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Control Strategy of Regeneration Braking system for Electric Vehicles

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Abstract: *Nowadays energy crisis is the most important issue faced by many countries. To tackle it efficient machine design and electric vehicles are best fit practical solutions. In advanced countries regenerative braking system is the area where most of the work is going on. In this project we are using this regenerative breaking concept to apply brakes to vehicle and creating electrical energy simultaneously by using alternator. Regenerative braking is an energy regaining mechanism that slows a vehicle or object by translating its kinetic energy into a form that can be either used immediately or stored until required. In the project we are applying this concept to one wheel which is rotating. Its mechanical rotary energy is converted into the electrical energy. This electrical energy can be stored and utilized in critical situations or to run the internal components present in the car. To develop and design this project we are using CATIA V5 CAD software. Then final manufacturing and testing will be done and results will be plotted out.*

Keywords: Electric Vehicle, Torque, Regenerative Braking

I. Introduction

1.1 Problem Statement

In electrical and hybrid vehicles battery is the most important part. It acts as a power house. In developed countries charging is done at electrical charging stations. In India these stations are yet to be placed. It is same as that of the petrol stations. But the main problem occurs when the charging station is not present and there is need to run the vehicle. In such a scenario when battery is discharged in electric vehicles there is a need for reserve supply.

1.2 Objectives

- To generate electricity by using the regenerative braking system.
- To apply brakes and stop vehicle.
- To store the generated electricity for crisis situation.
- To generate and study the model with the help of CATIA software.

1.3 Introduction

Moving vehicles have a lot of kinetic energy, and when brakes are applied to slow a vehicle, all of that kinetic energy has to go somewhere. Back in the Neanderthal days of internal combustion engine cars, brakes were solely friction based and converted the kinetic energy of the vehicle into wasted heat in order to decelerate a car. All of that energy was simply lost to the environment. Fortunately, we have evolved as a species and developed a better way. It is important to realize that on its own, regenerative braking isn't a magical range booster for electric vehicles. It doesn't make electric vehicles more efficient per se, it just makes them less inefficient. Basically, the most efficient way to drive any vehicle would be to accelerate to a constant speed and then never touch the brake pedal. Since braking is going to remove energy and require you to input extra energy to get back up to speed, you'd get your best range by simply never slowing down in the first place. But that obviously isn't practical. Since we need to brake often, regenerative braking is the next best thing. It takes the inefficiency of braking and simply makes the process less wasteful. To evaluate regenerative braking, we really need to look at two different parameters, efficiency and effectiveness. Despite sounding similar, the two are quite different. Efficiency refers to how well regenerative braking captures 'lost' energy from braking. Does it waste a lot of energy as heat, or does it turn all of that kinetic energy back into stored energy?

Effectiveness, on the other hand, refers to how large of an impact regenerative braking really makes. Does it measurably increase your range, or will you not notice much of a difference? No machine can be 100% efficient (without breaking the laws of physics), as any transfer of energy will inevitably incur some loss as heat, light, noise, etc. Efficiency of the regenerative braking process varies across many vehicles, motors, batteries and controllers, but is often somewhere in the neighborhood of 60-70% efficient. Regen usually loses around 10-20% of the energy being captured, and then the car loses another 10-20% or so when converting that energy back into acceleration, according to Tesla. This is fairly standard across most electric vehicles including cars, trucks, electric bicycles, electric scooters, etc. This system is called regenerative braking. At present, these kinds of brakes are primarily found in hybrid vehicles like the Toyota Prius, and in fully electric cars, like the Tesla Roadster. In vehicles like these, keeping the battery charged is of considerable importance.

If you get about town on a bicycle, it's very obvious that braking is a huge waste of energy. You have to pedal to get yourself going, and each time you brake and come to a standstill you waste all the momentum you've gained. Next time you want to move off, you have to start from scratch all over again. Put your hands anywhere near the brake pads on a bicycle and you'll know exactly where the energy goes: each time you brake and the rubber pads clamp on the wheel, friction between rubber and metal converts the energy you had when you were moving into heat, which disappears uselessly into the air, never to be seen again. Car drivers are pretty much oblivious to the energy that braking wastes because driving doesn't require any real, physical effort. Not only that, but car brakes are hidden out of sight, inside the wheels, where you can't see the heat energy they're wasting.

