overview of electrical kers for ic engine vehicles

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***Abstract* - kers is an automotive system or technology which is used for recovering the lost kinetic energy of an object undergoing deceleration or retardation. kers works on the basic principle of physics that states, "energy cannot be created or destroyed, it can only be endlessly converted". when a vehicle is being driven it has kinetic energy and the same energy is converted into heat and friction energy on braking. it is the rotational force of the car that comes to stop in case of braking and energy is lost. with the help of kers the energy losses are minimized. kers is a type of regenerative braking system which can recover and store the lost kinetic energy in various energy forms. in automobiles the lost energy is stored mechanically in flywheels or electrically in batteries using a complex system of energy recovery systems. this stored energy can further be used under acceleration or to power onboard electronics.**

***keywords* - motor generator unit (mgu), power control unit (pcu), kers, charging cycle, boost cycle, hybrid technology**

I. INTRODUCTION

KERS is a system of various parts that recovers and stores the kinetic energy released under braking. During the action of braking, energy is wasted because kinetic energy of the vehicle is mostly converted into heat or sometimes sound energy which is dissipated into the environment. Since the introduction of Electric/Hybrid vehicles, the use of battery powered propulsion is increased. So, in order to increase the efficiency or performance of the vehicle, KERS system are used. It is similar to having two sources of power for a vehicle, one is the engine and the other energy source is stored kinetically. When vehicles with KERS harness this energy they also assist in braking or deceleration and during acceleration at the touch of a button it provides an additional boost to the vehicle. KERS comprise of MGU (Motor-Generator Unit), the batteries/flywheel, the PCU (Power Control Unit). There are many types of KERS but the two most widely used types of KERS are Mechanical and Electrical KERS. The main difference between the two is in the way which they convert the energy and how it is stored in the vehicle. This technology has been in development since the 90's. With the increasing number of countries vying to cut carbon emissions and shifting towards more efficient, green and renewable technologies the need for KERS like hybrid systems is more than ever. It was first introduced to the general public in 2009 through the series of Formula One motorsport. KERS builders, Hybrid systems demonstrated a working Formula One Spec device at the Autosport international show. In the world of commercial automobiles, many manufacturers are trying to successfully integrate KERS or KERS based systems into their vehicles in order to increase the efficiency. For a brief period, it was being tested to be used in motorcycles. A KERS using a carbon fiber flywheel, originally developed for Williams Formula One team were modified for retrofitting to existing London double-decker buses. 500 buses from the Go-ahead group will be fitted will be fitted with this technology from 2014 to 2016, anticipated to improve fuel efficiency by approximately 20%. [1]

TYPES OF KERS SYSTEM

1. Mechanical KERS

Mechanical KERS has a flywheel as an energy storage device and it uses transmission directly to transfer energy and control it from the driveline.
The kinetic energy of the vehicle ends up as kinetic energy of rotating flywheel through the use of shaft and gears.
In mechanical KERS, energy doesn't need transformation from one type to the other type.

2. Electrical KERS

In this system the braking force is captured by an electric motor/generator unit. This also acts as the storage device for the system which is mounted in the crankshaft.
This system requires an array of onboard batteries and electronics to deal with the storage and deployment of energy.
Unlike mechanical KERS, Electrical KERS requires conversion of kinetic energy into electrical energy in order to store it into the batteries.

PROBLEM STATEMENT (CONVENTIONAL BRAKING)

In a conventional braking system, the energy generated during braking is entirely lost and cannot be recovered. This energy is dissipated in the form of noise and mainly heat, which is carried away by the air. The total amount of energy lost depends upon the total time for which brakes are applied, it's frequency and the intensity or how hard the brakes are applied. Hence in the case of conventional braking systems there is a lot of energy generated during braking which can be recovered and repurposed.

OBJECTIVES

The objectives of the paper are:

- System design and theoretical derivation of kinetic energy recovery system on various speed parameters for desired output power
- Energy audit of the system at assumed speed conditions.
- Minimize the energy loses by using Electrical KERS.
- To showcase the efficiency of the proposed system through calculations.

