(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 June 2018 (28.06.2018)

WIPO | PCT

(10) International Publication Number
WO 2018/116144 A1

(51) International Patent Classification:
B60L 5/00 (2006.01) *B60W 20/00* (2016.01)

(21) International Application Number:
PCT/IB2017/058095

(22) International Filing Date:
19 December 2017 (19.12.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
201641043265 19 December 2016 (19.12.2016) IN

(71) Applicant: TVS MOTOR COMPANY LIMITED [IN/IN]; Jayalakshmi Estates, No.29 (old No.8) Haddows Road, Chennai 600006 (IN).

(72) Inventors: **GEDDADI, Krishnamohan**; TVS Motor Company Limited, Jayalakshmi Estates, No.29 (old No.8) Haddows Road, Chennai 600006 (IN). **DAS, Surajit**; TVS Motor Company Limited, Jayalakshmi Estates, No.29 (old No.8) Haddows Road, Chennai 600006 (IN). **JABEZ DHINAGAR, Samraj**; TVS Motor Company Limited, Jayalakshmi Estates, No.29 (old No.8) Haddows Road, Chennai 600006 (IN).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

(54) Title: CONTROL SYSTEM FOR A VEHICLE AND A CONTROL METHOD THEREOF

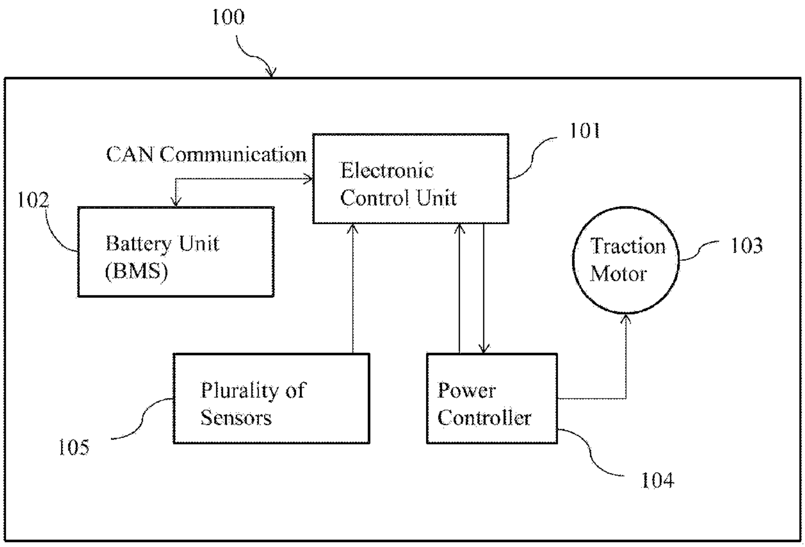

Fig.2

(57) Abstract: The present invention discloses a control system (100) for a vehicle for regulating magnitude of current, including duration of current, supplied to a traction motor (104) of the vehicle. The magnitude of current is regulated based on vehicle based information including temperature of components (101, 102, 103, 104) of the control system (100), vehicle speed and throttle input.

WO 2018/116144 A1

[Continued on next page]

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:
— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*
— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

CONTROL SYSTEM FOR A VEHICLE AND A CONTROL METHOD THEREOF

Technical Field

[1] The present subject matter described herein generally relates to a control system for a vehicle and particularly but not exclusively relates to a control system for regulating current delivered to a traction motor of said vehicle.

Background

[2] In recent times there is an increased demand to control emissions from automobiles, in view of stringent emission norms. As a result, a number of hybrid and electric vehicles (hereinafter EV) are seeing the light of the day in order to minimize the amount of emissions.

[3] For example, typical hybrid vehicles configured to be powered either by an internal combustion engine or a traction motor or both, are replacing normal engine powered vehicles. Said hybrid vehicles are configured to operate in different operating modes such as sole engine mode, sole traction motor mode, hybrid power mode, hybrid economy mode and the like. Further, said hybrid vehicles also include a battery to power the traction motor and an electronic control unit to control the input power supplied to the traction motor. Typically, said hybrid vehicles are configured to operate in sole traction motor mode/EVmode as a default drive mode during vehicle starting conditions. Therefore, in order to provide good initial acceleration for the vehicle at zero speed, it is required that the battery, the traction motor and the electronic control unit should work together for supply of high power. In other words, it is required that short time high current be supplied to the traction motor in order to achieve high initial acceleration. However, supply of short time high current through the traction motor results in damage to the traction motor winding due to the sudden rise in temperature of traction motor. Therefore, most manufacturers fail to use the full capacity of traction motor even though the traction motor may have good short time current capacity.

[4] There is therefore a need to control passage of short time high current through the traction motor so as to prevent damage to the traction motor winding, while ensuring that the initial acceleration of the hybrid/electric vehicle is not compromised.

[5] Known arts involve the use an additional temperature sensor for monitoring temperature of the traction motor, and based on which additional current is pumped through the windings of the traction motor for providing initial acceleration. However, use of an additional temperature sensor leads to an increase in the overall cost of the traction motor. Further, some known arts conventionally use the electronic control unit to store temperature of traction motor related information which is used for controlling passage of current through the traction motor. However, the use of the electronic control unit for storing temperature of traction motor related information proves to be disadvantageous especially while restarting the vehicle, since the electronic control unit loses the previously stored information including temperature of traction motor related information when the vehicle is switched OFF intermittently. Therefore, the chances of passing high current through the traction motor without considering its previous temperature increase while restarting the vehicle is high, thereby increasing the chances of traction motor damage.

