

(21) Application No: **0823432.0**  
(22) Date of Filing: **23.12.2008**

(51) INT CL:  
**B64C 25/32** (2006.01) **B60L 9/08** (2006.01)  
**B60L 9/14** (2006.01) **B60L 9/32** (2006.01)  
**B64F 1/10** (2006.01)

(71) Applicant(s):  
**Qingchang Zhong**  
**50 Swan Crescent, Liverpool, L15 8AL, United Kingdom**

(56) Documents Cited:  
**JP 050016897 A** **JP 2007145317 A**  
**US 20080258014 A1**

(72) Inventor(s):  
**Qingchang Zhong**

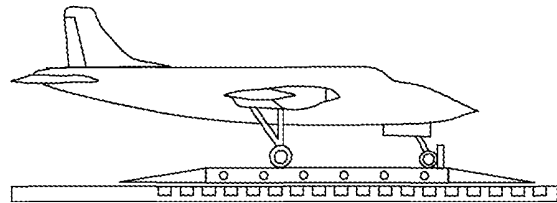
(58) Field of Search:  
INT CL **B60L, B64C**  
Other: **WPI; EPODOC**

(74) Agent and/or Address for Service:  
**Qingchang Zhong**  
**50 Swan Crescent, Liverpool, L15 8AL, United Kingdom**

(54) Abstract Title: **A system and a method for converting the kinetic energy stored in landing aircraft into electricity**

(57) A system and a method for converting the kinetic energy stored in landing aircraft into electricity consists of a parking vehicle for aircraft to move onto so that both can move together, the system comprises: a magnetic field generated by permanent magnets or energised coils laid into or onto the runway; coils mounted to the parking vehicle; a power conditioning device to process the generated electricity in the coils; a brush/conductor set to interface the coils with the fixed part of the system; and a runway controller to operate and control the whole system, according to the instructions from the control tower. After the aircraft touches down, it moves onto the parking vehicle, which then moves forward together with the aircraft. Because of the movement and the existence of a magnetic field, electricity is generated in the coils. After processing, the electricity is fed back to the grid and/or consumed by local loads. The coils can be driven by an external power source and hence the parking vehicle can move aircraft around for engineless taxiing and assisted takeoff.

Figure 3



## DESCRIPTION

The present invention is concerned with a system for converting the kinetic energy stored in landing aircraft into electricity.

Energy is fundamental to our daily life, from heating and lighting to transport, from industry to communication. Because of reduced gas, oil and coal production, governments have set various strategies to explore renewable energy sources, such as wind power, solar power, wave and tidal power etc, and to improve energy efficiency, e.g. via the use of combined heat and power (CHP) plants. For example, the UK government has introduced the Energy White Paper in 2003 and the Strategy for Combined Heat and Power in 2004. The EU has set a 22% target for the share of renewable energy sources and an 18% target for the share of CHP in electricity generation by 2010. As a result, the electrical power system is currently undergoing a dramatic change from centralised generation to distributed generation.

Another main driving force behind this change is the need to address the issue of climate change, mainly due to increased greenhouse gas emissions. Levels of carbon dioxide (CO<sub>2</sub>) in the atmosphere have risen by more than a third since the industrial revolution and are now rising faster than ever before. This has led to rising temperatures: over the 20th century, the earth warmed up by about 0.6°C largely due to increased greenhouse gas emissions from human activities. The 1990s were the warmest decade since records began. How to reduce human

activities to lead to a low carbon economy is crucial to this. Increasing the share of renewable energy and improving the energy efficiency are important means to reduce carbon emissions.

This patent is concerned about utilising an important energy-intensive power source: landing aircraft.