But the heat they generate is extraordinary: according to one manufacturer, Brembo, the brakes in formula-1 race cars can heat up as high as 1000°C (1830°F). The first of these systems to be revealed was the Flybrid. This system weighs 24 kg and has an energy capacity of 400 kJ after allowing for internal losses. A maximum power boost of 60 kW (81.6 PS, 80.4 HP) for 6.67 seconds is available. The 240 mm diameter flywheel weighs 5.0 kg and revolves at up to 64,500 rpm. Maximum torque is 18 Nm (13.3 ft lbs). The system occupies a volume of 13 litres Formula One have stated that they support responsible solutions to the world's environmental challenges, and the FIA allowed the use of 81 hp (60 kW; 82 PS) KERS in the regulations for the 2009 Formula One season. Teams began testing systems in 2008: energy can either be stored as mechanical energy (as in a flywheel) or as electrical energy (as in a battery or supercapacitor). Two minor incidents were reported during testing of KERS systems in 2008. The first occurred when the Red Bull Racing team tested their KERS battery for the first time in July: it malfunctioned and caused a fire scare that led to the team's factory being evacuated. The second was less than a week later when a BMW Sauber mechanic was given an electric shock when he touched Christian Klien's KERS-equipped car during a test at the Jerez circuit.

With the introduction of KERS in the 2009 season, four teams used it at some point in the season: Ferrari, Renault, BMW, and McLaren. During the season, Renault and BMW stopped using the system. Vodafone McLaren Mercedes became the first team to win a F1 GP using a KERS equipped car when Lewis Hamilton won the Hungarian Grand Prix on 26 July 2009 Although KERS was still legal in F1 in the 2010 season, all the teams had agreed not to use it. New rules for the 2011 F1 season which raised the minimum weight limit of the car and driver by 20 kg to 640 kg, along with the FOTA teams agreeing to the use of KERS devices once more, meant that KERS returned for the 2011 season. This is still optional as it was in the 2009 season; in the 2011 season 3 teams elected not to use it. For the 2012 season, only Marussia and HRT raced without KERS, and by 2013, with the withdrawal of HRT, all 11 teams on the grid were running KERS. In the 2014 season, the power output of the MGU-K (The replacement of the KERS and part of the ERS system that lso includes a turbocharger waste heat recovery system) was increased from 60 kW to 120 kW and it was allowed to recover 2 mega- joules per lap. This was to balance the sport's move from 2.4 litre V8 engines to 1.6 litre V6 engines. The fail-safe settings of the brake-by-wire system that now supplements KERS came under examination as a contributing factor in the crash of Jules Bianchi at the 2014 Japanese Grand Prix.

Auto Part Makers

Bosch Motorsport Service is developing a KERS for use in motor racing. These electricity storage systems for hybrid and engine functions include a lithium-ion battery with scalable capacity or a flywheel, a four to eight kilogram electric motor (with a maximum power level of 60 kW or 80 hp), as well as the KERS controller for power and battery management. Bosch also offers a range of electric hybrid systems for commercial and light-duty applications.

Carmakers

Automakers including Honda have been testing KERS systems. At the 2008 1,000 km of Silverstone, Peugeot Sport unveiled the Peugeot 908 HY, a hybrid electric variant of the diesel 908, with KERS. Peugeot planned to campaign the car in the 2009 Le Mans Series season, although it was not capable of scoring championship points. Peugeot plans also a compressed air regenerative braking powertrain called Hybrid Air. Vodafone McLaren Mercedes began testing of their KERS in September 2008 at the Jerez test track in preparation for the 2009 F1 season, although at that time it was not yet known if they would be operating an electrical or mechanical system. In November 2008 it was announced that Freescale Semiconductor would collaborate with McLaren Electronic Systems to further develop its KERS for McLaren's Formula One car from 2010 onwards. Both parties believed this collaboration would improve McLaren's KERS system and help the system filter down to road car technology.

Toyota has used a supercapacitor for regeneration on Supra HV-R hybrid race car that won the 24 Hours of Tokachi race in July 2007. BMW has used regenerative braking on their E90 3 Series as well as in current models like F25 5 Series under the Efficient Dynamics moniker. Volkswagen have regenerative braking technologies under the Blue Motion brand in such models as the MK7 Golf and MK7 Golf Estate / Wagon models, other VW group brands like SEAT, Skoda and Audi.

Motorcycles

KTM racing boss Harald Bartol has revealed that the factory raced with a secret kinetic energy recovery system (KERS) fitted to Tommy Koyama's motorcycle during the 2008 season-ending 125cc Valencian Grand Prix. This was against the rules, so they were banned from doing it afterwards.