[6] It is therefore essential to address problems set out in the known prior arts.

Summary of the Invention

[7] The present invention has been made in view of the above circumstances.

[8] It is an object of the present invention to provide a control system for a vehicle for regulating magnitude of current supplied to a traction motor of the vehicle.

[9] It is another object of the present invention to provide a control system for a vehicle for regulating the duration for which high current may be supplied to the traction motor of the vehicle.

[10] It is yet another object of the present invention to provide a control system for a vehicle capable of estimating temperature of traction motor without the use of additional temperature of traction motor sensor or a thermocouple.

[11] It is one more object of the present invention to provide a control system for a vehicle which includes a battery having a battery management system capable of storing estimated temperature of traction motor as calculated by an electronic control unit before vehicle ignition is switched OFF.

[12] It is still another object of the present invention to provide a control system including a battery management system capable of calculating temperature of traction motor to be achieved for vehicle restart condition.

[13] Accordingly, with the above and other objects in view, the present invention provides a control system for regulating passage of current I_{max} through a traction motor thereof based on estimated temperature of traction motor not only for initial acceleration conditions, but also for vehicle running and vehicle restart conditions. The control system as per the present invention includes a plurality of sensors disposed on one or more locations of the vehicle, a battery unit having a battery management system, an electronic control unit communicatively connected to said battery management system, a power controller communicatively connected to the electronic control unit and a traction motor operatively connected to the power controller.

[14] As per an aspect of the present invention, the electronic control unit is configured to calculate a requisite pulse duration T_PulseDuration for which high current I_{max} can be passed through said traction motor. The magnitude or value of I_{max} is greater than a predetermined value. Particularly, said electronic control unit calculates said requisite pulse duration T_PulseDuration based on a pulse duration limit estimated for each component of the control system including that of the battery unit, the electronic control unit, the power controller and the traction motor, said pulse duration limit for each component in turn being estimated based on the estimated temperature of each component. In the present embodiment, while the temperature of traction motor is estimated by the electronic control unit based on phase current of said traction motor, said phase current being calculated from DC bus current thereof, the temperature of battery unit is arrived at using temperature senor provided within said battery unit. Further, the pulse duration limit for the electronic control unit is also calculated based on temperature of the electronic control unit. Once the pulse duration limit is calculated for each component, the electronic control unit estimates the requisite pulse duration T_PulseDuration to initiate a trigger signal to be sent to the power controller, which on receiving said trigger signal enables passage of I_{max}. The T_PulseDuration is arrived at by comparing the pulse duration limit for each component and chooses a minimum pulse duration limit value corresponding to any one of said components as the requisite pulse duration T_PulseDuration. Besides estimating the requisite pulse duration T_PulseDuration for which I_{max} may be passed by the power controller, the electronic control unit also estimates the conditions under which current I_{max} can be sent to the traction motor by the power controller. For example, when the rate of rise of throttle input is greater than a threshold throttle input value and measured vehicle speed is lesser than threshold vehicle speed, the electronic control unit sends a trigger signal to the power controller which allows passage of current I_{max} for the requisite pulse duration T_PulseDuration. In other words, whenever there is a demand for higher acceleration, the power controller allows the passage of current I_{max} for the requisite pulse duration T_PulseDuration. However, in conditions where the vehicle speed exceeds threshold vehicle speed or when a measured duration for which current I_{max} circulated exceeds requisite pulse duration T_PulseDuration, the power controller restricts the passage of current I_{max} and causes passage of a reference current I_{nom} through the traction motor. I_{nom} is a nominal current. The magnitude of I_{nom} is lesser than the magnitude of I_{max}. The plurality of sensors is adapted to transmit at least one data signal to the electronic control unit. Said at least one data signal includes one or more of temperature of the battery unit, temperature of the electronic control unit, temperature of the power controller, temperature of the traction motor, throttle input, and vehicle speed.

[15] As per another aspect of the present invention, the control system is configured to store estimated temperature of traction motor at the instant when the ignition switch is turned OFF and further estimate reduction in temperature of traction motor to be achieved, so as to enable passage of current I_{max} for the corresponding requisite pulse duration T_PulseDuration through the traction motor during vehicle restart conditions, so that the traction motor is not damaged due to sudden passage of current I_{max} even when the traction motor is still hot. Particularly, in the present invention, the Battery Management System of the battery unit is configured to receive and store the estimated temperature of traction motor at the instant when the ignition switch is turned OFF and further configured to estimate reduction in temperature of traction motor to be achieved, so as to enable passage of current I_{max} for the requisite pulse duration T_PulseDuration through the traction motor during vehicle restart conditions.

[16] Thus, the control system as per the present invention aids in regulating passage of current I_{max} through the traction motor taking into consideration various parameters including temperature of traction motor, and temperature of battery unit, and thus enables in ensuring that there is minimal damage to the traction motor, while at the same time ensuring that sufficient high current is pumped through the traction motor for achieving high acceleration whenever there is a demand for the same. The present invention also serves as a cost effective means since it neither involves the use of a temperature sensor nor a thermocouple for estimating temperature of traction motor.

[17] Further, the present invention also describes a method of operation of said control system for regulating passage of current I_{max} through the traction motor.

[18] Summary provided above explains the basic features of the invention and does not limit the scope of the invention. The nature and further characteristic features of the present invention will be made clearer from the following descriptions made with reference to the accompanying drawings.