A fast travelling aircraft contains huge kinetic energy. When an aircraft lands, the huge kinetic energy is dissipated as waste heat. For example, the average power dissipated during the landing period, say 30 seconds, of a 40-ton aircraft with a touching speed of 150mph is 3MW. At Heathrow Airport, a landing happens about every two minutes. This gives a constant (average) power source of 750kW. For big aircraft, e.g. A380, the landing weight can be up to 386 tonnes, which gives an almost 10 times higher power. The present invention is to convert this huge kinetic energy source into an electrical power source. The electricity generated can be fed to the power grid and then electricity can be drawn from the grid to assist taking-off, which brings huge impact on carbon reduction and energy cost saving. It also improves air quality at the airport because of improved tear and wear on the tyres and breaks. This also enables engineless taxiing and pushing-back, which saves considerable amount of energy, reduces the noise level and improves air quality. Another benefit is that the fuel carried by the aircraft for taxiing/takeoff can be considerably reduced, which adds more benefit. The implementation of this invention will have great impact on improving energy efficiency, reducing energy cost and the impact on environment.

While preparing this application, the following US patent application was found:

MCCOSKEY WILLIAM R, VANDER WEL MICHAEL M, JOHNSON RICHARD N, Aircraft Kinetic landing energy conversion system, Application No.: US20080106135, Publication date: 2008-10-23.

The system incorporates at least one wheel supporting the aircraft for landing and takeoff coupled with a dynamic functioning motor/generator mounted to and operated by rotation of the wheel to create electrical energy from kinetic energy. An induction shoe, structurally connected to the aircraft and electrically connected to the motor/generator, draws the converted energy from the generator. This provides the generator circuit for conversion of the rotational energy of the wheel to electrical energy and creates braking drag. Additionally, the generator is employable as a motor, receiving energy from the storage system for traction power to the associated aircraft wheel. An induction grid or a surface mounted conductive layer mounted into or onto a runway is employed for transferring energy to and from the motor/generator.

The main differences of the present invention from the above US patent application lie in:

1. A linear, but not rotational, generator/motor is adopted in the present invention to convert the kinetic energy. Hence, what is essential to the energy conversion is the (translational) movement of the aircraft but not the rotation of the wheel.

2. In the present invention, it does not involve any modification to the aircraft. This does not add any extra weight to the aircraft and does not lead to extra safety tests for aircraft. However, the above US application involves the modification of the aircraft undercarriage.
3. In the present invention, the intervention of the pilot when landing could be minimised, as the energy recovery system is operated by the personnel at the airport.
4. The implementation of the present invention involves less effort from partners and hence is much easier. The implementation of the US patent application involves airframers, airlines and airports. The implementation of the present invention can be led by airports, who are the investor and also the beneficiary.

In accordance with a first aspect of the present invention there is a system for converting the kinetic energy of landing aircraft into electricity, comprising

a parking vehicle for aircraft to move onto so that both could move together,

a magnetic field generated by permanent magnets or energised coils laid into or onto the runway,

coils mounted to the parking vehicle, in which electricity is generated by movement of the parking vehicle,

a power conditioning device to process the generated electricity in coils

a brush/conductor set to interface with the coils and the fixed part of the system,

a runway controller to operate and control the whole system, according to the instructions from the control tower.

In accordance with a second aspect of the present invention, there is a method of converting the kinetic energy of landing aircraft into electricity, comprising the steps of

providing a linear generator operated by the movement of the aircraft,  
processing the generated electricity to meet the desired deceleration profile.

In accordance with a third aspect of the present invention, there is a method for taxiing the aircraft or assisted takeoff, comprising the step of processing an external power supply to drive a linear motor, which moves the aircraft.

Specific embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 represents the runway with permanent magnets laid inside;

Figure 2 represents the structure of a parking vehicle;

Figure 3 is an outlined assembly of the energy recovery system for landing aircraft;

Figure 4 shows the power processing and control subsystem;

Figure 5 shows the power-processing device;

Figure 6 (a) and (b) are graphs of different power profiles corresponding to different deceleration profiles.

The rest of this description is organised as follows. The motivation and benefits are described in Section I, followed by the technical route discussed in Section II.