II. Literature Survey

"A novel control strategy of regenerative braking system for electric vehicles under safety critical driving situations" by, Chengqun Qiua, Guolin Wang, Mingyu Meng, Yujie Shen.

This paper mainly focuses on control strategy of the regenerative braking system of an electric vehicle under safety critical driving situations. With the aims of guaranteeing the electric vehicle stability in various types of tire-road adhesion conditions, based on the characteristics of an electrified powertrain, a novel control strategy of regenerative braking system is proposed for electric vehicles during anti-lock braking procedures. Firstly, the main construction of the case-study electric car with regenerative braking system is introduced. Next, based on the phase plane theory, the optimal brake torque is calculated for ABS control of an electric vehicle. Then, an allocation control, wherein the required optimal brake torque is divided into two parts that are disposed respectively by the friction and regenerative brkes, is discussed. In addition, two parameters for evaluating regeneration braking energy efficiency contribution while in the deceleration braking process are defined. Furthermore, a novel regenerative braking control strategy named "serial control strategy" is proposed. Finally, the road tests are implemented in four types of tire-road adhesion conditions under safety-critical driving situations.

The test results validate the effectiveness and feasibility of the proposed control strategy. The regenerative brake force is removed rapidly when the commercial EV get into an emergency braking situation only when the friction brake takes charge of the ABS. This is a mature approach to ensure the brake safety with the conventional ABS, and actual

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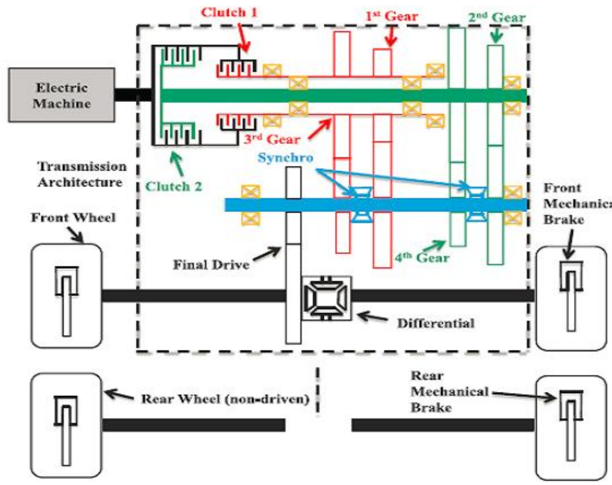
applications 47 show the pragmatically of this simplification. Nevertheless, these applications cannot adequately utilize the latent profits from the electric motor's regenerative brake so as to improving electric vehicle's dynamics control performance. Making use of the fast response and precise control of motor torque, researchers globally explore have explored diverse ways to recommend regenerative braking torque blend in ABS control, looking forward to improved control. A method utilizing proportional-integral-derivative control regenerative brake force as ABS operation is proposed. The simulation results on the basis of a quarter vehicle model display that "regenerative ABS" is beneficial during the critical braking process. Nevertheless, the regeneration abilities are based on the operating conditions of batteries and electric motors.

Therefore, the friction brake is likewise required to replenish the overall brake demand. A regenerative braking system by electrically-controlled according to the techniques with conventional hydraulic ABS is studied, and a control algorithm harmonizing the ABS control functions and braking energy regeneration is developed. Three control strategies, namely, the "model following control," "frequency selection by filter," and PQ-method" strategies are developed. The optimal ABS control is anticipated on the electric motor responds much more fastly and precisely than the friction brake. Road tests verified the control performance of the developed method. Passenger cars equipped with hydraulic ABS are mainly studied, but the concord control of pneumatic ABS and regenerative brake in EV's emergency braking systems is seldom discussed. On account of the dynamic behavior of a hydraulic braking system is quite a lot distinguished from a pneumatic one, the cooperation of pneumatic ABS and regenerative braking system is necessary to be researched, to improve the breaking control performance of EVs.

"Gearshift and brake distribution control for regenerative braking in electric vehicles with dual clutch transmission" by Jiejunyi Liang, PaulD. Walker, Jiageng Ruan ∗, Haitao Yang, Jinglai Wu, Nong Zhang.

