

A HYBRID ELECTRIC DRIVE SYSTEM FOR A MOTORCYCLE

FIELD OF THE INVENTION

[0001] Present invention relates to a hybrid electric motorcycle. More particularly, the present invention relates to a rear wheel drive plug-in Hybrid Electric Drive System (HDS) for a motorcycle.

BACKGROUND OF THE INVENTION

[0002] Background description includes information that may be useful in understanding the present invention. It is not an admission that any of the information provided herein is prior art or relevant to the presently claimed invention, or that any publication specifically or implicitly referenced is prior art.

[0003] One of the greatest challenges being faced by human race today is undoubtedly the climate change and its potentially catastrophic consequences for humanity. The ever rising greenhouse gas emissions coupled with massive urbanisation trends create a further challenge where large scale migration to urban areas is creating several high density population clusters that require tremendous resources for survival such as round the clock availability of utilities, products and services to support such urban lifestyle. As a consequence, one of the highest contributors to global greenhouse gas emissions is transportation sector, responsible for nearly quarter of greenhouse gas emissions every year. The urban vehicular emissions not only affect the global temperature rise and the climate, but also the health of the urban populations as they inhale those harmful vehicular emissions that create health hazards including early deaths and COPD (Chronic Obstructive Pulmonary Disorders).

[0004] There has been a strong scientific evidence and record of such health hazards and ailments which need to be addressed with the sense of urgency, by providing more workable solutions for sustainable mobility which reduces the quantum of harmful emissions. At the same time, the consumers of automobile sector are used to certain conveniences with respect to ease of fuelling, long range on a full fuel tank, as well as certain driving features which can't be taken away from them in an instant by switching to non-IC engine vehicles such as fully electric vehicles, which are short on features and conveniences keeping in mind the mass affordability factor. The fully electric vehicles have several shortcomings such as long recharge times, inconvenience of not having adequate charging facilities, range anxiety

for drivers and passengers as a result of relatively short range on a single charge, load carrying limitations in steep uphill terrains, etc.

[0005] Therefore, there is a need to first migrate to an intermittent stage of hybrid electric mobility solution whereby all shortcomings of a full electric vehicle as mentioned above can be effectively addressed and during urban and large parts of inter city transportation routes, the vehicles can operate on fully electric mode easily. This will create at least 80% more green miles by consumers switching to intelligent plug in hybrid electric vehicles and operating in zero emissions mode for most of the miles driven. The additional benefits of re-cycling and up-cycling of existing IC engine vehicle parts will reduce the greenhouse emissions further by extending the life of in-use products in the integrated supply chain. On a national level, the resulting savings of imported fuel and the consequential benefits to Indian economy is certainly a huge advantage and makes a strong case for economic stimulus to be given by the Government for faster and broader adoption of such sustainable mobility solutions, such as the one which is described in this application.

[0006] There is, therefore, a need in the art to develop a hybrid electric drive system of that results in a less polluting, eco-friendly, and low operational cost plug-in hybrid electric motorcycle. The present invention helps in transforming an existing petrol or diesel dependent IC engine driven rear wheel drive motorcycle into a less polluting, eco-friendly, and low operational cost rear wheel drive plug-in hybrid electric two wheeler.

OBJECTS OF THE PRESENT DISCLOSURE

[0007] Some of the objects of the present disclosure, which at least one embodiment herein satisfies are as listed herein below.

[0008] Accordingly, it is an object of the present invention to provide a hybrid electric drive to the motorcycle by providing the electric drive assembly comprising a hub type electric motor, a uniquely designed electro-mechanical overrunning clutch, a combined accelerator and a rear wheel suspension arrangement that is used to transfer and regulate both the IC engine and electric motor drive to the rear wheel. This assembly is mounted on the rear wheel of the motorcycle. This would enable a faster and simpler conversion method to convert IC engine driven motorcycle architectures to a plug-in hybrid electric motorcycle.

[0009] It is another object of the present invention to provide both the IC engine and electric motor drive to the rear wheel of the motorcycle either independently or in a combined manner without any major design changes to the existing motorcycle architecture by using a

uniquely designed electro-mechanical overrunning clutch that works in conjunction with the chain and sprocket drive mechanism.

[0010] It is another object of the present invention to provide a user-defined and control logic defined mode selection by using the uniquely designed electro-mechanical overrunning clutch. Such a design would enable the user to control the mode of operation of the vehicle in specifically mandated zero vehicular pollution zones in urban areas.

[0011] It is another object of the present invention to control both the IC engine and Electric motor drive in such a way that the rider can maintain the familiarity of riding a motorcycle using the twist type handle grip accelerator.

[0012] It is another object of the present invention to build a plug-in hybrid electric system for a IC engine driven motorcycle architecture that is a simple, manufacturer friendly & labour friendly production alternative to the existing well known IC engine motorcycle architectures and thereby allowing the re-cycling or up-cycling of the existing IC engine drive train components thus extending the usable lifetime of the motorcycle.

[0013] It is another object of the present invention to simplify the installation of an electric motor drive and battery along with an unique system comprising of parts such as electro-mechanical overrunning clutch, combined accelerator and re-designed rear wheel suspension with minimal modification to the existing design and the assembly process of the vehicle, thereby allowing the manufacturers to use the existing assembly lines with minimal additions and hence keep both the design and manufacturing costs low.

[0014] It is another object of the present invention to simplify the installation of an electric drive assembly comprising of parts such as electro-mechanical overrunning clutch, combined accelerator and re-designed rear wheel suspension with minimal modification for mounting the system thereby allowing easy and modular retrofitment solutions for already existing vehicles on the road.

[0015] It is another object of the present invention to combine the IC engine and electric drive and synchronize the torque addition in a way to utilize the specific torque-speed characteristics of the IC engine and the electric motor to enable a highly efficient and low emissions and low fuel consumption operation of the combined powertrain.

SUMMARY

[0016] Present invention relates to a hybrid electric motorcycle. More particularly, the present invention relates to a rear wheel drive plug-in Hybrid Electric Drive System (HDS) for a motorcycle.

[0017] According to an aspect of the present disclosure, a hybrid electric drive system comprises a hub type electric motor, an electro-mechanical overrunning clutch, a combined accelerator, and a rear wheel suspension arrangement. The hub type electric motor can be mounted on a rear wheel of a motorcycle, where the hub type electric motor is configured to drive the rear wheel of the motorcycle. The electro-mechanical overrunning clutch can be coupled to both the hub type electric motor through the body of the hub motor and an IC engine through a chain sprocket mechanism mounted on the rear wheel. Further, the electro-mechanical overrunning clutch can be configured to enable seamless transition between all the modes, and transmit IC engine drive and electric motor torque simultaneously to the rear wheel of the motorcycle. The combined accelerator is configured with the electric motor and the IC engine and is designed with a configurable phase lag that allows the electric motor to speed up earlier than the IC engine owing to high initial starting torque of the electric powertrain while being driven in the combined mode. The rear wheel suspension arrangement is connected to the rear wheel of the motorcycle comprising an arrangement including arrestor plates, pair of shock absorbers, and rear fork assembly. The arrestor plates prevent accidental rotation of motor axle and the rear fork assembly can be configured to transmit the electric drive to propel the motorcycle.

[0018] According to another aspect of the present disclosure, the electro-mechanical overrunning clutch comprises an outer hub assembly, an inner hub assembly, a set of rollers and springs, and a control unit. The outer hub assembly of the electro-mechanical overrunning clutch can be coupled to the chain sprocket mechanism, and is one of the elements configured to transmit the IC engine drive. The inner hub assembly can be coupled to the body of the electric motor, and is the second element configured to transmit the IC engine drive and seamlessly combine it with the electric motor drive. The set of rollers and springs with a recess arrangement can provide the necessary linkage between the outer hub and the inner hub assembly. In electric mode, when the IC engine is shut off and the electric motor is on, the outer hub assembly can be stationary and the inner hub assembly gets the torque from the electric motor. Further, the rollers get into a position to allow the inner hub assembly to rotate although the outer hub assembly is stationary, and the electric motor drive is transmitted to the rear wheel. In IC engine mode, when the IC engine is on and the electric motor is shut off, the inner hub assembly is not receiving torque from the electric motor and the outer hub assembly receives the torque from the IC engine. Further, the rollers get into a position to allow the outer hub assembly to transmit the torque to the inner hub assembly and the IC engine drive is transmitted to the rear wheel. In the combined mode, the rollers get into

a position same as that of IC engine mode and allow outer hub assembly to transmit the IC engine torque to the inner hub assembly, where the inner hub assembly also gets the electric motor torque, the two drives being seamlessly added and transmitted to the rear wheel. The control unit can be configured to compare torque value of the electric motor (TEM) and the IC engine (TICE) and transmit commands to a motor controller to enable both the IC engine and electric motor torque to be transmitted simultaneously to the rear wheel.

