DEVELOPMENT AND TEST OF A KINETIC ACCUMULATOR OF ELECTRIC ENERGY FOR AN HYBRID ELECTRICAL VEHICLE

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Abstract. The intention of the current paper is to present the results obtained from the development and test of a kinetic accumulator of electric energy for an application on a hybrid electrical vehicle. This system is electrical energy storage.

Key words

Kinetic accumulator, hybrid electrical vehicle, momentum wheel, energy storage, motor.

1. Introduction

Nowadays the most usual electrical accumulators are electrochemical Batteries (Lead-acid, Ni-Cd, Li), Capacitors and Inductances. Electrochemical batteries can withstand high current peaks in discharge state but can not withstand a quasi nominal current in a loaded steady state.

The Kinetic accumulator of electrical energy works storing and unloading electrical energy. This device uses the rotation motion of its mass to do both energy exchanges. The electrical machine converts the electrical energy into kinetic energy and vice versa, with high conversion ratios and with instant powers higher than Sealed Lead Acid batteries can achieve. This system is an electrical energy storage.

The purpose of this document is to present the results obtained from the development and test of a electric energy- kinetic's accumulatorapplied on a hybrid electrical vehicle.

2. Description

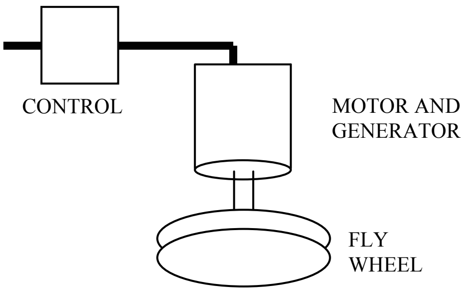
The Kinetic accumulator of electrical energy (in what follows named ACEE) is composed by a flywheel (rotating mass) directly coupled to an electrical machine with a control device.

When a hybrid electrical vehicle starts, the operation ratio of the Sealed Lead Acid batteries batteries goes easily down up to 20% per loading-unloading cycle. Opposite, the ACEE depends only on the operation ratio from electrical machine, which can easily reach 80% of the energy ratio per loading-unloading cycle.

Application in motor car allows to study specific cases where the fly wheel rotates at its nominal speed in short periods of time. This case could be the instantaneous breaking in front of a red traffic signal. During this stop period, the speed of the fly wheel could be increased using a power generator set. The vehicle starting after the green light signal take up less than one minute time. Using ACEE's discharge prevents high peak current demands from the batteries.

The ACEE has no limit number of loading-unloading cycles. Deep unloadings are feasible without problems.

The electrical machine can be designed to resist high instant power peaks in loading and unloading cycles. This is a very interesting feature in an application such as regenerative breaking.



In future design, the intention of the authors is to implement this system with superconductor technology. But it is mandatory to get done experience in design and assembly of the ACEE technology previusly.

In fact, there is little experience using and appling the ACEE about the friction looses as a result of wheel braking. There are many applications like hybrid electrical vehicles, that can improve successufully this type of devices. When high critical temperatures superconductors close to exist, they will ease the use and application of ACEE but it is of high interest to get periferical elements and applications ready until this moment arrives.

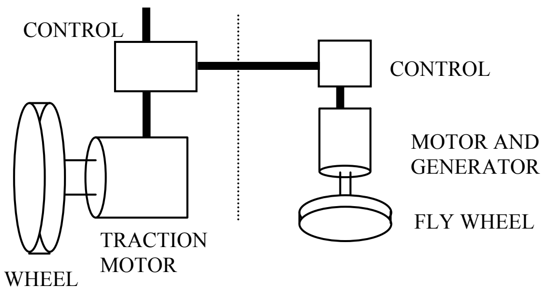
This system presents the following advantages:

- It is a compact system.
- Enviroment friendly in its duty life.
- Fast storage unloading.
- Able to withstand high peak instant power.

But it presents also the following disavantages when its compared with other materials:

- Friction looses.
- Electrical machine looses.

The friction looses can be reduced using vacuum magnetic levitation or superconductors.



The speed is an important design parameter in ACEE design, specially the critical ones or resonance speed. For security reasons the highest speed of the system had been limited to resonance speed.