WHY ELECTRICAL KERS?

- Electrical KERS is the modern version of energy recuperation system.
- It can power a number of onboard electricals.
- It can be used to fill in the torque gapes during phases when the engine is producing low torque output. This can be used to overcome turbo lag in turbocharged vehicles.
- Recovering & Re-using energy, reducing fuel consumption thereby lowering emission of CO_2 and other pollutant gases.
- Reduces wear & tear on vehicle brakes by providing majority of required braking capacity.
- It has fewer moving parts as compared to mechanical KERS.
- It has the efficiency of approximately 10-15%. [4]

BASIC COMPONENTS OF ELECTRICAL KERS

KERS needs more than just energy storage to be a complete system. It needs devices to 'translate' the energy between its various forms of kinetic, electrical and chemical energy. This energy 'translation' comes from an electric motor-generator unit (MGU) which can turn the kinetic energy of the car into electrical energy and vice versa. Battery/cells to store the energy and PCU to monitor it. In essence, KERS comprises of three main components, one for generating power, one for storing it and one to control it all.

1. Motor/Generator Unit (MGU)

MGU converts kinetic energy into electrical energy and vice versa. A motor generator set consist of distinct motor and generator machines coupled together. A single unit motor generator will have both rotor coils of the motor and generator wound around a single rotor and both coils share the same outer field coils or magnets. Working in two cycles, the MGU both creates and returns power to and from the batteries.

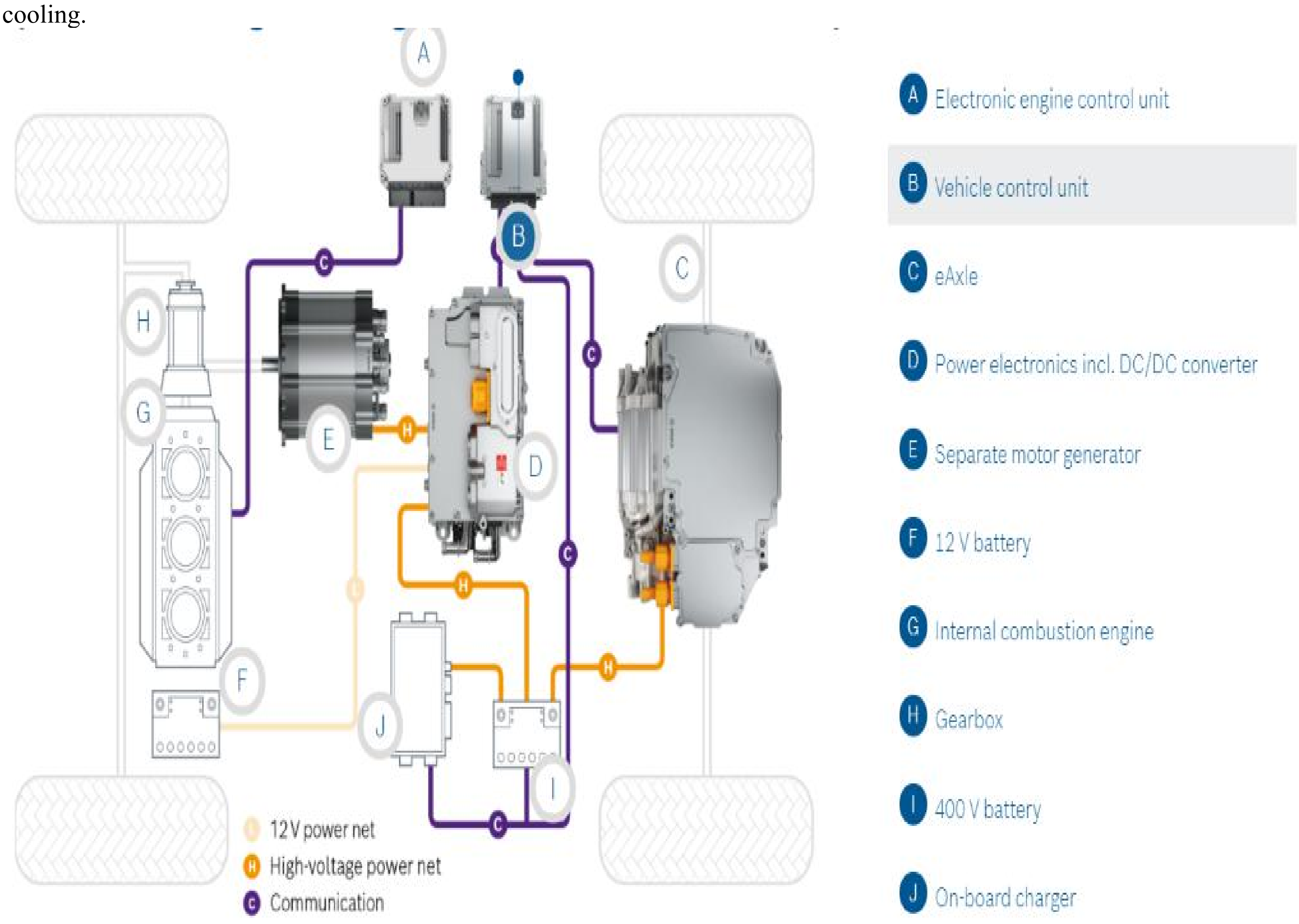
The Bosch Separate Motor Generator Unit that can be deployed as a driving motor in pure electric drive vehicles, and as a harvesting motor converting mechanical energy into electrical energy during deceleration in Hybrid drives. [2]