[0019] According to an aspect of the present disclosure, the hybrid electric drive system can be configured to perform the dual role of allowing drive from each powertrain to be transmitted individually to the rear wheel in either one of the modes such as an electric mode or an IC engine mode and adding the drive from each powertrain and seamlessly transmitting to the rear wheel in the combined mode.

[0020] According to an aspect of the present disclosure, the hybrid electric drive system can enable driving independently in either an electric mode, an IC engine mode, or a combined mode.

[0021] According to an aspect of the present disclosure, the hybrid electric drive system wherein for the combined mode the IC engine drive is transmitted to the rear wheel from the chain and sprocket mechanism through the overrunning clutch, where an electric motor torque is added to the inner hub and the combined torque is transmitted to the rear wheel of the vehicle.

[0022] According to an aspect of the present disclosure, the hybrid electric drive system includes the overrunning clutch mechanism that is configured to allow either the IC engine or the Electric Motor to provide the drive to the rear wheel, when the motorcycle is driven in a single mode. The overrunning clutch mechanism adds and synchronizes the IC engine drive and the Electric Motor drive when the motorcycle is driven in the combined mode.

[0023] According to an aspect of the present disclosure, the hybrid electric drive system includes the inner hub assembly that includes a circular disc with cylindrical rollers and recess arrangement. The interaction between the inner hub assembly and the outer hub assembly is provided through the spring loaded rollers and the recess arrangement.

[0024] According to an aspect of the present disclosure, the hybrid electric drive system includes a twist type handle grip that is coupled to a cylindrical drum, and which is configured to rotate along with the twist type handle grip, where the cylindrical drum can include a cable attached to it that gets wound or unwound as the drum turns.

[0025] According to an aspect of the present disclosure, the hybrid electric drive system includes the twist type handle grip whose twisting action can be configured to transmit the rider input to the combined accelerator.

[0026] According to an aspect of the present disclosure, the combined accelerator is designed with a configurable phase lag that allows the electric motor to speed up earlier than the IC engine owing to high initial starting torque of the electric power-train while being driven in the combined mode.

[0027] According to an aspect of the present disclosure, the hybrid electric drive system includes the electronic control unit which can be configured to measure the IC engine torque (T_{ICE}) and based on torque value commands the motor controller to deliver the electric motor torque (T_{EM}) that is less than the torque generated by the IC engine ($T_{EM} < T_{ICE}$).

[0028] According to an aspect of the present disclosure, the hybrid electric drive system includes the controller which is configured to manage the torque distribution in the combined mode to utilize the resultant torque-speed characteristics of the hybrid drive system more effectively compared to torque speed characteristics of the individual IC engine mode.

[0029] According to an aspect of the present disclosure, the hybrid electric drive system includes the controller which is placed in the front suspension fork of the motorcycle and its casing assembly is designed to provide adequate mounting capability for the controller and give sufficient protection and ventilation to the controller.

[0030] According to an aspect of the present disclosure, the hybrid electric drive system can include a set of battery packs which are mounted at the rear side of the motorcycle and on either side for preserving the bilateral symmetry of loads for balancing. Alternate electric power supply systems like a hydrogen fuel cell stack of customizable specifications or Ultra Capacitors can also be used to provide the necessary electric current to the motor.

[0031] According to an aspect of the present disclosure, the motorcycle is in the IC engine mode, the hub type electric motor is configured to act as a generator to charge the batteries depending upon the state of charge (SOC) of the battery pack in regeneration mode, where even during braking, irrespective of the mode of operation, the hub type electric motor is configured to act as a generator to charge the batteries depending upon the state of charge (SOC) of the battery pack.

[0032] According to an aspect of the present disclosure, a motorcycle comprising a hybrid electric drive system that comprises a hub type electric motor, an electro-mechanical overrunning clutch, a combined accelerator, and a rear wheel suspension arrangement. The

hub type electric motor can be mounted on a rear wheel of a motorcycle, where the hub type electric motor is configured to drive the rear wheel of the motorcycle. The electro-mechanical overrunning clutch can be coupled to both the hub type electric motor through the body of the hub motor and an IC engine through a chain sprocket mechanism mounted on the rear wheel.

Further, the electro-mechanical overrunning clutch can be configured to enable seamless transition between all the modes, and transmit IC engine drive and electric motor torque simultaneously to the rear wheel of the motorcycle. The rear wheel suspension arrangement is connected to the rear wheel of the motorcycle comprising an arrangement including arrestor plates, pair of shock absorbers, and rear fork assembly (16). The arrestor plates prevent accidental rotation of motor axle and the rear fork assembly can be configured to transmit the electric drive to propel the motorcycle.

[0033] According to another aspect of the present disclosure, the electro-mechanical overrunning clutch comprises an outer hub assembly, an inner hub assembly, a set of rollers and springs, and a control unit. The outer hub assembly of the electro-mechanical overrunning clutch can be coupled to the chain sprocket mechanism, and is one of the elements configured to transmit the IC engine drive. The inner hub assembly can be coupled to the body of the electric motor, and is the second element configured to transmit the IC engine drive and seamlessly combine it with the electric motor drive. The set of rollers and springs with a recess arrangement can provide the necessary linkage between the outer hub and the inner hub assembly. In electric mode, when the IC engine is shut off and the electric motor is on, the outer hub assembly can be stationary and the inner hub assembly gets the torque from the electric motor. Further, the rollers get into a position to allow the inner hub assembly to rotate although the outer hub assembly is stationary, and the electric motor drive is transmitted to the rear wheel. In IC engine mode, when the IC engine is on and the electric motor is shut off, the inner hub assembly is not receiving torque from the electric motor and the outer hub assembly receives the torque from the IC engine. Further, the rollers get into a position to allow the outer hub assembly to transmit the torque to the inner hub assembly and the IC engine drive is transmitted to the rear wheel. In the combined mode, the rollers get into a position same as that of IC engine mode and allow outer hub assembly to transmit the IC engine torque to the inner hub assembly, where the inner hub assembly also gets the electric motor torque, the two drives being seamlessly added and transmitted to the rear wheel. The control unit can be configured to compare torque value of the electric motor (TEM) and the IC engine (TICE) and transmit commands to a motor controller to enable both the IC engine and electric motor torque to be transmitted simultaneously to the rear wheel.

[0034] Various objects, features, aspects and advantages of the present disclosure will become more apparent from the following detailed description of preferred embodiments, along with the accompanying drawing figures in which like numerals represent like features.

[0035] Within the scope of this application it is expressly envisaged that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. Features described in connection with one embodiment are applicable to all embodiments, unless such features are incompatible.

10 **BRIEF DESCRIPTION OF DRAWINGS**

[0036] The accompanying drawings are included to provide a further understanding of the present disclosure, and are incorporated in and constitute a part of this specification. The drawings illustrate exemplary embodiments of the present disclosure and, together with the description, serve to explain the principles of the present disclosure. The diagrams are for illustration only, which thus is not a limitation of the present disclosure.

[0037] FIG. 1A illustrates an implementation of an electric mode in a motorcycle, in accordance with an embodiment of the present disclosure.

[0038] FIG. 1B illustrates an implementation of an engine mode in the motorcycle, in accordance with an embodiment of the present disclosure.

[0039] FIG. 1C illustrates an implementation of a combined mode in the motorcycle, in accordance with an embodiment of the present disclosure.

[0040] FIG. 1D illustrates an implementation of a regenerative mode in the motorcycle, in accordance with an embodiment of the present disclosure.

[0041] Fig. 1E illustrates the simplified block diagram showing various components of the system and interaction/connection, in accordance with an embodiment of the present disclosure.

[0042] FIG. 2A illustrates a general arrangement from right side of the motorcycle, in accordance with an embodiment of the present disclosure.

[0043] FIG. 2B illustrates a general arrangement from left side of the motorcycle, in accordance with an embodiment of the present disclosure.

[0044] FIG. 3A illustrates a wheel assembly from right side of the motorcycle, in accordance with an embodiment of the present disclosure.

[0045] FIG. 3B illustrates a wheel assembly from left side of the motorcycle, in accordance with an embodiment of the present disclosure.