Brief Description of Drawings

[19] The above and other features, aspects, and advantages of the subject matter will be better understood with regard to the following description and accompanying drawings where:

[20] **FIG.1** is a schematic representation of a vehicle in accordance with an embodiment of the present invention.

[21] **FIG.2** is a schematic representation of a control system in accordance with an embodiment of the present invention.

[22] **FIG.3** illustrates a flowchart depicting steps of a method of functioning of an electronic control unit of the control system during vehicle starting and vehicle running conditions.

[23] **FIG.4** illustrates a flowchart depicting steps of a method of functioning of the electronic control unit during ignition switch OFF condition.

[24] **FIG.5** illustrates a flowchart depicting steps of a method of operation of the battery management system of the control system during ignition switch OFF condition.

[25] **FIG.6** illustrates a flowchart for depicting steps of method of operation of the electronic control unit for regulating current I_{max} during vehicle restart conditions.

Detailed Description

[26] The present subject matter described herein relates to a control system for a vehicle which serves to regulate current I_{max} passing through a traction motor of said control system. Particularly, said control system serves to estimate a requisite pulse duration T_PulseDuration for which current I_{max} may be passed through the traction motor, without leading to damage of the traction motor due to high temperature.

[27] Exemplary embodiments detailing features of the control system, in accordance with the present invention will be described hereunder. The embodiments described herein apply to a vehicle powered by two or more power sources including an internal combustion engine, the traction motor and a battery unit. However, the present invention is not restricted in its application and is also applicable to vehicles employing only the traction motor and the battery unit, say for example an electric vehicle. Further, although the present invention has been exemplified for a two-wheeled vehicle, application of the present invention need

not be restricted to a two-wheeled vehicle, and maybe applied to any vehicle including a three-wheeled vehicle and a four-wheeled vehicle.

[28] The present invention has been exemplified for a hybrid vehicle as illustrated in **FIG.1**.

[29] With reference to **FIG.1**, a description is made of a hybrid two-wheeled vehicle, hereinafter “vehicle” **10** in accordance with an embodiment of the present invention. **FIG.1** is a side view of said vehicle **10**. Said vehicle **10** illustrated, has a step-through type frame assembly **15**. The step-through type frame assembly **15** includes a head tube **15A**, a main tube **15B** and a pair of side tubes **15C**. Particularly, the main tube **15B** extends downwards from a rear portion of the head tube **15A** and then extends rearwards in an inclined manner. Further, the pair of side tubes **15C** extends rearwardly from the main tube **15B**. Thus, the frame assembly **15** extends from a front portion **F** to rear a rear portion **R** of the vehicle.

[30] Said vehicle **10** further includes a plurality of body panels for covering the frame assembly **15**, and is mounted thereto. In the present embodiment said plurality of body panels includes a front panel **15FP**, a leg shield **15LS**, an under-seat cover **15SC**, and a left and a right side panel **15SP**. Further, a glove box may be mounted to said leg shield **15LS**.

[31] In a step through space formed between said leg shield **15LS** and said under seat cover **15SC**, a floorboard **12** is provided. Further, a seat assembly **25** is disposed above said under-seat cover **15SC**, and is mounted to the pair of side tubes **15C**. A utility box (not shown) is disposed below the seat assembly **25**. A fuel tank (not shown) is positioned below the utility box. A rear fender **26** for covering at least a portion of a rear wheel **27** is positioned below the fuel tank.

[32] One or more suspension(s)/shock absorbers **30** are provided in a rear portion of said vehicle **10** for comfortable ride. Further said vehicle **10** comprises of plurality of electrical and electronic components including a headlight **35A**, a taillight **35B**, a transistor controlled ignition (TCI) unit (not shown), a starter traction motor (not shown) and the like. A touch screen LCD unit in the form of an instrument display panel (not shown) is provided on a handle bar **11** to display various operating drive modes, power flow pattern and warning signals. Rear view mirrors **13** are mounted on the right and left sides of the handle bar **11**. Said vehicle **10** is also provided with hazard lamps (not shown).

[33] An internal combustion engine **14**, hereinafter “engine”, is arranged behind said floorboard **12** and supported between the pair of side tubes **15C**. Particularly, said engine **14** is supported by a swing arm **19**. The swing arm **19** is attached to a lower portion of the main tube **15B** by means of a toggle link (not shown). The other end of the swing arm **19** holds the rear wheel **27**. The rear wheel **27** and the swing arm **19** are connected to the pair of side frames **15C** by means of a pair of shock absorbers **30** provided on either side of the vehicle.

[34] Said hybrid vehicle **10** further includes a traction motor **103** (shown in **FIG.2**) mounted on a hub of the rear wheel **27**. In the present embodiment, said traction motor **103** (shown in **FIG.2**) is a Brushless Direct Current (hereinafter BLDC) traction motor. Further, said traction motor **103** is powered by a battery unit **102** (shown in **FIG.2**) disposed in a rear portion of the vehicle. An electronic control unit **101** (shown in **FIG.2**) is also provided to control various vehicle operative modes, such as sole engine mode, sole traction motor mode and hybrid power mode, based on the source of power being, respectively, the engine **14**, the battery unit **102** transmitted to the traction motor **103** and both. Said electronic control unit **101**, said power controller **104**, said plurality of sensors **105**, said battery unit **102** and said traction motor **103** constitute parts of a control system **100** of said hybrid vehicle **10**. The plurality of sensors **105** may include a first set of sensors to measure temperature of battery unit **102**, cell voltage, battery current, SOC. The plurality of sensors **105** may also include a second set of sensors to measure temperature of power controller **104** and temperature of electronic control unit **101**. The plurality of sensors **105** can further include sensors to measure throttle slope, a vehicle speed sensor, and the like.