2. Storage Device (Batteries, Supercapacitors, Flywheels)

Storage devices can be Batteries, Supercapacitors or Flywheels. In modern automobiles the preferred mode of storage is Lithium-Ion batteries. The first working models of KERS used flywheels as the energy storage mechanism.

3. Power Control Unit (PCU)

PCU is the most complex component in this system. PCU serves two important purposes, firstly to invert and control the switching of current from the batteries to the MGU and secondly to monitor the status of the individual cells in the batteries. The batteries consist of Lithium-Ion cells. When the cell reaches high temperatures the efficiency of the cells starts to decrease. Also, the failure of cells can lead to rapid overheating of the cell and its adjacent cells. This can cause safety issues. Hence managing the battery is critical and of all the KERS components PCU requires the most amount cooling.



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ystem map of an Electric Hybrid Vehicle can be seen here. The highlighted Marker B is the Vehicle Control Unit essentially serving as the brains of the Powertrain operation other excluding the IC engine marked by Marker G. [2]

OPERATING MODES:

Charging Cycle: In charging cycle, kinetic energy recovered during braking or deceleration by the MGU is accumulated in the batteries to be stored. During braking, the electric supply from the batteries is cut off by the PCU. As the vehicle is still moving forward, the MGU acts as an electric generator which helps in recovery of energy.

Boost Cycle: In boost cycle, the energy stored in the batteries is used to provide a boost to the vehicle or to power onboard electronics. This energy transfer is helped by the PCU (Power Control Unit). The MGU acts as an electric motor to draw energy from the batteries to provide boost.

ENERGY REQUIREMENTS

The electrical loads carried by a commercial vehicle is increasing due to improvements in driving performance and comfort. Electrical loads are of three types, Continuous loads, Prolonged loads, and Intermittent loads. The Approximation of these loads is given in tables 1, 2 and 3

Table 1: Intermittent electrical loads [3]

Intermittent Loads	Power (W)	Current (A) 14V	28V
Heater	50	3.5	2.0
Indicators	50	3.5	2.0
Brake Lights	40	3.0	1.5
Front Wipers	80	6.0	3.0
Rear Wipers	50	3.5	2.0
Electric Windows	150	11.0	5.5
Radiator Cooling Fan	150	11.0	5.5
Heater Blower Motor	80	6.0	3.0
Heated rear window	120	9.0	4.5