[0046] FIG. 4A illustrates rear suspension arrangement from right side of the motorcycle, in accordance with an embodiment of the present disclosure.

5 [0047] FIG. 4B illustrates rear suspension arrangement from left side of the motorcycle, in accordance with an embodiment of the present disclosure.

[0048] FIG. 5A-5F illustrates the electro-mechanical overrunning clutch mechanism of the motorcycle, in accordance with an embodiment of the present disclosure.

[0049] FIG. 6 illustrates the combined accelerator of the motorcycle, in accordance with an embodiment of the present disclosure.

[0050] FIG. 7 illustrates a Mechanical Safety Interlock System (Gear-box “Neutral Lock”), in accordance with an embodiment of the present disclosure.

[0051] FIG. 8A illustrates graphical representation of the motorcycle with resultant torque-speed characteristics, in accordance with an embodiment of the present disclosure.

15 [0052] FIG. 8B illustrates graphical representation of the motorcycle with resultant torque-speed characteristics under various drive cycles, in accordance with an embodiment of the present disclosure.

[0053] FIG. 8C illustrates graphical representation of the motorcycle with resultant reduction in IC engine usage, in accordance with an embodiment of the present disclosure.

20 [0054] Fig. 9 illustrates the graphical representation of the logic of the controller 224.

DETAILED DESCRIPTION

[0055] The following is a detailed description of embodiments of the disclosure depicted in the accompanying drawings. The embodiments are in such detail as to clearly communicate the disclosure. However, the amount of detail offered is not intended to limit the anticipated variations of embodiments; on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the present disclosure as defined by the appended claims.

[0056] In the following description, numerous specific details are set forth in order to provide a thorough understanding of embodiments of the present invention. It will be apparent to one skilled in the art that embodiments of the present invention may be practiced without some of these specific details.

[0057] Embodiments of the present invention include various steps, which will be described below. The steps may be performed by hardware components or may be embodied

in machine-executable instructions, which may be used to cause a general-purpose or special-purpose processor programmed with the instructions to perform the steps. Alternatively, steps may be performed by a combination of hardware, software, and firmware and/or by human operators.

5 **[0058]** Various methods described herein may be practiced by combining one or more machine-readable storage media containing the code according to the present invention with appropriate standard computer hardware to execute the code contained therein. An apparatus for practicing various embodiments of the present invention may involve one or more computers (or one or more processors within a single computer) and storage systems
10 containing or having network access to computer program(s) coded in accordance with various methods described herein, and the method steps of the invention could be accomplished by modules, routines, subroutines, or subparts of a computer program product.

[0059] If the specification states a component or feature “may”, “can”, “could”, or “might” be included or have a characteristic, that particular component or feature is not
15 required to be included or have the characteristic.

[0060] As used in the description herein and throughout the claims that follow, the meaning of “a,” “an,” and “the” includes plural reference unless the context clearly dictates otherwise. Also, as used in the description herein, the meaning of “in” includes “in” and “on” unless the context clearly dictates otherwise.

20 **[0061]** Exemplary embodiments will now be described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments are shown. These exemplary embodiments are provided only for illustrative purposes and so that this disclosure will be thorough and complete and will fully convey the scope of the invention to those of ordinary skill in the art. The invention disclosed may, however, be embodied in many
25 different forms and should not be construed as limited to the embodiments set forth herein. Various modifications will be readily apparent to persons skilled in the art. The general principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the invention. Moreover, all statements herein reciting embodiments of the invention, as well as specific examples thereof, are intended to
30 encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future (i.e., any elements developed that perform the same function, regardless of structure). Also, the terminology and phraseology used is for the purpose of describing exemplary embodiments and should not be considered limiting. Thus, the present invention is

to be accorded the widest scope encompassing numerous alternatives, modifications and equivalents consistent with the principles and features disclosed. For purpose of clarity, details relating to technical material that is known in the technical fields related to the invention have not been described in detail so as not to unnecessarily obscure the present invention.

[0062] Thus, for example, it will be appreciated by those of ordinary skill in the art that the diagrams, schematics, illustrations, and the like represent conceptual views or processes illustrating systems and methods embodying this invention. The functions of the various elements shown in the figures may be provided through the use of dedicated hardware as well as hardware capable of executing associated software. Similarly, any switches shown in the figures are conceptual only. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control and dedicated logic, or even manually, the particular technique being selectable by the entity implementing this invention. Those of ordinary skill in the art further understand that the exemplary hardware, software, processes, methods, and/or operating systems described herein are for illustrative purposes and, thus, are not intended to be limited to any particular named element.

[0063] Systems depicted in some of the figures may be provided in various configurations. In some embodiments, the systems may be configured as a distributed system where one or more components of the system are distributed across one or more networks in a cloud computing system.

[0064] Each of the appended claims defines a separate invention, which for infringement purposes is recognized as including equivalents to the various elements or limitations specified in the claims. Depending on the context, all references below to the "invention" may in some cases refer to certain specific embodiments only. In other cases, it will be recognized that references to the "invention" will refer to subject matter recited in one or more, but not necessarily all, of the claims.

[0065] All methods described herein may be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., "such as") provided with respect to certain embodiments herein is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention otherwise claimed. No language in the specification should be construed as indicating any non-claimed element essential to the practice of the invention.

[0066] Various terms as used herein are shown below. To the extent a term used in a claim is not defined below, it should be given the broadest definition persons in the pertinent art have given that term as reflected in printed publications and issued patents at the time of filing.

5 **[0067]** Present invention relates to a hybrid electric motorcycle. More particularly, the present invention relates to a rear wheel drive plug-in Hybrid Electric Drive System (HDS) for a motorcycle.

[0068] According to an aspect of the present disclosure, a hybrid electric drive system comprises a hub type electric motor, an electro-mechanical overrunning clutch, a combined
10 accelerator, and a rear wheel suspension arrangement. The hub type electric motor can be mounted on a rear wheel of a motorcycle, where the hub type electric motor is configured to drive the rear wheel of the motorcycle. The electro-mechanical overrunning clutch can be coupled to both the hub type electric motor through the body of the hub motor and an IC engine through a chain sprocket mechanism mounted on the rear wheel. Further, the electro-
15 mechanical overrunning clutch can be configured to enable seamless transition between all the modes, and transmit IC engine drive and electric motor torque simultaneously to the rear wheel of the motorcycle. The combined accelerator is configured with the electric motor and the IC engine and is designed with a configurable phase lag that allows the electric motor to speed up earlier than the IC engine owing to high initial starting torque of the electric power-
20 train while being driven in the combined mode. The rear wheel suspension arrangement is connected to the rear wheel of the motorcycle comprising an arrangement including arrestor plates, pair of shock absorbers, and rear fork assembly. The arrestor plates prevent accidental rotation of motor axle and the rear fork assembly can be configured to transmit the electric drive to propel the motorcycle.

25 **[0069]** According to another aspect of the present disclosure, the electro-mechanical overrunning clutch comprises an outer hub assembly, a inner hub assembly, a set of rollers and springs, and a control unit. The outer hub assembly of the electro-mechanical overrunning clutch can be coupled to the chain sprocket mechanism, and is one of the elements configured to transmit the IC engine drive. The inner hub assembly can be coupled
30 to the body of the electric motor, and is the second element configured to transmit the IC engine drive and seamlessly combine it with the electric motor drive. The set of rollers and springs with a recess arrangement can provide the necessary linkage between the outer hub and the inner hub assembly. In electric mode, when the IC engine is shut off and the electric motor is on, the outer hub assembly can be stationary and the inner hub assembly gets the

torque from the electric motor. Further, the rollers get into a position to allow the inner hub assembly to rotate although the outer hub assembly is stationary, and the electric motor drive is transmitted to the rear wheel. In IC engine mode, when the IC engine is on and the electric motor is shut off, the inner hub assembly is not receiving torque from the electric motor and the outer hub assembly receives the torque from the IC engine. Further, the rollers get into a position to allow the outer hub assembly to transmit the torque to the inner hub assembly and the IC engine drive is transmitted to the rear wheel. In the combined mode, the rollers get into a position same as that of IC engine mode and allow outer hub assembly to transmit the IC engine torque to the inner hub assembly, where the inner hub assembly also gets the electric motor torque, the two drives being seamlessly added and transmitted to the rear wheel. The control unit can be configured to compare torque value of the electric motor (TEM) and the IC engine (TICE) and transmit commands to a motor controller to enable both the IC engine and electric motor torque to be transmitted simultaneously to the rear wheel.