[35] The hybrid vehicle **10** is configured to be propelled either by the engine **14** alone or by said traction motor **103** alone or by both engine **14** and said traction motor **103** simultaneously. At zero vehicle speed, a rider can select any of the following four operating drive modes with the help of a mode switch (not shown). The four operating drive modes of the hybrid vehicle **10** are: (a) a sole engine mode where engine **14** alone powers the vehicle (b) a sole traction motor mode where the traction motor **103** alone powers the vehicle (c) a hybrid power mode wherein the engine **14** and the traction motor **103** together power the vehicle (d) a hybrid economy mode wherein only the engine **14** or only the traction motor **103** or both power the hybrid vehicle depending on the vehicle operating conditions. The vehicle operating conditions includes the vehicle speed and vehicle rpm.

[36] In other words, the rear wheel **27** of the vehicle is driven by either the engine **14** alone or by the traction motor **103** alone or by both the engine **14** and the traction motor **103** simultaneously. Particularly, power from the engine **14** to the rear wheel **27** is transmitted by a transmission assembly including a drive system (not shown) as per an embodiment of the present invention. However, when the traction motor **103** drives, power from the traction motor **103** is directly transmitted to the rear wheel **27**. In the present embodiment, said traction motor **103** is covered by a traction motor shroud from at least one side. As per an aspect of the present invention, said traction motor shroud serves to at least partially encompass/house one or more parts of the drive system and therefore constitutes a part of the drive system. On another side of the wheel shaft, the traction motor shroud serves to house a brake drum (not shown).

[37] Said vehicle **10** as described above includes the control system **100** as shown in **FIG.2**. As seen in **FIG.2**, said control system **100** includes the electronic control unit **101**, the plurality of sensors **105** is adapted to transmit at least one data signal to the electronic control unit **101** the power controller **104** communicatively connected to the electronic control unit **101**, the battery unit **102** communicatively connected to said electronic control unit **101** and said traction motor **103** operatively connected to said power controller **104**. In the present embodiment, said electronic control unit **101** is powered by said battery unit **102**, said battery unit **102** having its own control unit called battery management system, hereinafter "BMS". The BMS as per the present embodiment receives and sends signals from and to the electronic control unit **101.** Particularly, in the present embodiment, said BMS is configured to communicate with said electronic control unit **101**, information relating to battery parameters including temperature of battery unit

102. In the present embodiment, temperature of battery unit **102** is calculated using temperature sensors, from the plurality of sensors **105**, provided in said battery unit **102**. Further, based on the temperature of the battery unit **102** and other battery parameters such as cell voltage, battery current, SOC, and the like, which are detected by one or more of the plurality of sensors **105**, the BMS estimates a battery unit **102** based pulse duration limit t3 for which current I_{max} can be supplied to the traction motor **103.** The estimated t3 is transmitted to the electronic control unit **101**.

[38] In the present embodiment, said electronic control unit **101** is also configured to estimate its own temperature based on inputs provided by the set of temperature sensors, of the plurality of sensors **105**, regarding heat sink temperature. In the present embodiment, for estimation of temperature of the traction motor **103**, the traction motor **103** is neither provided with an independent temperature sensor nor a thermocouple. However, the electronic control unit **101** is configured to estimate the temperature of traction motor **103**. Particularly, as per an aspect of the present invention, the electronic control unit **101** is configured to calculate the estimated temperature of traction motor **103** using phase current of the traction motor **103.** The phase current is calculated using DC bus current of the traction motor **103** with the aid of standard formulae stored in said electronic control unit **101** for calculation of the same.

[39] As per an aspect of the present invention, said control system **100** is configured to regulate current I_{max} through the traction motor **103** during vehicle starting and vehicle running conditions based on the estimated temperature of traction motor **103** calculated. Further, the control system **100** as per another aspect of the present invention is also configured to regulate current I_{max} passed through the traction motor **103** when the vehicle is restarted after intermittently switching OFF the ignition. Particularly, said control system **100** regulates the current I_{max} passed through the traction motor **103** by controlling time interval for which current I_{max} is passed through the traction motor **103**. Steps involved in the regulation of current I_{max} through the traction motor **103** is elaborated in the following paragraphs and are supported with corresponding flowcharts.

[40] **FIG.3** illustrates steps of working of the electronic control unit **101** during vehicle starting conditions, especially for providing high initial acceleration to the vehicle. Particularly, flowchart **200** in **FIG.3** denotes the steps of operation of the electronic control unit **101** for regulating current I_{max} through the traction motor **103** during vehicle starting conditions and during vehicle running conditions.