### I. Motivation and benefits

For an aircraft, weighing  $m = 40 \text{ ton} = 4 \times 10^4 \text{ kg}$  and moving at a speed of  $v_0 = 150 \text{ mph} = 0.44704 \times 150 = 67 \text{ m/s}$ , the kinetic energy stored in the aircraft is

$$E = \frac{1}{2}mv_0^2 = 2 \times 10^4 \times 67^2 = 8.98 \times 10^7 \text{ Joule,}$$

which is equivalent to

$$E = \frac{8.98 \times 10^7}{1000 \times 3600} = 25 \text{ kWh.}$$

Assume that the landing process takes about 30 seconds. The kinetic energy has to be converted into other energy, e.g. waste heat nowadays. The average rate of energy transfer is about

$$P = \frac{E}{t} = \frac{8.98 \times 10^7}{30} \approx 3 \text{ MW.}$$

If there is a landing every two minutes, e.g. at Heathrow Airport, then the average power is 750 kW. In the near future, it is expected that big aircraft, such as Airbus A380, will be the main carriers at major international airports. This will give an average power of about 7.5 MW, which is equivalent to the capacity of three to four wind turbines widely used nowadays.

The benefits of converting this energy into electricity are much more than just recovering the energy and saving the energy cost. The potential benefits include:

- Using the facility established for assisted take-off, which will considerably reduce the impact of carbon emission and improve air quality as well. This may also mean that increased payload can be carried.
- Extending the facility to taxiway so that engineless taxiing and pushing back can be implemented, which will considerably improve the energy efficiency involved, as the engine are designed to run at high speeds and the efficiency of the engine is very low at low speeds. The running of the engine also causes environmental issues such as increased emissions, noise, bad air quality etc.
- Reducing the amount of fuel to be carried for takeoff and landing/taxiing, which considerably reduces the energy consumption when travelling in the air.

## II. Technical route

Technically, the kinetic energy can be converted into electricity using electric machines. One way is to mount a rotating machine on the undercarriage, as normally done for regenerative braking of vehicles. This was adopted in the above-mentioned US patent application. Another way is to change the combination of the aircraft and runway into a linear machine and the interaction between the aircraft and the runway generates electricity, which is then fed into the power grid.

#### *A. Energy conversion*

The technical route taken is to make the aircraft as the movable part (rotor) of a linear electric machine and to make the runway as the fixed part (stator) of the machine. Permanent magnets are laid onto or into the runway, as shown in Figure 1. Once the aircraft is landed, it moves onto the parking vehicle shown in Figure 2 and parks on the vehicle once it meets the risen barriers on the vehicle. Because of the inertia of the landing aircraft, the parking vehicle keeps moving forward. This generates electricity in the coils mounted underneath the parking vehicle. The generated electricity can be transferred via a brush/conductor set and then processed by a power conditioning and control system on the ground. It can be stored locally or fed back to the grid. A sketch of the whole system is shown in Figure 3. If the coils on the parking vehicle are energised, the vehicle can be moved forward or backward to taxi the aircraft.

#### *B. Power conditioning and control*

The power conditioning and control system is shown in Figure 4. There are two operation modes: Landing (L) and taxiing/takeoff (T). When the system works in the landing mode, the coils are connected to the power-conditioning device so that the generated electricity can be processed and fed back to the grid or stored locally; when the system works in the assisted takeoff or taxiing mode, the coils are connected to a power supply. The change of the operation mode, as well as the drive for taxiing/takeoff and the power conditioning, are controlled by the runway controller. A mechanism to indicate the mode of the runway should be visible from the aircraft to ensure safety.

At the landing mode, the electricity generated from the coils has a variable voltage and a variable frequency because the speed of the aircraft (parking vehicle) decreases when time goes. Also the speed, mass and braking force of one aircraft are different from those of others. Hence, there is a need to process the electrical power recovered from the landing aircraft. This device normally consists of a rectifier, a DC-DC converter, temporary energy storage, and a DC-AC converter that interfaces with the power grid; see Figure 5. Moreover, this power-conditioning device needs to be able to cope with a much higher transient power than the average power.

At the taxiing mode, the coils are energised so that the parking vehicle can be moved forward or backward. This involves running the machine as a motor and is implemented via the drive device.