[0070] According to an aspect of the present disclosure, the hybrid electric drive system can be configured to perform the dual role of allowing drive from each powertrain to be transmitted individually to the rear wheel in either one of the modes such as an electric mode or an IC engine mode and adding the drive from each powertrain and seamlessly transmitting to the rear wheel in the combined mode.

[0071] According to an aspect of the present disclosure, the hybrid electric drive system can enable driving independently in either an electric mode, an IC engine mode, or a combined mode.

[0072] According to an aspect of the present disclosure, the hybrid electric drive system wherein for the combined mode the IC engine drive is transmitted to the rear wheel from the chain and sprocket mechanism through the overrunning clutch, where an electric motor torque is added to the inner hub and the combined torque is transmitted to the rear wheel of the vehicle.

[0073] According to an aspect of the present disclosure, the hybrid electric drive system includes the overrunning clutch mechanism that is configured to allow either the IC engine or the Electric Motor to provide the drive to the rear wheel, when the motorcycle is driven in a single mode. The overrunning clutch mechanism adds and synchronizes the IC engine drive and the Electric Motor drive when the motorcycle is driven in the combined mode.

[0074] According to an aspect of the present disclosure, the hybrid electric drive system includes the inner hub assembly can that includes a circular disc with cylindrical

rollers and recess arrangement. The interaction between the inner hub assembly and the outer hub assembly is provided through the spring loaded rollers and the recess arrangement.

[0075] According to an aspect of the present disclosure, the hybrid electric drive system includes a twist type handle grip that is coupled to a cylindrical drum, and which is configured to rotate along with the twist type handle grip, where the cylindrical drum can include a cable attached to it that gets wound or unwound as the drum turns.

[0076] According to an aspect of the present disclosure, the hybrid electric drive system includes the twist type handle grip whose twisting action can be configured to transmit the rider input to the combined accelerator.

[0077] According to an aspect of the present disclosure, the combined accelerator is designed with a configurable phase lag that allows the electric motor to speed up earlier than the IC engine owing to high initial starting torque of the electric power-train while being driven in the combined mode.

[0078] According to an aspect of the present disclosure, the hybrid electric drive system includes the electronic control unit which can be configured to measure the IC engine torque (T_{ICE}) and based on torque value commands the motor controller to deliver the electric motor torque (T_{EM}) that is less than the torque generated by the IC engine ($T_{EM} < T_{ICE}$).

[0079] According to an aspect of the present disclosure, the hybrid electric drive system includes the controller which is configured to manage the torque distribution in the combined mode to utilize the resultant torque-speed characteristics of the hybrid drive system more effectively compared to torque speed characteristics of the individual IC engine mode.

[0080] According to an aspect of the present disclosure, the hybrid electric drive system includes the controller which is placed in the front suspension fork of the motorcycle and its casing assembly is designed to provide adequate mounting capability for the controller and give sufficient protection and ventilation to the controller.

[0081] According to an aspect of the present disclosure, the hybrid electric drive system can include a set of battery packs which are mounted at the rear side of the motorcycle and on either side for preserving the bilateral symmetry of loads for balancing. Alternate electric power supply systems like a hydrogen fuel cell stack of customizable specifications or Ultra Capacitors can also be used to provide the necessary electric current to the motor.

[0082] According to an aspect of the present disclosure, the motorcycle is in the IC engine mode, the hub type electric motor is configured to act as a generator to charge the batteries depending upon the state of charge (SOC) of the battery pack in regeneration mode,

where even during braking, irrespective of the mode of operation, the hub type electric motor is configured to act as a generator to charge the batteries depending upon the state of charge (SOC) of the battery pack.

[0083] According to an aspect of the present disclosure, a motorcycle comprising a

5 hybrid electric drive system that comprises a hub type electric motor, an electro-mechanical overrunning clutch, a combined accelerator, and a rear wheel suspension arrangement. The hub type electric motor can be mounted on a rear wheel of a motorcycle, where the hub type electric motor is configured to drive the rear wheel of the motorcycle. The electro-mechanical overrunning clutch can be coupled to both the hub type electric motor through the body of the
10 hub motor and an IC engine through a chain sprocket mechanism mounted on the rear wheel. Further, the electro-mechanical overrunning clutch can be configured to enable seamless transition between all the modes, and transmit IC engine drive and electric motor torque simultaneously to the rear wheel of the motorcycle. The combined accelerator is configured with the electric motor and the IC engine and is designed with a configurable phase lag that
15 allows the electric motor to speed up earlier than the IC engine owing to high initial starting torque of the electric power-train while being driven in the combined mode. The rear wheel suspension arrangement is connected to the rear wheel of the motorcycle comprising an arrangement including arrestor plates, pair of shock absorbers, and rear fork assembly (16). The arrestor plates prevent accidental rotation of motor axle and the rear fork assembly can
20 be configured to transmit the electric drive to propel the motorcycle.

[0084] According to another aspect of the present disclosure, the electro-mechanical overrunning clutch comprises an outer hub assembly, an inner hub assembly, a set of rollers and springs, and a control unit. The outer hub assembly of the electro-mechanical overrunning clutch can be coupled to the chain sprocket mechanism, and is one of the
25 elements configured to transmit the IC engine drive. The inner hub assembly can be coupled to the body of the electric motor, and is the second element configured to transmit the IC engine drive and seamlessly combine it with the electric motor drive. The set of rollers and springs with a recess arrangement can provide the necessary linkage between the outer hub and the inner hub assembly. In electric mode, when the IC engine is shut off and the electric
30 motor is on, the outer hub assembly can be stationary and the inner hub assembly gets the torque from the electric motor. Further, the rollers get into a position to allow the inner hub assembly to rotate although the outer hub assembly is stationary, and the electric motor drive is transmitted to the rear wheel. In IC engine mode, when the IC engine is on and the electric motor is shut off, the inner hub assembly is not receiving torque from the electric motor and

the outer hub assembly receives the torque from the IC engine. Further, the rollers get into a position to allow the outer hub assembly to transmit the torque to the inner hub assembly and the IC engine drive is transmitted to the rear wheel. In the combined mode, the rollers get into a position same as that of IC engine mode and allow outer hub assembly to transmit the IC engine torque to the inner hub assembly, where the inner hub assembly also gets the electric motor torque, the two drives being seamlessly added and transmitted to the rear wheel. The control unit can be configured to compare torque value of the electric motor (TEM) and the IC engine (TICE) and transmit commands to a motor controller to enable both the IC engine and electric motor torque to be transmitted simultaneously to the rear wheel.

10 **[0085]** FIG. 1A illustrates an implementation of an electric mode in a vehicle, in accordance with an embodiment of the present disclosure.

[0086] According to an embodiment, a hybrid electric drive system 106 is implemented in a motorcycle 100 (also interchangeably referred to as rear wheel drive hybrid electric two wheeler). The hybrid electric drive system 106 (also interchangeably referred as hybrid electric drive train) comprising an electric motor 108, an electro mechanical overrunning clutch 110, battery 114, and motor controller 112. The motorcycle 100 includes an internal combustion (IC) engine assembly 118, a gearbox 116 (also interchangeably referred to as “manual gear box”), front wheels of the vehicle 102, rear wheels of the vehicle 104, a battery 114, motor controller 112, and fuel unit 120.

20 **[0087]** According to an embodiment, the motorcycle 100 includes the electric motor 108, the electro mechanical overrunning clutch 110, a combined accelerator 600 and the motor controller 112. The mechanism implemented in the present invention is used for converting an existing IC engine driven motorcycle in to a plug-in hybrid electric motorcycle as a retrofit solution. Further, the present invention is used for building a plug-in hybrid electric motorcycle at manufacturing stage using the prevalent IC engine vehicle architecture.

25 **[0088]** In an embodiment, the present invention allows the seamless integration of an electric drive on a IC engine motorcycle. The electro-mechanical overrunning clutch 110 of hybrid electric drive system 106 performs the dual role of allowing drive from each powertrain to be transmitted individually to the rear wheel of the vehicle as demanded by the user. Further, the electro-mechanical overrunning clutch 110 adds the drive from each powertrain together and seamlessly transmits it to the rear wheel of the motorcycle 100 as demanded by the user. Integrating the electric motor in the rear wheel 104 of the motorcycle 100 maintains the well-acclimatized to and well-known driving dynamics and road handling of the motorcycle 100. The hybrid electro mechanical overrunning clutch 110 facilitates

addition and synchronization of the drives from the two different power-trains while in the combined mode and thereby takes advantage of the resultant torque-speed characteristics of the hybrid electric drive system 106. The hybrid electric drive system 106 provides seamless synchronization of the IC engine drive and the electric drive by taking it from the IC engine assembly 118, the gear box 116, and the electric motor 108. Further, the combined accelerator 600 performs the function of accelerator for both the IC engine and electric motor 108 and thus provides ease of operation to the user who can maintain their existing driving habits.

