the magnetic coupling. In a preferred though surprising embodiment the pick-up coil was shorted out by closing a switch across it and the capacitor of the resonant component. In practice, this approach was quite radical because a short-circuited conventional transformer secondary would lead to a power failure and a possibly dangerous situation. But this turned out to work well with loosely coupled inductive power distribution. In the opposed patent, turning on of a switch to short-circuit the capacitor of the resonant component (as in Figures 12 and 14) did not serve to maintain resonance in the pick-up, but rather to prevent resonant current from flowing and to inhibit power transfer to the pick-up means, as was clearly specified in the claims. It was not necessary, in the circuits of Figures 12 and 14 of the opposed patent, to synchronise this switching action with the resonant cycles because inductors 12L1 and 14121, which were connected differently from the inductor 88 in D2, protected the switch from being subjected to instantaneous high currents. The duration of the short-circuiting had to be sufficiently long to achieve the effect that transfer of power was inhibited when the resonant current was prevented from flowing.

D2 (and similarly also D1) taught away from the invention in that these circuits tried to maintain the pick up circuit in a resonant (D2) or a near resonant (D1) state. Many passages in D2 (eg column 1, lines 64 to 66; column 2, lines 30 to 35; column 5, lines 35 to 39; column 10, lines 10 to 12) made it clear that current was maintained through the pick-up means of the device and shunted away from the load so that a constant voltage was maintained across the output terminals despite load variations. FET 96 of D2 was nowhere disclosed as operating to decouple the pick-up from the primary conductive path and prevent resonant current from flowing in the pick-up means. To perform the shunting action in D2, FET 96 had to be synchronised with the resonance frequency of the pick-up means and was only turned on for part of one half resonant cycle. This switching action was incapable of dissipating the energy in the resonance circuit, which would also be contrary to the stated aim of avoiding shunting excessive current (D2, column 9, lines 35 to 39). The resonant current was rather held in stasis than prevented from flowing in the resonant pick-up. Though the instantaneous power in the resonant circuit would be zero at four separate intervals in every cycle of the natural voltage or current of the resonant circuit, this was not a controlled feature of the circuit, but part of the natural operation of the circuit, and could not in any way be referred to as decoupling. The reference in D2 (column 7, lines 51 to 58) to the resonant oscillation being stopped was made in relation to a fault or overload condition, and did not relate to controlled operation of the circuit.

The differences between the circuit of D2, Figure 2, and the circuits of Figures 12 and 14 of the opposed patent clearly emerged from simulations carried out by an independent expert, the results of which were filed in an affidavit. These simulations showed large instantaneous reactive power flowed from the primary to the pick-up which was not eliminated by the regulation action in D2. Also the appellant's basic and abstract circuit models filed as appendices to the statement of grounds of appeal confirmed this because they showed that during normal operation of the circuit in D2, Figure 2, the current through the resonant component did not cease while shunted by the switch, but actually increased. Since the resonant capacitor was short-circuited in this phase, the increasing current could only be sourced from the primary conductive path.

D1 referred to an inductive power transfer system for vehicles. An onboard control computer tuned the system in response to vehicle current demands by automatically adjusting the capacitance of a variable capacitor bank. There was no teaching or suggestion of complete decoupling. Likewise, there was nothing in E4 that referred to control techniques for resonant pick-up circuits or to decoupling. Since D2 did not disclose decoupling of a pick-up means either, the subject-matter claimed in the opposed patent was not obvious in view of the prior art.

Reasons for the Decision

1. The appeal is admissible.

2. Claims 1, 47 and 49 all specify "decoupling means" which are actuable by "control means". The latter control the power applied to the output load. The decoupling means include functional features: "to inhibit the transfer of power from said primary conductive path … by preventing resonant current from flowing … thereby to substantially completely disengage said at least one inductive pick-up means from the primary conductive path". The meaning of these terms has been in dispute.

2.1 It is clear from the wording of these claims, without any consideration of the description and drawings, that the decoupling and control means have to be such that the pick-up means is disengaged from the primary conductive path for a sufficiently long time, and to a sufficient degree, that resonant current, in response to actuation by the control means, is stopped for some time and substantially no electric power is induced, during this time, in the inductive pick-up means. Since the primary conductive path remains on and develops a magnetic field, the mutual inductance between the primary and the secondary has to be sufficiently reduced to inhibit transfer of power.

2.2 The description of the opposed patent, starting from column 14, line 39, discloses the underlying technical problem (in the context of Figures 16 to 18) and embodiments of decoupling means of the devices (see Figures 19, 23 and 24). A lightly loaded device (vehicle) shifts the operating frequency away from the resonance frequency of the resonant component. This may cause high levels of current circulating through the pick-up coil and can block electric power from reaching other devices because the mutual coupling M between the primary and the device transfers an equivalent load resistance to the primary side (patent specification, column 14, lines 42 to 49; column 15, line 33 to column 16, line 15). By reducing the mutual coupling, the magnetic flux linked with the pick-up coil (and the impedance reflected back to the primary) will be reduced. Decoupling and thus disengagement of the pick-up means may be obtained mechanically (eg by physical separation of the pick-up coil from the primary conductive path; column 15, lines 1 to 4), or electrically by opening a series switch (column 15, lines 4 to 15; Figure 24). Disengagement may also be obtained by electro-magnetically reducing the linking magnetic flux. To this effect, a second pick-up coil (to shield the main pick-up coil; column 13, lines 25 to 27; column 15, lines 23 to 29; column 16, lines 23 to 30; Figures 11 and 19) or the main pick-up coil itself may be shorted by closing a switch in parallel with the coil (column 15, lines 15 to 22; Figure 23). It is clear from the description as a whole that the devices must include a resonant component having a pick-up resonant frequency as specified in the claims, but the primary conductive path is not necessarily resonant. In response to action by the control means, the resonant current is prevented from flowing in the inductive pick-up means thereby to disengage it from the active primary side and to inhibit the transfer of power to the decoupled device.