Interior lights	10	1.0	0.5
Horns	40	3.0	1.5
Rear lights	40	3.0	1.5
Reversing lights	40	3.0	1.5
Auxiliary fog/spot lamps	110	8.0	4.0
Cigarette lighter	100	7.0	3.5
Headlight wash wipe	100	7.0	3.5
Seat movement	150	11.0	5.5
Seat heater	200	14.0	7.0
Sun-roof motor	150	11.0	5.5
Electric mirrors	10	1.0	0.5
Total (approximately)	1.7 kW	126 A	65 A

Table 2: Continuous electrical Loads [3]

Continuous Loads	Power (W)	Current (A) 14V	28V
Ignition	30	2.0	1
Fuel Injection	70	5.0	2.5
Fuel Pump	70	5.0	2.5
Instruments	10	1.0	0.5
Total	180	13.0	6.5

Table 3: Prolonged electrical Loads [3]

Prolonged Loads:	Power (W)	Current (A) 14 V	28 V
Side and tail lights	30	2.0	1.0
Number plate lights	10	1.0	0.5
Headlights main dip beam	180	13.5	6.5
Dashboard lights	25	2.0	1.0
Radio/Cassettes/CD	15	1.0	0.5
Total	260	19.5	9.5

In order to meet these energy demands, efficient engine performance and the use of a Battery based Kinetic Energy Recovery System (KERS) is proposed. Currently KERS is only being used in Ph-EVs and EVs in the market. If the same KERS system is deployed in IC engine vehicles by using a Motor Generator Unit drawing power from the Trans-Axle assembly, it can power the auxiliary on-board electronics like the Dashboard lights or the infotainment system, thus taking the load off the Main Battery.

CALCULATIONS:

The Total Kinetic Energy of a vehicle with mass 1.5 T will be given by the formula:

K.E. = 1/2 m v2

Here, the total mass of the vehicle is 1.5 Tons, or 1500 Kg. Assume the vehicle is travelling at a velocity of 20 m/s, or 72 km/Hr. Using these values in the formula, we get the value of Kinetic Energy as,

KE_1 = 0.5 x 1500 x 20 x 20

KE_1 = 300000 Joules

KE_1 = 300 kJ (1)

Finding the energy, assuming the vehicle mass stays the same in both scenarios, when the vehicle is slowed down to half the current speed of 72 km/hr. (20 m/s) to 36 km/hr. (10 m/s) with the same formula:

KE_2 = 0.5 x 1500 x 10 x 10

KE_2 = 75000 Joules

KE_2 = 75 kJ (2)

Thus, from (1) and (2) we can see, the Kinetic Energy lost under deceleration is 225 kJ, most of it dissipated in the form of heat from the brake calipers.

The approximate energy recovered by the Electrical KERS system is anywhere between 10-15 % of the total energy lost. [4]

Therefore, in the above-mentioned example, an Electrical KERS system will harvest and recover 22.5 kJ from the kinetic energy that would have been otherwise completely lost as Friction heat under braking.

This 22500 J or 22.5 kJ of the recovered energy, can be used to power the Auxiliary electronics from Table 1.

BENEFITS:

1. A main battery of lower rating can be installed as the intermittent loads will be fueled from the KERS battery pack.

2. Less energy wastage, and improved fuel economy owing to the engine working that much less for charging a smaller main battery.
3. Increment in the life of Brake Pads due to the vehicle slowing down partially due to the Motor Generator Unit.

LIMITATIONS:

1. Battery storage capability.
2. Weight Increment due to battery pack.

CONCLUSION:

Cars with a Battery-based energy recovery system, though significantly more expensive than cars without this system, can equip smaller main batteries and reduce the load on the engine for charging the battery. Currently, the concept of MGU and energy harvesting is limited to only hybrid and pure Electric Vehicles. This technology can bring up revolution in the automotive industry by making every passenger and commercial vehicle eco-friendly. Thus, in this paper, we have tried to showcase the Benefits of deploying an electrical KERS system in Conventional IC engine vehicles.

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