To alleviate the problem of limited driving range per charge in electric vehicles, a dual clutch transmission based regenerative braking power-on shifting control system is proposed and investigated in this paper. Power-on shifting refers to the shift process where the power flow between the wheel and the power source is not cut offend could be maintained around a desirable value. This character is more important for regenerative braking than the normal driving conditions as the regenerative braking force from the motor accounts for a large part of the total braking force. Due to the difference between the normal driving condition and the regenerative braking process, existing normal driving shifting control strategies, which could introduce significant torque interruption, cannot be directly applied for regenerative braking. As a result, the energy recovery capability and efficiency are compromised. To solve this problem, a power on shifting control strategy for regenerative braking is proposed as well as an energy-safety oriented braking strategy. To demonstrate the effectiveness of the proposed system, mathematical models are built and dynamic responses of the transmission system during braking both in up-shift and down-shift processes are presented. Moreover, the efficiency and recovery capability improvements made by achieving power-on shifting during regenerative braking are verified through a typical deceleration driving cycle and a specially designed daily deceleration scenario. To improve the regenerative braking performance of electric vehicles, a 4-speed transmission system with corresponding control strategies is proposed and investigated. The system is based on a full-size sedan to which regenerative braking is more significant. Based on the selected vehicle specifications, systematic approaches are adopted to select the motor, design the shifting strategy and choosing suitable gear numbers. In order to achieve power on shifting during regenerative braking, a detailed mathematical model is built and an advanced multispeed transmission power-on shifting strategy is proposed. Due to the difference between acceleration and deceleration, braking force distribution is investigated and an eco- safety regenerative braking strategy is proposed which could both recover more energy and guarantee safety in emergency situations.

To verify the effectiveness of the proposed system, the power-on shifting performance during regenerative braking is evaluated as along with the efficiency improvements achieved by the proposed system in two braking scenarios. In the dynamic performance evaluation, the torque interruption within gear shifting during the regenerative braking has been adequately compensated and the regenerative braking force has been kept around the desirable value which makes the shifting during regenerative braking practical.



"A simulation study of installation locations and capacity of regenerative absorption inverters in DC 1500 V electric railways system" by Chang Han Bae.

The paper presents the determination scheme of the power capacity and installation location for regenerative inverters in a DC 1500 V electric railway system. Using
Train Performance Simulation (TPS) and Power Flow Simulation (PFS) software, loss ratios of the regenerative power in a subway line and root-mean-square values of regenerative power are calculated for each substation. According to varying the number of regenerative inverters installed, these values are calculated repeatedly and allow determining the suitable installation number, location and power capacity of regenerative inverters in a subway line. The report concludes that, to confirm this determination scheme, the simulation results of TPS and PFS of a Seoul subway line are applied. if a regenerative inverter is installed in inverse-parallel with the diode rectifier, it contributes to absorb the dump regenerative energy and transmits the energy into the electric supply grid.

The regenerative inverter can reduce the overhead line voltage fluctuation effectively and recycle the surplus regenerative energy to the electric supply grid. The simulation results indicated that it is desirable to install three regenerative inverters on three substations economically in Seoul subway line-5. The continuous and intermittent peak power rating of the regenerative inverters installed has been determined and also, the amount of regenerative energy delivered back to the electric supply grid by regenerative inverters has been estimated. This paper suggested an effective means of determining the installation location and power capacity of regenerative inverters for a DC 1500 V electric railway system. First, the loss ratio of regenerative energy and the root-mean-square value of regenerative power are calculated for each substation on a subway line using the TPS and PFS developed by the KRRI. Next, the loss ratio value of regenerative power in a subway line is compared according to varying the number of regenerative inverters. Finally, the suitable installation location and the number of regenerative inverters has been selected to reduce the loss ratio of regenerative power in a subway line with at least regenerative inverters.

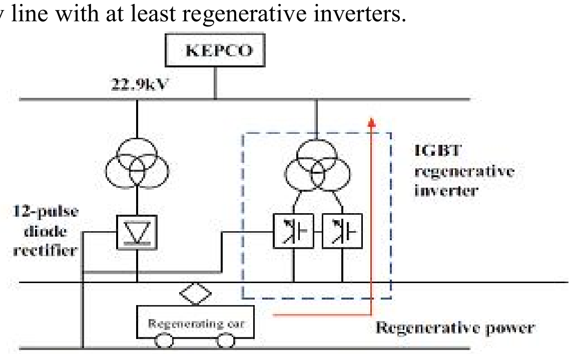


Fig. 1. DC electric railway substation with a regenerative inverter.