[41] In a first step of its operation at block **201**, the electronic control unit **101** causes the vehicle to start in an EV mode/electric mode and passes a trigger signal to the power controller **104** which allows passage of current I_{max} through the traction motor **103** for providing high initial acceleration for the vehicle. However, the power controller **104** allows the passage of current I_{max} through the traction motor **103** only for a certain duration in order to prevent damage to windings of the traction motor **103**. Particularly, said electronic control unit **101** arrives at a requisite pulse duration T_PulseDuration for passage of I_{max} by performing the steps from block **202-207**. For example, in the present embodiment, the electronic control unit **101** continuously/dynamically monitors a throttle input, said throttle input being provided by at least one of the plurality of sensors **105**. The electronic control unit **101** calculates slope of throttle input, which is rate of rise of throttle, dtps_dt at block **202**. The electronic control unit **101** further estimates temperature of traction motor **103** by firstly estimating phase current of the traction motor at block **203**, with said phase current in turn being estimated using DC bus current. Further, the electronic control unit **101** estimates temperature of the traction motor **103** based pulse duration limit t1, temperature of electronic control unit **101** based pulse duration limit t9 and temperature of the power controller **104** based pulse duration limit t2 at blocks **204**, **205** respectively. Further the electronic control unit **101** receives CAN communication regarding temperature of battery unit **102** based pulse duration limit t3 at block **206**. In the present embodiment, while the electronic control unit **101** estimates t1, t9 and t2 based on the respective temperature of traction motor **103** temperature of the electronic control unit **101** and temperature of power controller **104** calculated by the electronic control unit **101**; t3 as read by the BMS and communicated to the electronic control unit **101** is directly processed by the electronic control unit **101**. Following the estimation of t1, t9, t2 and t3, the

electronic control unit **101** arrives at the requisite pulse duration T_PulseDuration value by choosing a minimum pulse duration limit value from the estimated the pulse duration limit values t1, t9, t2 and t3, at block **207**. By selecting the minimum pulse duration limit value from the estimated pulse duration limit values as the requisite pulse duration T_PulseDuration, it is ensured that the duration for which current I_{max} is passed through the traction motor **103** is limited taking into consideration the temperature of the traction motor **103**, of the battery unit **102** and that of the electronic control unit **101** itself, and thereby taking care to ensure that none of the components of the control system **100** are subjected to damage due to passage of high current.

[42] After arriving at the requisite pulse duration T_PulseDuration for the passage of current I_{max} at block **207**, the electronic control unit **101** also checks whether the conditions at which vehicle is being ridden demands the passage of current I_{max}. For example, at block **208** the electronic control unit **101** checks whether a measured slope of throttle input, which is rate of rise of throttle, dtps_dt is greater than a threshold slope of throttle input or threshold input value of rate of rise of throttle, dtps_dt_TH. If the measured rate of rise of throttle dtps_dt is greater than a threshold input value of rate of rise of throttle dtps_dt_TH the electronic control unit **101** further checks for vehicle speed at block **209**. If a measured vehicle speed is less than a threshold vehicle speed, then electronic control unit **101** sends a trigger signal to the power controller **104** which allows passage of current I_{max}. In other words, whenever there is a need for more power, especially when the rider is giving throttle at low vehicle speed, the electronic control unit **101** sends a trigger signal to the power controller **104** which dynamically allows passage of current I_{max} through the traction motor **103** for requisite duration T_PulseDuration at block **210**, said T_PulseDuration being calculated as per the steps from **204**-**207**. The throttle value, vehicle speed and temperature of each component of the control system **100** are received by the electronic control unit **101** from the plurality of sensors **105**.

[43] Further, at block **211** the electronic control unit **101** also checks if measured duration for which I_{max} is circulated through the traction motor **103** has exceeded the requisite pulse duration T_PulseDuration. If the measured duration (in seconds) exceeds the requisite T_PulseDuration then the electronic control unit **101** sends a trigger signal to the power controller **104** which stops the passage of current I_{max} and causes passage of nominal current, $I_{nom,}$ through the traction motor **103** at block **212**. However, if the measured duration for which current I_{max} passed through the traction motor **103** has not exceeded the requisite pulse duration T_PulseDuration, then the electronic control unit **101** checks for the measured vehicle speed at block **213**. If the measured vehicle speed is greater than the threshold vehicle speed, then the electronic control unit **101** sends a trigger signal to the power controller **104** which allows nominal current to be passed through the traction motor **103** rather than current I_{max}. Thus, the control system **100** as per the present invention, aids in regulating the passage of current I_{max} through the traction motor **103** under different riding conditions while taking into account temperature of the traction motor **103**, temperature of the battery unit **102**, the temperature of the power controller **104** and that of the electronic control unit **101** simultaneously.

[44] Further, as per another aspect of the present invention, the control system **100** is also configured to communicate and store the estimated temperature of traction motor **103** for use during vehicle restart conditions. Particularly, said electronic control unit **101** of the control system **100** is configured to communicate the estimated temperature of traction motor **103** to the BMS of the battery unit **102** under certain conditions. The flowchart **300** in **FIG.4** denotes the steps of working of the electronic control unit **101** in communicating the estimated temperature of traction motor **103** as calculated by it to the BMS of the battery unit **102**. For example, as may be seen in **FIG.4**, in a running condition of the vehicle, the electronic control unit **101** dynamically calculates the estimated temperature of traction motor **103** as described in the preceding paragraphs. At block **301**, the electronic control unit **101** checks whether the Ignition is switched ON, and in a condition where the Ignition switch is switched OFF, the electronic control unit **101** immediately communicates via Controller Area Network (hereinafter CAN) communication the estimated temperature of traction motor **103** to the BMS of the battery unit **102** at block **302** which is capable of storing said estimated temperature of the traction motor **103** for further use during vehicle restarting conditions. In all other conditions, the electronic control unit **101** continues to calculate the estimated temperature of the traction motor **103** and the corresponding requisite pulse duration T_PulseDuration.