[0089] In an embodiment, FIG 1A illustrates an implementation of an electric mode in the motorcycle 100. The rear wheel drive hybrid electric two wheeler 100 can be operated in electric mode. A hub type electric motor 202 (also interchangeably referred to as BLDC motor) in rear wheel 104 provides a direct drive to the rear wheel 104 through the electro-mechanical overrunning clutch 110.

[0090] In an embodiment, FIG. 1B illustrates an engine mode in the motorcycle 100. The rear wheel drive hybrid electric two wheeler 100 can be operated in an engine mode. The IC engine 118 provides the drive to the rear wheel 104 through the gearbox 116 and the electro-mechanical overrunning clutch 110 in conjunction with a chain-sprocket mechanism 206.

[0091] In an embodiment, FIG. 1C illustrates a combined mode in the motorcycle 100. The rear wheel drive hybrid electric two wheeler can be operated in combined mode. Both the rear wheel 104 mounted hub type electric motor 202 and the IC engine 118 provides the drive to the rear wheel 104 through the electro-mechanical overrunning clutch 110 in conjunction with the chain-sprocket mechanism 206.

[0092] In an embodiment, FIG. 1D illustrates a regeneration mode in the motorcycle 100. The rear wheel drive hybrid electric two wheeler can be operated in their generation mode. The rear wheel mounted hub type electric motor 202 acts as a generator and charges the battery 114 as required while in the regenerative mode.

[0093] In an embodiment, Fig. 1E illustrates the simplified block diagram showing various components of the system and interaction/connection. The electro-mechanical overrunning clutch consists of the outer hub assembly, the inner hub assembly and a set of rollers and springs. The inner hub is physically connected to the electric hub motor and the outer hub is physically connected to the IC engine drive through the chain and sprocket mechanism. The rollers and the springs provide the necessary mechanical linkage to transfer the drive between the two hub assemblies – the inner and the outer. During the combined

mode of operation, the control unit 270 compares the torque generated by the IC engine and the electric motor and commands the motor controller 224 to deliver the electric motor torque that is less than the torque generated by the IC engine.

[0094] In another embodiment, the present invention includes an energy recuperation system that makes innovative use of mechanical power transfer from different elements of the hybrid electric drive system 106 to result in varying levels of regeneration current being fed back into the battery 114 when the vehicle 100 is decelerating or there is a need to apply brakes.

[0095] FIG. 2A illustrates a general arrangement from right side of the motorcycle, in accordance with an embodiment of the present disclosure.

[0096] FIG. 2B illustrates a general arrangement from left side of the motorcycle, in accordance with an embodiment of the present disclosure.

[0097] In an embodiment, the motorcycle 200 includes a hub type electric motor 202 (also interchangeably referred to as BLDC motor) in rear wheel 104, an electro-mechanical overrunning clutch 204, a chain sprocket 206, a battery bank 208, a drive chain 210, a charging point 212, a ICE key switch 214, a EV key switch 216, an indication panel 220, an accelerator grip 222, a motor controller 224 (also interchangeably known as a microprocessor controlled system), a foot brake paddle 226, a foot brake safety switch 228, an inverter and DC convertor 230, a rear fork assembly 232.

[0098] FIG. 2B illustrates a general arrangement of the general arrangement from left side of the rear wheel drive two wheeler 200. The vehicle 200 includes the hub type electric motor 202, the battery bank 208, the ICE key switch 214, the EV key switch 216, an indication panel 220, the motor controller 224, a brake calliper 234, a brake disc 236, a gear box safety assembly 238, a gear shifter pedal 240, an IC engine 242, a light switch 244.

[0099] In an embodiment, FIGS 2A and 2B describes the general arrangement of the electric hybrid power train of the motorcycle 100. The hybrid electric drive system 106 design is based that the existing internal combustion engine drive train up to the main sprocket 206 of the chain drive 210 for the rear wheel 104 is kept unaltered. The rear wheel suspension is modified to accommodate the hub type electric motor 202, which provides a direct electric drive to the rear wheel 104. Additionally the rear wheel 104 also has the chain and sprocket 206 working in conjunction with the electro-mechanical overrunning clutch 204 to transmit the IC engine 242 drive thereby allowing both the drives to be transmitted to the rear wheel 104 of the motorcycle 100.

[00100] In an embodiment, the hybrid electric drive train comprise of the electro-mechanical overrunning clutch mechanism 204, the combined accelerator control 218, which is custom built, the controller unit 224, the hub type electric motor 202 is mounted on the rear suspension provided through the re-engineered rear fork suspension assembly 232, which is provided with additional stiffening plates and arrester plates 252 that are custom designed and built. The electric power is derived from the battery pack 208 mounted into the holding cases on the rear of the motorcycle 200, thus maintaining the new additions within the bodyline of the motorcycle 200 and preserving the bilateral symmetry of loads for balancing. Battery charging point 212 is located at a very convenient and easy accessible point on the vehicle and charging is done by an external 5A charger. The batteries are portable and hence can also be removed and charged off the vehicle. The cable harness provided under the rider's seat is for the power & control circuits and regeneration circuit of the motor controller 224, brake safety switch interlock 228, charging circuit and vehicle operations.

[00101] FIG. 3A illustrates a wheel assembly from right side of the motorcycle 200, in accordance with an embodiment of the present disclosure.

[00102] In an embodiment, the rear wheel assembly from right side of the motorcycle 200 includes the hub type electric motor 202, the electro-mechanical overrunning clutch mechanism 204, the chain sprocket 206, a motor axle 246, and an adapter sleeve for sprocket 248.

[00103] FIG. 3B illustrates a wheel assembly from left side of the motorcycle 200, in accordance with an embodiment of the present disclosure.

[00104] In an embodiment, the rear wheel assembly from left side of the motorcycle 200 includes the hub type electric motor 202, the electro-mechanical overrunning clutch mechanism 204, the brake calliper 234, a brake disc 236, and a disk adaptor sleeve 250.

[00105] FIG. 4A illustrates rear suspension arrangement from right side of the motorcycle, in accordance with an embodiment of the present disclosure.

[00106] In an embodiment, the rear suspension arrangement from right side of the motorcycle 200 includes the hub type electric motor 202, the electro-mechanical overrunning clutch mechanism 204, the chain sprocket 206, the rear fork assembly 232, the motor axle 246, the adapter sleeve for sprocket 248, an arrester plate assembly 252, and a rear shock absorber (254, 256).

[00107] FIG. 4B illustrates rear suspension arrangement from left side of the motorcycle, in accordance with an embodiment of the present disclosure.

[00108] In an embodiment, the rear suspension arrangement from left side of the motorcycle 200 includes the hub type electric motor 202, the rear fork assembly 232, the brake calliper 234, a brake disc 236, the motor axle 246, the disk adaptor sleeve 250, the rear shock absorber (254, 256), and an arrest or plate assembly 258.

5 **[00109]** In an embodiment, FIGS. 3A-3B, and 4A-4B disclose the direct electric drive mounted in the rear wheel 104 and the re-engineered rear suspension assembly. FIG. 3A and 3B disclose the detailed attachments of the electric motor 108. The hub type electric motor 202 is mounted on the custom designed rear swing arm suspension and fork 232 with the help of shock absorber spring units (254, 256). The arrestor plates 252 and its fasteners are
 10 provided to arrest the accidental rotation of the motor axle 246, which needs to be fixed, thereby allowing only rim and the tire to rotate with full traction power. The Motor axle 246 is securely held in position using the nuts and locknuts. The electric drive from the wheel is transmitted to the motorcycle 200 as follows - from hub type electric motor 202 to the electro-mechanical overrunning clutch mechanism 204 subsequently to the rear suspension
 15 fork assembly 232 and from the rear suspension fork assembly 232 to the chassis of the motorcycle and hence the motorcycle 200. The IC engine drive 242 is transmitted to the rear wheel 104 through the commonly used chain and sprocket mechanism 206 in conjunction with the electro-mechanical overrunning clutch mechanism 204.

[00110] FIG. 5A illustrates the electro-mechanical overrunning clutch mechanism of
 20 the motorcycle 200, in accordance with an embodiment of the present disclosure.