"A new electric braking system with energy regeneration for a BLDC motor driven electric vehicle" by A. Joseph Godfrey, V. Sankaranarayanan

In this article it presents, A new electric braking system is proposed for a brushless DC (BLDC) motor driven electric vehicle (EV) in this paper based on stopping time and energy regeneration. This new braking system is developed by combining various regenerative methods and plugging. Other than the existing performance measures such as boost ratio, braking torque, and maximum conversion ratio; stopping time and energy recovery for various methods are studied for different running conditions. It is observed that the stopping time is less for plugging and increases in the order of two, three and single switch method. In addition, energy recovery is better for single and three switch method. Based on these performances, a new braking strategy is proposed which combine all the regenerative braking methods including plugging and switch among themselves based on the brake pedal depression. The effectiveness of the proposed method is shown using both simulation and experiment results

III. CONSTRUCTIONS

It consists of various stationary and moving components.it has following components-

1. Tyre

A tire or tyre is a ring-shaped covering that fits around a wheel rim to protect it and enable better vehicle performance by providing a flexible cushion that absorbs shock while keeping the wheel in close contact with the ground.

The fundamental materials of modern tires are synthetic rubber, natural rubber, fabric and wire, along with other compound chemicals. They consist of a tread and a body. The tread provides traction while the body ensures support. Before rubber was invented, the first versions of tires were simply bands of metal that fitted around wooden wheels to prevent wear and tear.

2. Shaft

A shaft is a rotating machine element, usually circular in cross section, which is used to transmit power from one part to another, or from a machine which produces power to a machine which absorbs power. The various members such as pulleys and gears are mounted on it. The material used for ordinary shafts is mild steel. When high strength is required, an alloy steel such as nickel, nickelchromium or chromium-vanadium steel is used. Shafts are generally formed by hot rolling and finished to size by cold drawing or turning and grinding. They are mainly classified into two types.

- Transmission shafts are used to transmit power between the source and the machine absorbing power; e.g. counter shafts and line shafts.
- Machine shafts are the integral part of the machine itself; e.g. crankshaft.

The disc and belt which are used for skimming purpose are mounted on this shaft. With the help of chain drive it rotates and eventually the disc and the belt mounted on the shaft starts rotating.

3. Bearing:

A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts Most bearings facilitate the desired motion by minimizing friction. Bearings are classified broadly according to the type of operation., there are many applications where a more suitable bearing can improve efficiency, accuracy, service intervals, reliability, speed of operation, size, weight, and costs of purchasing and operating machinery.

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4. Alternator

Alternator is the device used to generate electricity from mechanical energy. Mechanical energy of the wheel is gets converted into electrical energy.

5. Electric Motor

An electric motor is an electrical machine that converts electrical energy into mechanical energy. Most electric motors operate through the interaction between the motor's magnetic field and winding currents to generate force in the form of rotation. Electric motors can be powered by direct current (DC) sources, such as from batteries, motor vehicles or rectifiers, or by alternating current (AC) sources, such as a power grid, inverters or electrical generators. An electric generator is mechanically identical to an electric motor, but operates in the reverse direction, accepting mechanical energy (such as from flowing water) and converting this mechanical energy into electrical energy. Electric motors may be classified by considerations such as power source type, internal construction, application and type of motion output. In addition to AC versus DC types, motors may be brushed or brushless, may be of various phase (see single-phase, two-phase, or three-phase), and may be either air-cooled or liquid-cooled. General-purpose motors with standard dimensions and characteristics provide convenient mechanical power for industrial use. The largest electric motors are used for ship propulsion, pipeline compression and pumped-storage applications with ratings reaching 100 megawatts. Electric motors are found in industrial fans, blowers and pumps, machine tools, household appliances, power tools and disk drives. Small motors may be found in electric watches.

IV. Working

We are designing the project for the purpose of generating electricity from kinetic energy simultaneously applying the brakes. When wheel is rotating, on the same shaft disc is attached. The arrangement is made in such a way that when we make alternator to come in contact with the disc, it acts as a braking element. The alternator starts rotating in the opposite direction as that of the wheel direction. As the dimeter of alternator face is very small we get high rpm as an input for the alternator. These rpms are used to generate electricity and mechanical kinetic energy of the system is gets converted in to the electrical energy. This energy is can be stored with the help of battery or can be directly utilize for other work.

V. Design of System

Computer-aided design (CAD) is the use of computers to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. CAD is used as follows:

1. To produce detailed engineering designs through 3-D and 2-D drawings of the physical components of manufactured products.
2. To create conceptual design, product layout, strength and dynamic analysis of assembly and the manufacturing processes themselves.
3. To prepare environmental impact reports, in which computer-aided designs are used in photographs to produce a rendering of the appearance when the new structures are built.