Other critical point is the ACEE bearings. Bearings fix the resonance speed and, therefore, the fly wheel's speed limit.

3. Prototype

In this prototype, we use a 800W axial flux machine manufactured by MAVILOR Motors (MSS-8 model) as electrical motor-generator . Its main features is:

- Nominal speed: 3000 rpm
- Nominal voltage: 90V
- Nominal current: 10.7 A
- Nominal torque: 2.56 Nm
- Maximum torque: 15.38 Nm
- Inertia momemtum: 0.00082 Kgm^2
- Weight: 8 Kg

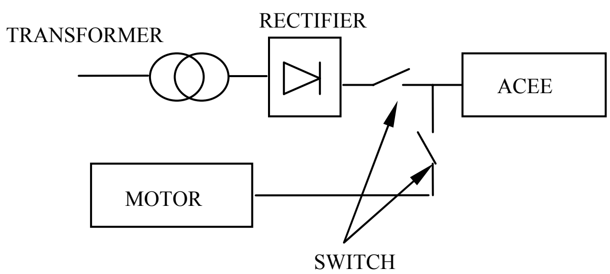
We couple a fly wheel with electrical motor-generator. This fly wheel is a disk cylinder with a 200 mm of radius and 20 mm height. It has 17 Kg of weight. The inertia moment is 0.34 Kgm^2.

The storage energy with this values reaches 1,850 J at 1,000 rpm. With a voltage of 110 V, the resulting storage energy is 32,000 J.

The loading test has been carried on using a traction electrical motor. This electrical motor is a direct current motor with serial excitation. Its main characteristics are:

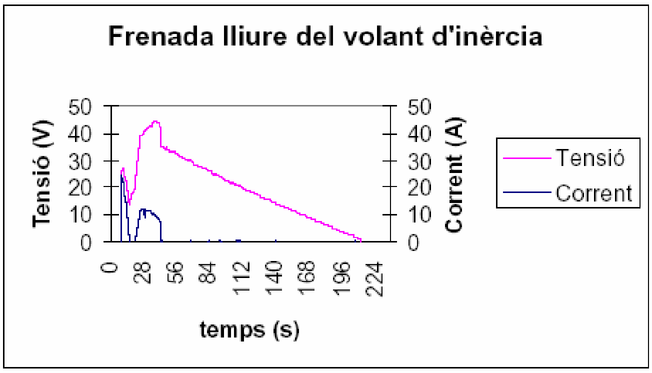
- Nominal power: 2,200 W
- Maximum power: 4,000 W
- Nominal voltage: 110 V
- Nominal current: 24 A
- Nominal speed: 4,000 rpm
- Starting torque with at 100 A: 44 Nm
- Starting torque with 32 V voltage applied: 30Nm
- Resistance of excitance coil: 0.58 Ω
- Resistance of induced coil: 0.7 Ω
- Weight: 55Kg

The electrical circuit to test the prototype is following down:



4. Test prototype

It has been observed that after accelerating the fly wheel with a 45 V voltage, the ACEE takes more than 3 minutes to stop.This means Friction losses.

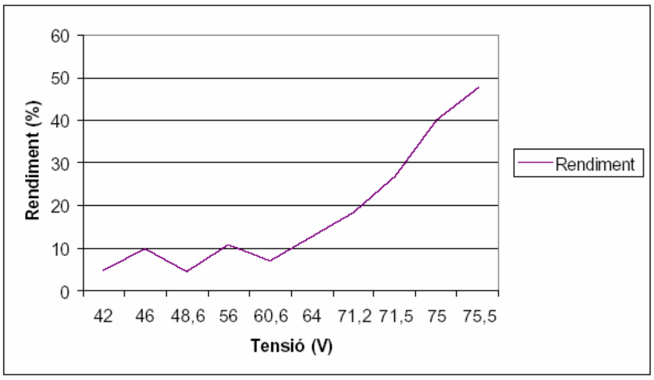


After a number of loading and unloading cycles, efforts have been focused on the study of the starting transient of a serial excitation direct current motor, which is mounted on an hybrid electrical automobile as unloading.