[00111] In an embodiment, the electro-mechanical overrunning clutch mechanism of the motorcycle 200 includes the hub type electric motor 202, an electro-mechanical overrunning clutch 204, the charging point 212, the rear fork assembly 232, rear shock absorber 256, and an over running clutch control unit 270 (also interchangeably referred to as
 25 control unit).

[00112] FIG. 5B-5C, 5E illustrates the electro-mechanical overrunning clutch mechanism of the motorcycle 200, in accordance with an embodiment of the present disclosure.

[00113] In an embodiment, the electro-mechanical overrunning clutch mechanism of
 30 the motorcycle 200 includes the chain sprocket 206, an outer hub assembly 260, an inner hub assembly 262, a set of springs and rollers (264, 266) and recess arrangement 268.

[00114] FIG. 5D illustrates the electro-mechanical overrunning clutch mechanism of the motorcycle 200, in accordance with an embodiment of the present disclosure.

[00115] In an embodiment, the electro-mechanical overrunning clutch mechanism of the motorcycle 200 includes the inner hub assembly 262, a set of springs and rollers (264, 266), a set of separation plates 272, a set of circular disc 274.

[00116] FIG. 5F illustrates the electro-mechanical overrunning clutch mechanism of the motorcycle 200, in accordance with an embodiment of the present disclosure.

[00117] In an embodiment, the electro-mechanical overrunning clutch mechanism of the motorcycle 200 includes the outer hub assembly 260, the inner hub assembly 262, and a cover plate 276.

[00118] In an embodiment, the electro-mechanical overrunning clutch mechanism 204 is mounted on the rear wheel 104 of the motorcycle 200 and allows the motorcycle 200 to run in either electric, combined mode or IC engine mode. The overrunning clutch mechanism 204 is electro-mechanical type and includes the control unit 270, which is configured to compare the torque value of the electric motor (T_{EM}) and the torque value of the IC engine (T_{ICE}) and accordingly sends commands to the motor controller 224. The electro-mechanical overrunning clutch mechanism 204 is configured to allow either the IC engine 242 or the hub type electric motor 202 to provide the drive to the wheel when the motorcycle 200 is driven in a single mode. Further, the electro-mechanical overrunning clutch mechanism 204 also adds and synchronizes the IC engine 242 drive and the hub type electric motor 202 drive when the vehicle is driven in the combined mode thereby allowing to make use of the combined resultant improved torque-speed characteristics of the hybrid powertrain.

[00119] In another embodiment, the electro-mechanical overrunning clutch mechanism 204 includes an outer hub assembly 260 that is connected to the chain sprocket mechanism 206 and transmits the IC engine 242 drive. The electro-mechanical overrunning clutch mechanism 204 includes an inner hub assembly 262 which is connected to hub type electric motor 202 and transmits the electric motor drive. The interaction between the inner hubs 262 and the outer hubs 260 is through a set of spring loaded rollers and recess arrangement (264, 266, and 268). The outer hub assembly 260 has the chain sprocket 206 on its outer side and it houses the inner hub assembly 262. A cover plate 276 at both ends keeps the electro-mechanical overrunning clutch mechanism 204 protected from dust ingestion. The inner hub assembly 262 consists of 3 modules each consisting of a circular disc 274 with cylindrical rollers 266 and recess arrangement 268. Between each module 274 and at the ends 276 there is a separation plate 272 that keeps the modules dust free. These modules 274 and plates 272, 276 are firmly held in place with a rivet arrangement to form the inner hub assembly 262. The modules 274 are riveted together in such a way that the rollers 266 are off-set from the

neighbouring module as shown in FIG. 5D. This off-set allows for uniform distribution of contact stresses and pressures generated during the interaction of the outer hub assembly 260 and inner hub assembly 262, onto the three set of rollers 266 and cylindrical discs 274 that constitute the inner hub 262, thereby increasing the fatigue life by almost three times. Since the rollers 266 have a line contact, the radial forces are distributed uniformly on the inner hub 262 as well as the outer hub 260 thereby improving the life of the electro-mechanical overrunning clutch mechanism 204. Since the contact pressure zones are spread over the three modules 274, no same contact area is subjected to contact stresses during every engagement and disengagement. Such a design of the inner hub 262 and outer hub assemblies 260 allows the transfer of drive to be smooth, silent and shock free. When the IC engine 242 is shut off and the electric motor is on, the electro-mechanical overrunning clutch mechanism 204 is as shown in FIG. 5B.

[00120] In an embodiment, Fig. 9 illustrates the outer hub 260 is stationary while the inner hub 262 is receiving the torque and will try to rotate. The IC engine gearbox 116 might not be in neutral position and hence the sprocket will be locked. The electric motor torque will force the inner hub 262 to rotate and cause the set of rollers 266 to compress the springs 264 against the spring force and thereby allowing the inner hub 262 to rotate and hence transmit the electric motor drive to the motorcycle 200. When the IC engine 242 is providing the necessary drive and the electric motor is shut off, the electro-mechanical overrunning clutch mechanism 204 is as shown in FIG. 5C. The outer hub assembly 260 will rotate with the chain sprocket mechanism 206 as it gets the IC engine 242 drive while the inner hub 262 is stationary as it is not receiving any torque from the electric motor. This causes the set of rollers 266 to move into their respective recess areas 268 thereby allowing the rotation of the outer hub 260 to be transmitted to the inner hub 262 and hence causing it to rotate and transmit the IC engine drive to the rear wheel. In combined mode, the torque assist from the electric motor is provided. In combined mode the IC engine 242 drive is transmitted to the rear wheel 104 from the chain and sprocket mechanism 206 through the electro-mechanical overrunning clutch mechanism 204 as described in the IC engine mode case. The electric motor torque then gets added to the inner hub 262. Thus the combined torque is then transmitted to the rear wheel 104 of the motorcycle 200. The control unit 270 measures the IC engine torque (T_{ICE}) and based on this torque value commands the motor controller 224 to deliver the electric motor torque (T_{EM}) which is always less than the torque generated by the IC engine ($T_{EM} < T_{ICE}$). By maintaining this condition the electro-mechanical overrunning clutch mechanism 204 can then add and transmit both the IC engine and electric motor torque

at the same time to the rear wheel 104 and hence to the motorcycle 200. The proportion by which the electric motor torque (T_{EM}) should be less than the IC engine torque (T_{ICE}) is programmable and can be set as per the application. In this manner, the control unit 270 together with the electro-mechanical overrunning clutch mechanism 204, which constitute an electro-mechanical system that enables the hub type electric motor 202 to provide assistance to the IC engine 242 while being in combined mode of operation.

[00121] FIG. 6 illustrates the combined accelerator of the motorcycle, in accordance with an embodiment of the present disclosure.

[00122] In an embodiment, FIG 6 discloses the combined accelerator 600 that performs the function of accelerator for both electric and engine drives and hence gives ease of operation to the driver maintaining their driving habits. The handle grip 302 operates both electric and internal combustion engine accelerator in unison. The module 218 consists of the combined arrangement for operating the IC engine accelerator and the electric motor accelerator. The handle grip 302 has a cylindrical drum 278 attached to it which rotates along with the grip. The cylindrical drum 278 includes a cable attached to it that gets wound or unwound as the drum turns. The twisting action of the handle grip 302 transmits the riders input. The combined accelerator 600 can be configured with the electric motor 108 and the IC engine 118 and is designed with a configurable phase lag that allows the electric motor 108 to speed up earlier than the IC engine 118 owing to high initial starting torque of the electric power-train while being driven in the combined mode. FIG. 7 illustrates a Mechanical Safety Interlock System (Gear-box “Neutral Lock”), in accordance with an embodiment of the present disclosure.

[00123] In an embodiment, when the motorcycle 200 is to be run in electric mode an additional mechanically operated gearbox safety mechanism can be provided. While in the electric mode it is better if the gearbox connected to the IC engine stays in “neutral mode”. This action has to be a fool proof system and is obtained by keeping the gear changing lever on the motorcycle locked in “neutral” position. The locking of the gear lever in “neutral” position is achieved with the help of a mechanical safety interlock system shown in FIG 7. The gear box safety assembly mechanism (FIG 2B (238) and FIG 7) is mounted on the body of the motorcycle 200 rigidly near the gear changing foot pedal 240 using the mounting plate or the hinge plate 306. The foot rest or gearbox safety plate 308 acts as preventer for shifting of the gear lever pedal 240. The foot rest 308 swings about the hinge pins 310 and provides the swing in-out operation for shifting from IC engine to electric mode and vice versa. This two position latch assembly positively locks the position of the foot rest for neutral gear as

shown in FIG 7. For the Electric mode which means the gear lever should stay in neutral position, the foot rest stays at 90 degrees to the mounting plate and on top of the gear lever as shown in Fig 7. For the IC engine mode which means changing of gears through the gear lever is required, the foot rest is swung upward at 180 degrees to the mounting plate by pressing the plate against the compression springs 312 and pivoting about the hinge pins 310. Thus this mechanical safety interlock system (FIG 2B (238) & FIG 7) allows only one latching mode at a time imparting safe operation of the motorcycle 200 by the rider.