The whole system is controlled by the runway controller, which receives instructions from the control tower.

### C. Power profile

Assume that the braking force  $f$  is constant, which gives a constant deceleration  $a \text{ m/s}^2$ , then the braking power is

$$p = f \cdot v = f \cdot (v_0 - at),$$

which decreases as the speed decreases. For the data given in Section I, the deceleration is

$$a = \frac{67}{30} = 2.23 \text{ m/s}^2$$

and the braking force is

$$f = ma = 4 \times 10^4 \times 2.23 = 8.93 \times 10^4 \text{ N}.$$

As a result, the instantaneous braking power is

$$p = 8.93 \times 10^4 (67 - 2.23t) \text{ W},$$

as shown in Figure 6(a). The transient power is much higher than the average power.

Assume that the braking force applied increases with time, i.e.,  $f = ma_0 t$ .

This gives a linearly increasing deceleration  $a = a_0 t$ . The velocity is

$$v = v_0 - \frac{1}{2} a_0 t^2$$

and the instantaneous braking power is

$$p = ma_0t(v_0 - \frac{1}{2}a_0t^2).$$

For the data given in Section I,  $a_0 = 0.1489 \text{ m/s}^3$  with a maximum deceleration of  $4.667 \text{ m/s}^2$  at  $t=30$  second. In this case, the profile of the braking power is shown in Figure 6(b). The above shows that the profile of the instantaneous power could be changed by changing the acceleration/deceleration profile.

CLAIMS

1. A system for converting the kinetic energy of landing aircraft into electricity, comprising
  - a parking vehicle for aircraft to move onto so that both could move together,
  - a magnetic field generated by permanent magnets or energised coils laid into or onto the runway,
  - coils mounted to the parking vehicle, in which electricity is generated by movement of the parking vehicle,
  - a power conditioning device to process the generated electricity in coils
  - a brush/conductor set to interface with the coils and the fixed part of the system,
  - a runway controller to operate and control the whole system, according to the instructions from the control tower.
  
2. A system as claimed in claim 1 further comprising a switching device, controlled by the runway controller, for the coils on the parking vehicle to be energised from an external power supply to drive the parking vehicle and the aircraft, if any parked on top of it.
  
3. A system as claimed in claim 2 in which the external power supply is provided by a drive controlled by the runway controller.

4. A system as claimed in claim 1 in which the parking vehicle has ramps on both ends so that the aircraft can move on and off, and a barrier or bollard having a controllable height on one end to prevent the aircraft from moving on the vehicle while being parked.

5. A system as claimed in claim 1 in which the air gap between the parking vehicle and the runway magnets is maintained via means of mechanical support or electrical control.

6. A system as claimed in claim 1 in which the power-conditioning device consists of a rectifier to convert the generated electricity into a DC source, a DC-DC converter to regulate the voltage level, a local storage system to smooth out the power level and a DC-AC inverter to interface with the power grid and/or to supply local loads.

7. A system as claimed in claims 1 and 6 in which the power profile processed by the power-conditioning device, and hence the deceleration/acceleration profile of the parking vehicle/aircraft, are controlled by the runway controller.

8. A method for converting the kinetic energy of landing aircraft into electricity, comprising the steps of

providing a linear generator operated by the movement of the aircraft,

processing the generated electricity to meet the desired deceleration profile.

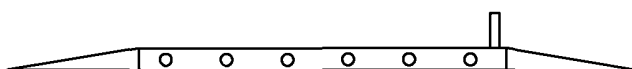
9. A method for taxiing the aircraft or assisted takeoff, comprising the step of processing an external power supply to drive a linear motor, which moves the aircraft.