[45] As per one more aspect of the present invention, the control system **100** is also configured to calculate the estimated temperature of traction motor **103** for vehicle restart condition. Flowchart **400** denoted in **FIG.5** denotes the steps involved in the working of the BMS of the battery unit **102**. In a condition where the ignition switch of the vehicle is switched OFF and where the BMS of the battery unit **102** receives the estimated temperature of traction motor **103** previously calculated and communicated by the electronic control unit **101**, the BMS at block **401** of the flowchart checks whether the estimated temperature of traction motor **103** received is greater than a predetermined threshold temperature. If the estimated temperature of traction motor **103** received is greater than the predetermined threshold temperature, the BMS estimates a reduction in temperature to be achieved for the traction motor **103** at block **402**, so that when the ignition switch of the vehicle is turned ON after being intermittently switched OFF, said reduction in temperature to be achieved is communicated to the electronic control unit **101** at block **403**. The electronic control unit **101** on receiving communication regarding the reduction in temperature to be achieved for the traction motor **103** calculates the requisite restart pulse duration T_RestartPulseDuration for which current I_{max} may be passed through the traction motor **103**.

[46] For example, **FIG.6** illustrates a flowchart **500** depicting a method of operation of the electronic control unit **101** for regulating passage of current I_{max} during vehicle restart conditions. Once the ignition switch is turned ON after being intermittently switched OFF, the vehicle is restarted in the EV mode by the electronic control unit **101**. Further, once the vehicle is restarted, the electronic control unit **101** receives input regarding the reduction in temperature to be achieved for the traction motor **103** from the BMS at block **501**. Further, based on the input received regarding the reduction in temperature to be achieved, the electronic control unit **101** estimates temperature of traction motor **103** based restart pulse duration t1R at block **502**. The electronic control unit **101** also estimates the temperature of the power controller **104** based restart pulse duration limit t2R and temperature of the electronic control unit **101** based restart pulse duration limit t9R and processes the temperature of battery unit **102** based restart pulse duration limit t3R received from the BMS at blocks **503** and **504** respectively. Furthermore, the electronic control unit **101** calculates requisite restart pulse duration T_PulseDuration by choosing a minimum restart pulse duration limit value from the estimated restart pulse duration limit values t1R, t9R, t2R and t3R, at block **505.** Thereafter, at block **506** the power controller **104** allows passage of current I_{max} on receiving the trigger signal from the electronic control unit **101** for the requisite restart pulse duration T_PulseDuration through the traction motor **103**, thereby ensuring that flow of current I_{max} through the traction motor **103** is limited while the traction motor **103** is still hot during vehicle restart conditions.

[47] As is apparent from the present teaching, the control system as per the present invention aids in regulating passage of current through the traction motor in all conditions including vehicle starting and restarting conditions without compromising on initial acceleration provided to the vehicle, taking into consideration different parameters such as temperature of traction motor and temperature of battery unit without involving the use of additional temperature sensors or thermocouples for estimating temperature of traction motor.

We claim:

1. A control system (**100**) for a vehicle, said control system (**100**) comprising a battery management system including a battery unit (**102**), an electronic control unit (**101**) communicatively connected to said battery management system, a power controller (**104**) communicatively connected to the electronic control unit (**101**), a traction motor (**103**) operatively connected to the power controller (**104**) and a plurality of sensors (**105**) communicatively connected to the electronic control unit (**101**), said plurality of sensors (**105**) being disposed on one or more locations on the vehicle, wherein the electronic control unit (**101**) is adapted to receive at least one data signal from said plurality of sensors (**105**), the electronic control unit (**101**) is configured to calculate a T_PulseDuration based on said at least one data signal, said T_PulseDuration being a requisite pulse duration for allowing passage of I_{max}, and I_{max} being a magnitude of current greater than a predetermined value.

2. The control system (**100**) as claimed in claim 1, wherein said at least one data signal includes one or more of temperature of the battery unit (**102**), temperature of the electronic control unit (**101**), temperature of the power controller (**104**), temperature of the traction motor (**103**), throttle input, and vehicle speed.

3. The control system (**100**) as claimed in claim 1 or claim 2, wherein the temperature of the traction motor (**103**) is estimated by the electronic control unit (**101**) based on phase current of the traction motor (**103**), and wherein the phase current of the traction motor (**103**) is calculated from DC bus current of the traction motor (**103**).

4. The control system (**100**) as claimed in claim 1 or claim 2, wherein the temperature of the battery is measured by a temperature sensor of said plurality of sensors (**105**), said temperature sensor being disposed within the battery unit (**102**), and wherein the pulse duration estimation limit for the battery unit (**102**) is measured by the battery management system.

5. The control system (**100**) as claimed in claim 1, wherein the electronic control unit (**101**) transmits a trigger signal based on said T_PulseDuration to said power controller (**104**), wherein said power controller (**104**) on receiving the trigger signal allows flow of the I_{max} to the traction motor (**103**), said I_{max} being allowed to flow for the requisite pulse duration defined by said T_PulseDuration.

6. The control system (**100**) as claimed in claim 1 or claim 5, wherein the T_PulseDuration is a minimum pulse duration limit value of a set of values recorded for pulse duration limit estimation for each of the battery unit (**102**), the electronic control unit (**101**), the power controller (**104**) and the traction motor (**103**) of the control system (**100**).

7. The control system (**100**) as claimed in claim 1 or claim 5, wherein the flow of I_{max} is allowed by the power controller (**104**) on satisfaction of at least one event of a set of events, said set of events including an event of rate of rise of throttle being greater than a threshold input value of rate of rise of throttle and an event of a measured vehicle speed being lesser than a threshold vehicle speed.