[00124] In an embodiment, the motor controller 224 is configured to manage the torque distribution in the combined mode to utilize the resultant torque-speed characteristics of the hybrid electric drive system 106. When the motorcycle 200 is in combined mode and is starting from standing start, the required torque is provided by the electric drive from the hub type electric motor 202 and the IC engine 242, which is not providing torque as it is not switched on. After reaching a speed threshold (25 to 35 kmph) that is configurable, the hybrid electric drive system 106 alerts the rider via the visual display 220 to switch on the IC engine 242 by pressing the clutch and put the transmission in 2nd or 3rd gear. Once the clutch is released by the rider the torque is now provided by the IC engine 242 and the hub type electric motor 202 is in assist mode. The transition from electric drive to combined mode is seamlessly done by the electro-mechanical overrunning clutch mechanism 204, which controls the torque of the hub type electric motor 202 below the torque of the IC engine 242. When the speed of the motorcycle 200 reaches another threshold (say 50 kmph) that is configurable, the motor controller 224 switches the motor off and the IC engine is solely providing the required torque. When the motorcycle 200 is decelerating and the speed falls below the first threshold (25 to 35 kmph), the motor controller 224 switches on the motor if the rider demands increase in speed and the additional torque is thereby provided by the hub type electric motor 202 in assist mode without the rider having to downshift the transmission into lower gear. If increase in speed not demanded, then the motor controller 224 doesn't switch on the hub type electric motor 202 below the threshold speed. Additionally during steady state cruise condition, if the speeds are steady over a third threshold speed (75 to 85 kmph) which is also configurable, the motor controller 224 switches on the hub type electric motor 202 and alerts the rider to switch off the IC engine (FIG 2B (21)) by shifting the transmission to neutral position. The engine can be turned on again by the rider if so desired and the vehicle put in the necessary gear by operating the clutch. Such mode transitions are allowed only when the user is operating the vehicle in combined mode. If the single mode either electric or IC engine is selected then the vehicle continues to run in the selected single

mode with no interference from the logic based motor controller 224 and thereby allowing full autonomy to the user. FIG. 9 illustrates graphical representation of this logic of the controller on how it manages the torque distribution in the combined mode to better utilize the resultant torque-speed characteristics.

5 **[00125]** In an embodiment, the motorcycle 200 includes the rear disc brake 236 and speedometer sensors are provided on the hub type electric motor 202. Digital speed sensing by a sensor ring and a speed sensor is used to measure the speed of the motorcycle 200.

10 **[00126]** In an embodiment, the motorcycle 200 includes two independent electric key switches 214, 216, which are provided to isolate electric and engine mode. Speed and other display parameters are shown on instrument cluster 220 of the motorcycle 200.

15 **[00127]** In an embodiment, the motorcycle 200 includes the motor controller 224. A 1k ohm pre charging resistor is added across the mains contactor. Similarly, 1K ohm resistor is also added across the key switch (214,216) for electric mode. The magnetically coupled combined accelerator (218, 302) interacts with the motor controller 224 to provide desired speed control. The motor controller 224 provides the proportionate power as per the torque speed demand as directed by the combined accelerator. Thermister control is provided internally through this motor controller 224 for the protection of the motor winding from over-heating during rotor lock situation. Thus protection interlocks are achieved. The brake safety interlock switch 226 prevents accidental running of motor while brakes are engaged.
20 The brake lever 224 is used to actuate this switch 226. Further, the motor controller 224 provides a regeneration mode during braking done by either front or rear wheel brakes, thereby charging the batteries. Thus this action is capable to further add extra miles as a result of regeneration.

25 **[00128]** FIG. 8A illustrates graphical representation of the motorcycle with resultant torque-speed characteristics, in accordance with an embodiment of the present disclosure.

30 **[00129]** FIG. 8B illustrates graphical representation of the motorcycle with resultant torque-speed characteristics under various drive cycles, in accordance with an embodiment of the present disclosure.

35 **[00130]** FIG. 8C illustrates graphical representation of the motorcycle with resultant reduction in IC engine usage, in accordance with an embodiment of the present disclosure.

40 **[00131]** In an embodiment, FIG 8A graphically represents the resultant representational torque speed characteristics delivered by the hybrid electric drive system 106. It can be seen that the resultant torque of the hybrid system eclipses the maximum torque possible of the IC engine 242 and this high resultant torque is available even at very low initial starting speed

thereby reducing the load on the IC engine 242 significantly. FIG 8B graphically represents the resultant representational torque speed characteristics delivered by the hybrid drive system under various drive cycles like start-up and heavy acceleration (power zone), partial load condition (eco zone) and steady state cruise condition (cruise zone). It can be seen that majority of the high torque from the resultant hybrid drive becomes available even from low initial speeds. This helps in keeping the engine speeds much lower than desired as the engine isn't required to provide the complete torque needed to meet the load. By synchronizing the drives, the hybrid electric drive system can reduce the load on the IC engine and thereby reduce the fossil fuel consumption and carbon and other harmful emissions by nearly up to 70%. Further reduction in harmful emissions can be achieved by improving the efficiency of the electric motor and battery pack. FIG. 8B includes representation of different gears such as 1st gear, 2nd gear, 3rd gear, 4th gear etc of the IC engine gearbox along with various zones such as cruise zone, eco zone and power zone. It can be seen that the resultant torque-speed characteristics of the hybrid electric system allows the vehicle to be operated in 3rd or higher gears in the power zone unlike when in the IC engine mode where 1st or 2nd gear is needed in power zone. This translates to the engine being loaded less to provide the necessary drive while in the combined mode, thereby resulting in savings of fuel and reduction in harmful emissions from the IC engine. FIG. 8C represents the graph indicating a reduction in usage of IC engine power and in turn reduction in usage of fossil fuel and reduction in tail-pipe emissions by utilizing the uniquely designed hybrid system.

[00132] Although this present invention has been described herein with respect to a number of specific illustrative embodiments, the foregoing description is intended to illustrate, rather than to limit the invention. Those skilled in the art will realize that many modifications of the illustrative embodiment could be made which would be operable. All such modifications, which are within the scope of the claims, are intended to be within the scope and of the present invention.

ADVANTAGES OF THE PRESENT DISCLOSURE

[00133] The present disclosure provides an efficient mechanism by providing a faster and simpler conversion method to convert IC engine driven motorcycle architectures to a plug-in hybrid electric motorcycle.

[00134] The present disclosure provides a hybrid electric drive system that includes a uniquely designed electro-mechanical overrunning clutch that works in conjunction with the chain and sprocket drive mechanism.

[00135] The present disclosure provides a hybrid electric drive system that provides a user-defined and control logic defined mode selection by using the uniquely designed electro-mechanical overrunning clutch. Such a design would enable the user to control the mode of operation of the vehicle in specifically mandated zero vehicular pollution zones in urban areas.

[00136] The present disclosure provides a hybrid electric drive system to control both the IC engine and Electric motor drive in such a way that the rider can maintain the familiarity of riding a motorcycle using the twist type handle grip accelerator.