Figure 1



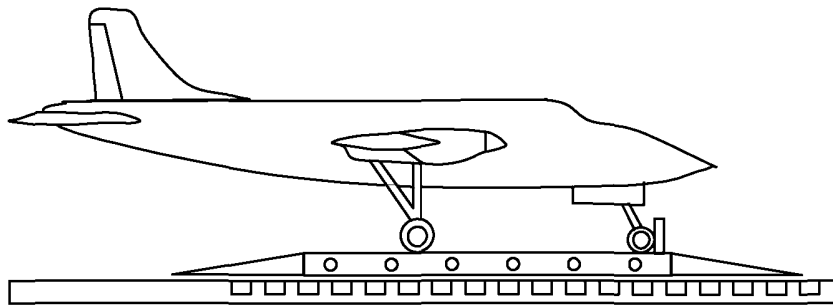
19 01 09

Figure 2



19 01 09

Figure 3



19 01 09

Figure 4

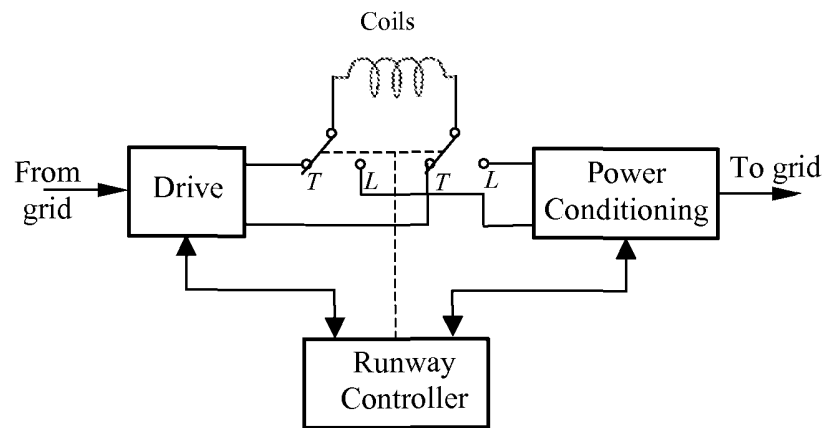


Figure 5

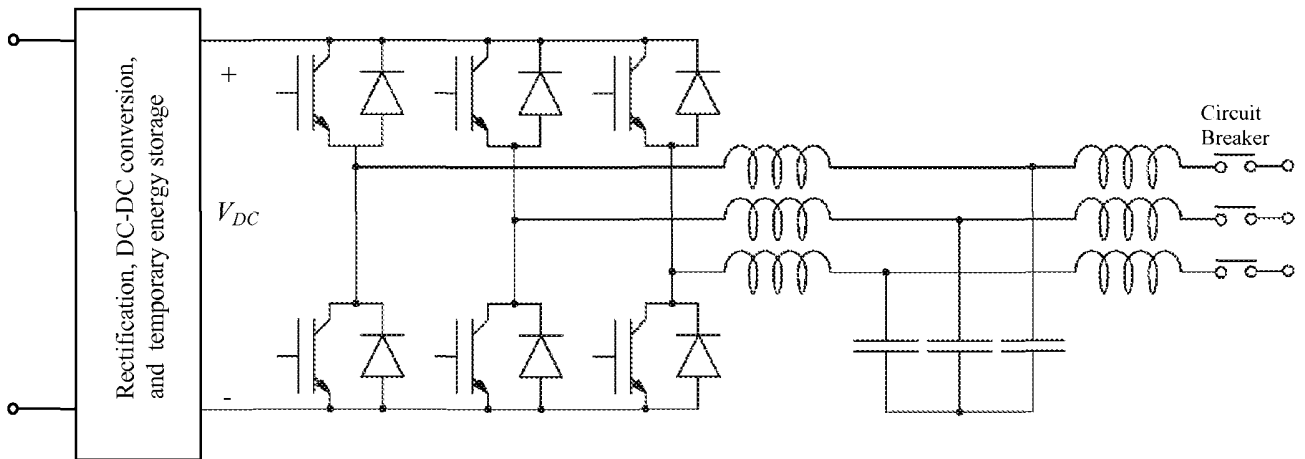
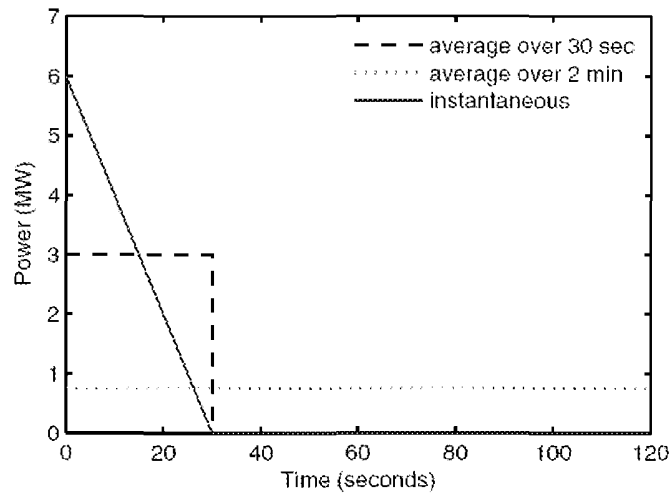
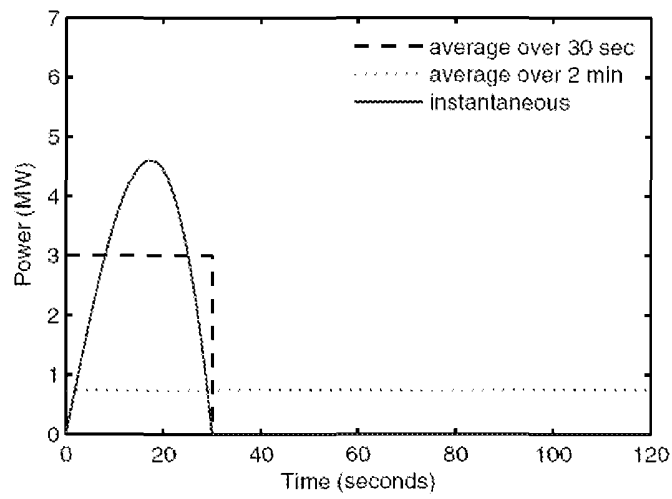