8. The control system (**100**) as claimed in claim 1 or claim 5, wherein the power controller (**104**) passes a reference current I_{nom} in the event of the measured vehicle speed being greater than the threshold vehicle speed, the reference current I_{nom} being a nominal current.

9. The control system (**100**) as claimed in claim 1 or claim 2, wherein the battery management system is configured to store an estimated temperature of the traction motor (**103**) at an instant of turning off an ignition switch.

10. The control system (**100**) as claimed in claim 1 or claim 9, wherein the battery management system is operable to estimate reduction of the estimated temperature of the traction motor (**103**) to be achieved, wherein said reduction of the estimated temperature of the traction motor (**103**) is calculated in an event of the value of the estimated temperature of the traction motor (**103**) at the instant of turning off an ignition switch being greater than a predetermined threshold temperature.

11. The control system (**100**) as claimed in claim 1, wherein the T_PulseDuration is based on pulse duration limit estimation for the battery unit (**102**), the electronic control unit (**101**), the power controller (**104**) and the traction motor (**103**).

12. The control system (**100**) as claimed in claim 1 or claim 11, wherein the pulse duration limit estimation for each of the battery unit (**102**), the electronic control unit (**101**), the power controller (**104**) and the traction motor (**103**) is based on said at least one data signal from the plurality of sensors (**105**).

13. A control method to regulate passage of I_{max} through a traction motor (**103**) of a vehicle, wherein said I_{max} being a magnitude of current greater than a predetermined value, and wherein said control method comprises steps of:

allowing initial passage of said I_{max} through the traction motor (**103**) for a predetermined duration, wherein said initial passage of said I_{max} is on starting of said vehicle;

sensing at least one data by a plurality of sensors (**105**) disposed on one or more locations on the vehicle, wherein said plurality of sensors (**105**) are communicatively connected to an electronic control unit (**101**);

receiving of said at least one data by the electronic control unit (**101**),

estimating pulse duration limit for each of a battery unit (**102**), the electronic control unit (**101**), a power controller (**104**) and the traction motor (**103**) based on said at least one data signal from the plurality of sensors (**105**), wherein said at least one data signal includes temperature of the battery unit (**102**), temperature of the electronic control unit (**101**), temperature of the power controller (**104**), temperature of the traction motor (**103**), throttle input, and vehicle speed;

calculating a T_PulseDuration by the electronic control unit (**101**), said T_PulseDuration being a requisite pulse duration for allowing passage of I_{max}, wherein the T_PulseDuration is a minimum pulse duration limit value of a set of values recorded for the pulse duration limit estimated for each of the battery unit (**102**), the electronic control unit (**101**), the power controller (**104**) and the traction motor (**103**);

sending a trigger signal by the electronic control unit (**101**) to the power controller (**104**), said trigger signal being based on said T_PulseDuration;

allowing passage of a current by the power controller (**104**) on receiving said trigger signal from the electronic control unit (**101**), the current being passed to the traction motor (**103**), the magnitude of the current being calculated based on satisfaction of a set of events, wherein the magnitude of the current is I_{nom} in the event of the measured vehicle speed being greater than a threshold vehicle speed, said I_{nom}

being a nominal current, and wherein the magnitude of the current is said I_{max} in the event of the measured vehicle speed being lesser than a threshold value, and wherein the a measured duration of passage of said I_{max} is lesser than said T_PulseDuration, said T_PulseDuration being a requisite pulse duration for allowing passage of said I_{max}, and wherein the magnitude of the current is reduced to said I_{nom} in the event of the duration of passage of I_{max} is greater than said T_PulseDuration, wherein magnitude of said I_{max} is greater than the magnitude of said I_{nom},.

14. The control method as claimed in claim 13, wherein said at least one data signal includes the temperature of the traction motor (**103**), said temperature of the traction motor (**103**) being estimated by estimating DC bus current and estimating phase current of the traction motor (**103**).

15. The control method as claimed in claim 13, wherein said at least one data signal includes the temperature of the battery unit (**102**), wherein the pulse duration limit based on the temperature of the battery unit (**102**) is transmitted to the electronic control unit (**101**) through CAN communication.

16. The control method as claimed in claim 13, wherein said set of events, in the step of allowing passage of the current to the traction motor (**103**), includes an event of a measured rate of rise of throttle being greater than a threshold input value of rate of rise of throttle, wherein the magnitude of the current is I_{max} in the event of the measured rate of rise of throttle being greater than said threshold input value of rate of rise of throttle.

17. The control method as claimed in claim 13, wherein the step of calculating the T_PulseDuration includes calculating a T_RestartPulseDuration for which I_{max} is passed through the traction motor (**103**), said T_RestartPulseDuration being a requisite restart pulse duration, and wherein T_RestartPulseDuration is based on a reduction in temperature of the traction motor (**103**) to be achieved.

18. The control method as claimed in claim 13 or claim 17, wherein said reduction in the temperature of the traction motor (**103**) to be achieved is communicated by a battery management system to the electronic control unit (**101**), said battery management

system being adapted to communicate in the event of the estimated temperature of the traction motor (**103**) being greater than a predetermined threshold temperature.