Unloading tests are performed loading different voltages with the same gear ratio. The vehicle moves on a planar horizontal surface.

Tests consist on moving the ACEE with a certain speed and afterwards, to discharge this energy on vehicle's traction motor.

Supply Voltage (V)	Theoric Accumulated Energy (J)	Returned Energy (J)	Eficiency (%)
42	11405.9	538	4.7
46	11405.9	1130	9.9
48.6	12731.7	577	4.5
56	16904.1	1840	10.8
60.6	19795.2	1370	6.9
64	22078.8	2830	12.8
71.2	27325.9	5030	18.4
71.5	27556.7	7410	26.9
75	30320.6	12220	40.2
75.5	30726.2	14700	47.8



The authors of this document have observed that low energy is returned at low speeds causing a low operation ratio. A speed up makes returned energy to increase, reaching operation ratios up to 48% with an applied voltage of 76 V (speed 425.1 rad/s, theoretical stored energy 30,726.3 J. Returned energy, 14,700 J).

This table shows unloading times of the ACEE to a DC motor (serial excitation).

Supply Voltage (V)	Unload Time (s)	Unload Voltage Peak (V)	Unload Current Peak (A)
42	15	10	20
46	20	25	23
48.6	20	12	25
56	21	20	10
64	33	45	12
71.2	35	50	27
72.2	37	52	28
75	40	65	30
75.5	40	62	30

The returned energy is converted into mechanical energy, that moves the vehicle, i e, running distances line these:

- When 42 V voltage applied, runs 0.31 m.
- When 56 V voltage applied, runs 0.58 m
- When 64 V voltage applied, runs 4 m
- When 71.2 V voltage applied, runs 8 m
- When 75 V voltage applied, runs 12 m
- When 76 V voltage applied, runs 14 m

The operation ratio of the set is greatly affected by the performance of serial excitation direct current traction motor.

5. Conclusion prototype

The conclusions are, as expected, at low input voltages the operation ratio of the system is low. It is also observed that for applied input voltage higher than 70V the operation ratio increases significantly. The operation ratio of the ACEE is close to 50%.

With a stored energy of 30 kJ, the ACEE moves 14 meters a vehicle of 810 Kg weight.

If the supply voltage is higher than 75V, the stored energy increase more than 30 KJ and it's possible to have an eficiency bigger than 60%.

Using ACEE helping vehicle starting can save a high amount of energy and, therefore, to increase the autonomy of electrical vehicles.

Close future

We have experience in elecrical machines but not about mechanical machines. So, the new ACEE don't pass a 4,000 rpm by the moment. (This speed is reliable for us).

The most important question is the energy management because current and voltage peaks are high.

When a car brakes from a 50 Km/h speed to zero, loosed energy is around 90 KJ. Then, we will make a new ACEE with a bigger energy storage (aprox. 80 KJ).

Instantaneous power has an effect on the electrical machine and its peformance is very important for the ACEE. The management of instantaneous power is dificult to make.

The control of instantaneous power forces to use direct servomachines like servers of energy.

Increase the speed of fly wheel means increase the specific power of ACEE. Another work grup from the team uses the rotation speed close to 20,000 rpm.

If we want to increase the ACEE power, we have to mind about security of the system. It is necessarily no use steel in the fly wheel construction. If we never arrive to critical speed, the fly wheel must break in a little pieces (it isn't the case of steel wich have high kinetic energy but don't cause seriosly damage.

For example, we use a fly wheel fibre-maded inside a security box. If it breaks, it will explode but without little piece.

The second prototype of ACEE has a fly wheel with 40

Kg of mass (330mm of diameter and 60 mm of hight). The electrical machine has 90% efficiency in comparation with 84% efficiency achived on the first prototype.

This efficiency motor affect directly to the efficiency of ACEE (we believe that increases a 12% efficiency of ACEE respect the first prototype).

The new electrical machine has a bigger supply voltatge 200V opposite 90 V of the first prototype. In addition, the nominal torque increases per 10 while the maximum torque increases per 6. These increases the energy storage and the instantaneous power.

The complexity of this system puts forward the use of an electronic control based on microcontroller.