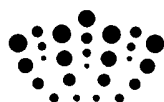
Figure 6



(a) Constant deceleration



(b) Linearly increasing deceleration



**Application No:** GB0823432.0

**Examiner:** Mr Kevin Hewitt

**Claims searched:** 1 to 9

**Date of search:** 12 May 2009

**Patents Act 1977: Search Report under Section 17**

**Documents considered to be relevant:**

| Category | Relevant to claims | Identity of document and passage or figure of particular relevance                     |
|----------|--------------------|--|
| A        | -                  | US 2008/0258014 A1<br>(McCOSKEY ET AL) See especially the Abstract and all Figures.    |
| A        | -                  | JP 2007145317 A<br>(SORITON SYSTEMS) See especially the Abstract and Figures 1 to 4.   |
| A        | -                  | JP 05016897 A<br>(MITSUBISHI HEAVY INDUSTRIES) See especially the Abstract and Figure. |

**Categories:**

|   |   |   |  |
|---|---|---|--|
| X | Document indicating lack of novelty or inventive step   | A | Document indicating technological background and/or state of the art.  |
| Y | Document indicating lack of inventive step if combined with one or more other documents of same category. | P | Document published on or after the declared priority date but before the filing date of this invention.          |
| & | Member of the same patent family  | E | Patent document published on or after, but with priority date earlier than, the filing date of this application. |

**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>X</sup> :

|  |
|--|
|  |
|--|

Worldwide search of patent documents classified in the following areas of the IPC

|            |
|------------|
| B60L; B64C |
|------------|

The following online and other databases have been used in the preparation of this search report

|             |
|-------------|
| WPI; EPODOC |
|-------------|

**International Classification:**

| Subclass | Subgroup | Valid From |
|----------|----------|------------|
| B64C     | 0025/32  | 01/01/2006 |
| B60L     | 0009/08  | 01/01/2006 |
| B60L     | 0009/14  | 01/01/2006 |
| B60L     | 0009/32  | 01/01/2006 |
| B64F     | 0001/10  | 01/01/2006 |