We Claim:

1. A hybrid electric drive system (106) comprising:

a hub type electric motor (202) mounted on a rear wheel (104) of a motorcycle (200),
the hub type electric motor (202) is configured to drive a rear wheel (104) of the motorcycle
5 (200);

characterized in that comprising:

an electro-mechanical overrunning clutch (204) coupled to both the hub type electric
motor (202) through the body of the motor and an IC engine (242) through a chain sprocket
mechanism (206) mounted on the rear wheel (104), and the electro-mechanical overrunning
10 clutch (204) is configured to enable seamless transition between all the modes, and transmit
IC engine drive and electric motor torque simultaneously to the rear wheel (104) of the
motorcycle (200), wherein the electro-mechanical overrunning clutch (204) comprises:

an outer hub assembly (260) coupled to the chain sprocket mechanism (206),
and is one of the elements configured to transmit the IC engine drive;

15 an inner hub assembly (262) coupled to the body of the electric motor (202),
and is the second element configured to transmit the IC engine drive and seamlessly
combine it with the electric motor drive; and

a set of springs and rollers (264, 266) with a recess arrangement (268) that
provide the necessary linkage and interaction between the outer hub (260) and the
20 inner hub assembly (262),

wherein,

for electric mode when the IC engine is shut off and the electric
motor is on, the outer hub assembly (260) is stationary and the inner
hub assembly (262) gets the torque from the electric motor, the rollers
25 (266) get into a position to allow the inner hub assembly (262) to rotate
although the outer hub assembly (260) is stationary, and the electric
motor drive is transmitted to the rear wheel (104);

for IC engine mode when the IC engine is on and the electric
motor is shut off, the inner hub assembly (262) is not receiving torque
30 from the electric motor and the outer hub assembly (260) receives the
torque from the IC engine, the rollers (266) get into a position to allow
the outer hub assembly (260) to transmit the torque to the inner hub

assembly (262) and the IC engine drive is transmitted to the rear wheel (104), and

for combined mode, the rollers (266) get into a position same as that of IC engine mode and allow outer hub assembly (260) to transmit the IC engine torque to the inner hub assembly (262), the inner hub assembly (262) also gets the electric motor torque, the two drives being seamlessly added and transmitted to the rear wheel (104), wherein the electro-mechanical overrunning clutch (204) adds and synchronizes the IC engine (242) drive and the hub type electric motor (202) drive in the combined mode;

a control unit (270) is configured to compare torque value of the electric motor (TEM) and the IC engine (TICE) and transmit commands to a motor controller (224) to enable both the IC engine and electric motor torque to be transmitted simultaneously to the rear wheel (104);

a combined accelerator (600) is configured with the electric motor (108) and the IC engine (118) and is designed with a configurable phase lag that allows the electric motor (108) to speed up earlier than the IC engine owing to high initial starting torque of the electric power-train while being driven in the combined mode; and

a rear wheel suspension arrangement is connected to the rear wheel (104) of the motorcycle (200) comprising an arrangement including a set of arrestor plates (252), a pair of shock absorbers (254, 256) and rear fork assembly (232), wherein the set of arrestor plates (252) prevent accidental rotation of motor axle (246) and the rear fork assembly (232) is configured to transmit the electric drive to propel the motorcycle (200).

2. The hybrid electric drive system (106) as claimed in claim 1, wherein the hybrid electric drive system (106) is configured to perform the dual role of allowing drive from each powertrain to be transmitted individually to the rear wheel (104) in either one of the modes such as an electric mode or an IC engine mode and adding the drive from each powertrain and seamlessly transmitting to the rear wheel (104) in the combined mode.

3. The hybrid electric drive system (106) as claimed in claim 1, wherein in the combined mode the IC engine drive is transmitted to the rear wheel (104) from the chain and sprocket mechanism (206) through the electro-mechanical overrunning clutch (204), wherein an

electric motor torque is added to the inner hub assembly (262) and the combined torque is transmitted to the rear wheel (104) of the motorcycle (200).

4. The hybrid electric drive system (106) as claimed in claim 1, wherein the electro-mechanical overrunning clutch (204) is configured to allow either the IC engine (242) or the hub type electric motor (202) to provide the drive to the rear wheel (104) when the motorcycle (200) is driven in a single mode.
5. The hybrid electric drive system (106) as claimed in claim 1, wherein the inner hub assembly (262) includes a set of circular disc (274) with cylindrical rollers (266) and recess arrangement (268).
- 10 6. The hybrid electric drive system (106) as claimed in claim 1, wherein a twist type handle grip (302) is coupled to cylindrical drum (278) that is configured to rotate along with the twist type handle grip (302), wherein the cylindrical drum (278) includes a cable attached to it that gets wound or unwound as the drum turns.
- 15 7. The hybrid electric drive system (106) as claimed in claim 1, wherein twisting action of the twist type handle grip (302) is configured to transmit the rider input via a cable to the combined accelerator (600).
8. The hybrid electric drive system (106) as claimed in claim 1, wherein the control unit (270) is configured to measure the IC engine torque (T_{ICE}) and based on torque value, commands the motor controller (224) to deliver the electric motor torque (T_{EM}) that is less than the torque generated by the IC engine ($T_{EM} < T_{ICE}$).
- 20 9. The hybrid electric drive system (106) as claimed in claim 1, wherein the motor controller (224) is configured to manage the torque distribution in the combined mode to utilize the resultant torque-speed characteristics of the hybrid drive system (106) more effectively compared to the torque-speed characteristics of the individual IC engine mode.
- 25 10. The hybrid electric drive system (106) as claimed in claim 1, wherein the motor controller (224) is placed in the front suspension fork of the motorcycle (200) and its casing assembly is designed to provide adequate mounting capability for the controller and give sufficient protection and ventilation to the controller.

11. The hybrid electric drive system (106) as claimed in claim 1, wherein a set of battery packs (208) are mounted at the rear side of the motorcycle (200) and on either side for preserving the bilateral symmetry of loads for balancing.

12. The hybrid electric drive system (106) as claimed in claim 1, wherein the motorcycle (200) is in the IC engine mode, the hub type electric motor (202) is configured to act as a generator to charge the batteries (208) depending upon the state of charge (SOC) of the battery pack in regeneration mode, where even during braking, irrespective of the mode of operation, the hub type electric motor (202) is configured to act as a generator to charge the batteries depending upon the state of charge (SOC) of the battery pack.

13. A motorcycle (200) comprising:

a hybrid electric drive system (106) that comprises;

a hub type electric motor (202) mounted on a rear wheel (104) of a motorcycle (200), the hub type electric motor (202) is configured to drive a rear wheel (104) of the motorcycle (200);

an electro-mechanical overrunning clutch (204) coupled to both the hub type electric motor (202) through the body of the motor and an IC engine (242) through a chain sprocket mechanism (206) mounted on the rear wheel (104), and the electro-mechanical overrunning clutch (204) is configured to enable seamless transition between all the modes, and transmit IC engine drive and electric motor torque simultaneously to the rear wheel (104) of the motorcycle (200), wherein the electro-mechanical overrunning clutch (204) comprises:

an outer hub assembly (260) coupled to the chain sprocket mechanism (206), and is one of the elements configured to transmit the IC engine drive;

a inner hub assembly (262) coupled to the body of the electric motor (202), and is the second element configured to transmit the IC engine drive and seamlessly combine it with the electric motor drive; and

a set of springs and rollers (264, 266) with a recess arrangement (268) that provide the necessary linkage and interaction between the outer hub (260) and the inner hub assembly (262),

wherein,

for electric mode when the IC engine is shut off and the electric motor is on, the outer hub assembly (260) is stationary and the inner hub assembly (262) gets the torque from the electric motor, the rollers

(266) get into a position to allow the inner hub assembly (262) to rotate although the outer hub assembly (260) is stationary, and the electric motor drive is transmitted to the rear wheel (104);

for IC engine mode when the IC engine is on and the electric motor is shut off, the inner hub assembly (262) is not receiving torque from the electric motor and the outer hub assembly (260) receives the torque from the IC engine, the rollers (266) get into a position to allow the outer hub assembly (260) to transmit the torque to the inner hub assembly (262) and the IC engine drive is transmitted to the rear wheel (104), and

for combined mode, the rollers (266) get into a position same as that of IC engine mode and allow outer hub assembly (260) to transmit the IC engine torque to the inner hub assembly (262), the inner hub assembly (262) also gets the electric motor torque, the two drives being seamlessly added and transmitted to the rear wheel (104), wherein the electro-mechanical overrunning clutch (204) adds and synchronizes the IC engine (242) drive and the hub type electric motor (202) drive in the combined mode;

a control unit (270) is configured to compare torque value of the electric motor (TEM) and the IC engine (TICE) and transmit commands to a motor controller (224) to enable both the IC engine and electric motor torque to be transmitted simultaneously to the rear wheel (104);

a combined accelerator (600) is configured with the electric motor (108) and the IC engine (118) and is designed with a configurable phase lag that allows the electric motor to speed up earlier than the IC engine owing to high initial starting torque of the electric power-train while being driven in the combined mode; and

a rear wheel suspension arrangement is connected to the rear wheel (104) of the motorcycle (200) comprising an arrangement including a set of arrestor plates (252), a pair of shock absorbers (254, 256) and rear fork assembly (232), wherein the set of arrestor plates (252) prevent accidental rotation of motor axle (246) and the rear fork assembly (232) is configured to transmit the electric drive to propel the motorcycle (200).