2.3 The circuits of Figures 12 and 14 of the opposed patent are described as showing each a voltage control means which attempts "to maintain the output voltage between an upper and a lower limit, and maintains the resonant current within the pickup coil below an upper limit" (column 14, lines 34 to 37). The result of the switching action which shorts out the pick-up coil is that "power transferred from the pickup coil is virtually zero" (column 13, lines 37 to 52). However, this is not inconsistent with the functioning of the above mentioned embodiments. In the case of a lightly loaded device, the voltage across the tuned circuit and the load voltage increase (column 13, lines 42 to 45; column 16, lines 37 to 40). When the output voltage in either of Figures 12 and 14 exceeds an upper limit, a switch (Figure 12: 12T1; Figure 14: 14113) connected in parallel with the pick-up coil (as in Figure 23) will short-circuit the pick-up coil and the tuning capacitor. If these circuits are used as embodiments of claims 1, 47 and 49 (and not as additional circuits for regulating the output voltage), the switching action has to be done in conformity with the principles specified in the claims, ie the resonant current has to be prevented from flowing. This is possible because the preferred rate of the switching action is nominally 30 Hz (column 14, lines 15 to 18) compared with 10 kHz as a "reasonable design figure" for the resonance frequency of the pick-up circuit (column 8, lines 42 to 46). In this example, one switching cycle would short out more than 300 resonant cycles, ie the resonant component is short-circuited for a sufficiently long time to allow the resonant current to decay completely when the energy stored in the resonant components has been dissipated.

2.4 A person skilled in the art would thus derive from the disclosure of the opposed patent that disengagement neither has to be one hundred percent to avoid a blocking of power transfer to other devices, nor does it have to immediately prevent resonant current from flowing. In the context of the opposed patent, the terms "to substantially completely disengage" the inductive pick-up means do therefore, in combination with the other features relating to disengagement, sufficiently clearly define the matter for which protection is sought by claims 1, 47 and 49 (Article 84 EPC).

3. It is common ground that D2 discloses the features of the precharacterising parts of the present claims 1 and 49. The electrical devices in D2 are passenger seat groups within the cabin of an aircraft having passenger entertainment and service systems as loads. The mutual coupling between the resonant pick-up means (70, 78, 80, 82) disposed at the movable seat groups and the primary conductive path (68) within the floor may vary significantly (D2, column 1, lines 40 to 63; column 3, lines 9 to 21; column 4, lines 64 to 68; column 7, lines 3 to 11). D2 discloses a precisely controlled constant current source for maintaining a constant current flow through the primary conductive path and a specific voltage regulator for maintaining a constant voltage across the electrical load without producing unacceptable electromagnetic interference and possible disruption of the constant current source (column 1, line 50 to column 2, line 2; column 4, lines 14 to 17). The voltage regulator cyclically shunts part of the current circulating within the pick-up means so that it

does not reach the output when the output voltage across the load is above the desired nominal level. Under no load conditions, "two amps" (ie the full load current) of the "approximately eight amps" will be shunted away from the output while the full resonant current will continue to flow in the pick-up means (D2, column 2, lines 30 to 35; column 5, lines 32 to 39; column 7, lines 34 to 36 and lines 48 to 51; Figures 1 and 2). Therefore, during normal operation of the devices in D2, including no load conditions, resonant current is not prevented from flowing and transfer of power is not inhibited from the primary conductive path to the devices. The shunting action provided by FET 96, which only operates during a portion of each waveform (D2, column 9, lines 35 to 39), artificially increases the average load of the pick-up means, by creating a short-circuit condition for a brief period of each cycle, to compensate for variations in the load and/or the mutual coupling between the primary and the pick-up means. In this way, resonant current can be maintained flowing in the pick-up means. In contrast to its function under normal and no load conditions, the control means disclosed in D2 does not switch on FET 96 when the output voltage drops below a reference level (D2, column 8, lines 17 to 38). If the load current exceeded a certain level, the resonance circuit would become detuned and stop resonating (D2, column 7, lines 51 to 66). The control means would not intervene to actuate FET 96 because there is no current to shunt, the pick-up means is overloaded and the output voltage would be below the reference level of the voltage regulator. Therefore, D2 does not disclose any decoupling means actuable by control means as specified in claims 1, 47 and 49 of the opposed patent.

4. None of the other prior art documents discloses such decoupling means. This has not been in dispute. Since D2 does not disclose them either, it was not obvious to a person skilled in the art, starting from prior art as disclosed in D1 or E4, to arrive at the subject-matter of claims 1, 47 or 49 by combining it with the teaching of D2. The subject-matter of these claims thus has to be considered as involving an inventive step in the meaning of Article 56 EPC.

5. Consequently, the Board considers that the amended patent and the invention to which it relates meet the requirements of the Convention (Article 103(2) EPC).

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

D. Sauter W. J. L. Wheeler