CAD systems exist today for all of the major computer platforms, including Windows, Linux, Unix and Mac OS X. The user interface generally centers around a computer mouse, but a pen and digitizing graphic tablet can also be used. View manipulation can be accomplished with a space mouse (or space ball). Some systems allow stereoscopic glasses for viewing 3-D models. In our olden days, engineers, designers and draughts men were struggling to produce and submit engineering drawings in their scheduled times.

It was mainly due to tremendous efforts they had taken to produce both new drawings or edited/updated drawings. Every line, shapes, measurements, scaling of the drawings -all made them headache to the design / drafting field. All these difficulties and pressures over-ridden by Computer Aided Design Drafting (CAD Drafting) technology. The advantages of CAD include: the ability to producing very accurate designs; drawings can be created in 2D or 3D and rotated; other computer programmes can be linked to the design software. With manual drafting, you must determine the scale of a view before you start drawing. This scale compares the size of the actual object to the size of the model drawn on paper. With CAD, you first decide what units of measurement you will use, and then draw your model at 1:1 scale, should one of the main benefits of CAD. When you draft manually, you first select a sheet, which usually includes a pre-printed border and title block. Then you determine the location for views' plans, elevations, sections, and details. Finally, you start to draw. With CAD, you first draw your design, or model, in a working environment called model space. You can then create a layout for that model in an environment called paper space.A layout represents a drawing sheet. It typically contains a border, title block, dimensions, general notes, and one or more views of the model displayed in layout viewports. Layout viewports are areas, similar to picture frames or windows, through which you can see your model.

You scale the views in viewports by zooming in or out. Manual drafting requires meticulous accuracy in drawing line-types, line-weights, text, dimensions, and more. Standards must be established in the beginning and applied consistently. With CAD, you can ensure conformity to industry or company standards by creating styles that you can apply consistently. You can create styles for text, dimensions, and line-types.

With manual drafting, you use drawing tools that include pencils, scales, compasses, parallel rules, templates, and erasers. Repetitive drawing and editing tasks must be done manually .In CAD, you can choose from a variety of drawing tools that create lines, circles, spline curves, and more. You can easily move, copy, offset, rotate, and mirror objects. You can also copy objects between open drawings. With manual drafting, you must draw objects carefully to ensure correct size and alignment. Objects drawn to scale must be manually verified and dimensioned. With CAD, you can use several methods to obtain exact dimensions. The simplest method is to locate points by snapping to an interval on a rectangular grid. Another method is to specify exact coordinates. Coordinates specify a drawing location by indicating a point along an X and Y axis or a distance and angle from another point. With object snaps, you can snap to locations on existing objects, such as an endpoint of an arc, the midpoint of a line, or the centre point of a circle. With polar tracking, you can snap to previously set angles and specify distances along those angles. Revisions are a part of any drawing project. Whether you work on paper or with CAD, you will need to modify your drawing in some way. On paper, you must erase and redraw to make revisions to your drawing manually. CAD eliminates tedious manual editing by providing a variety of editing tools. If you need to copy all or part of an object, you don't have to redraw it. If you need to remove an object, you can erase it with a few clicks of the mouse. And if you make an error, you can quickly undo your actions. Once you draw an object, you never need to redraw it. To work efficiently using the cad the organization must focus on the following areas where it needs to be on upper side.

1. Most popular CAD software like AutoCad, ProgeCAD, Microstation are high priced for individuals. Alternatively, individuals can try free open source CAD drafting software QCAD, LibreCAD and OpenSCAD.
2. Every new release of the CAD software, operator has to update their skills.
3. Improper use of blocks and layers make updating and modification of the drawings a cumbersome task for another person.

VI. Advantages

- It improves the fuel economy of the vehicle.
- It allows for traditional friction-based brakes.
- It prolongs the charge of the battery.
- It reduces the wear and tear on the braking system.
- It offers a sliding scale of benefits.
- It offers a different feel to the driver

VII. Conclusion

A serial control strategy of regeneration braking system for electric vehicles under safety-critical driving situations is designed in this paper. The primary vehicle components associated with the and regenerative blending brakes of the electric car are introduced. According to the phase plane theory, the aim anti-lock control brake torque is given to insure making the most of road adhesion. Based on the disparate system dynamics of friction and regenerative brakes, a blending anti-lock braking control is introduced where the brake demanding torque is segmented into dynamical and steady parts that are coordinately operated respectively by the regenerative and pneumatic brakes.

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