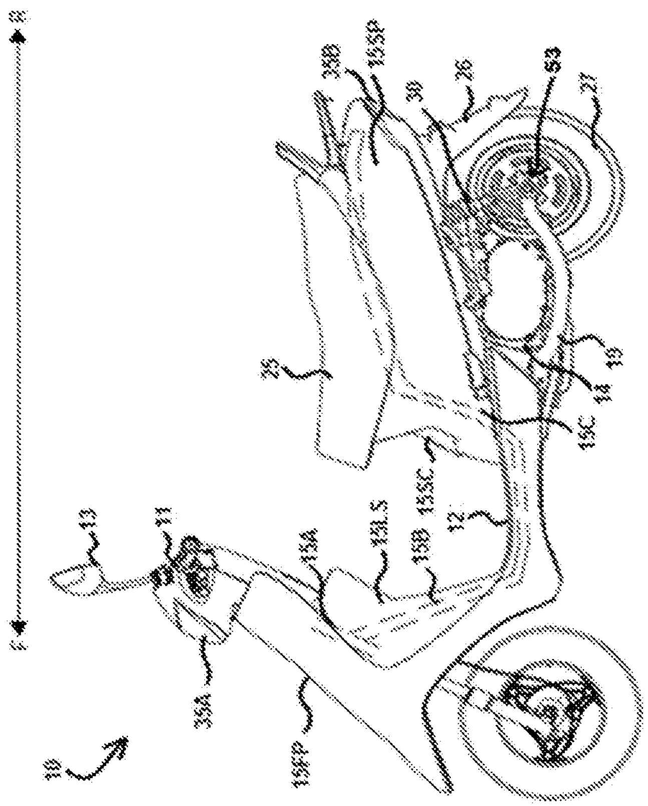
F
R
10
35A
15FP
13
11
15A
15LS
15B
15SC
12
25
15C
14
15
35B
15SP
30
26
63
27

Fig.1

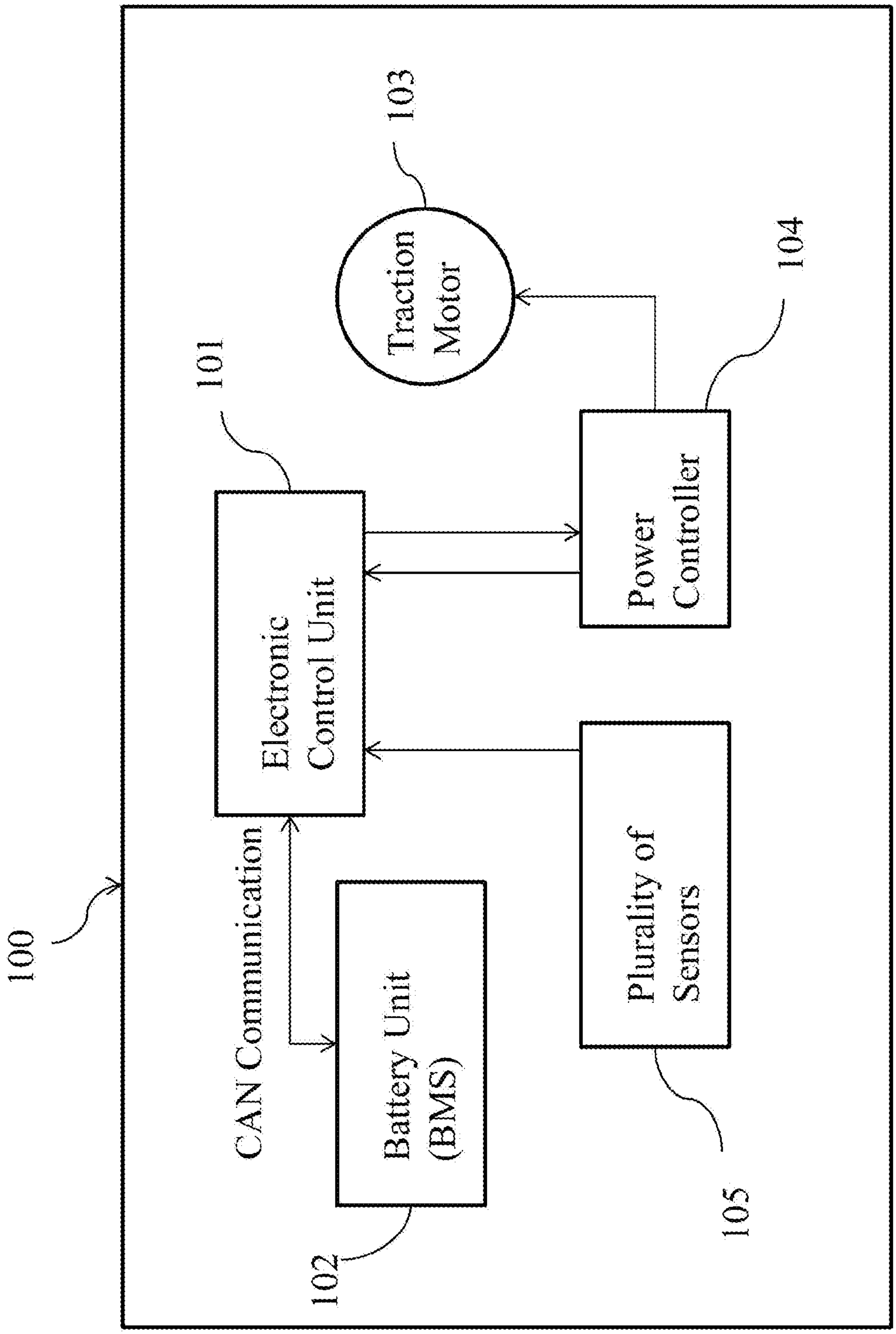
100
101
Electronic Control Unit
103
Traction Motor
104
Power Controller
CAN Communication
Battery Unit (BMS)
102
Plurality of Sensors
105

Fig.2

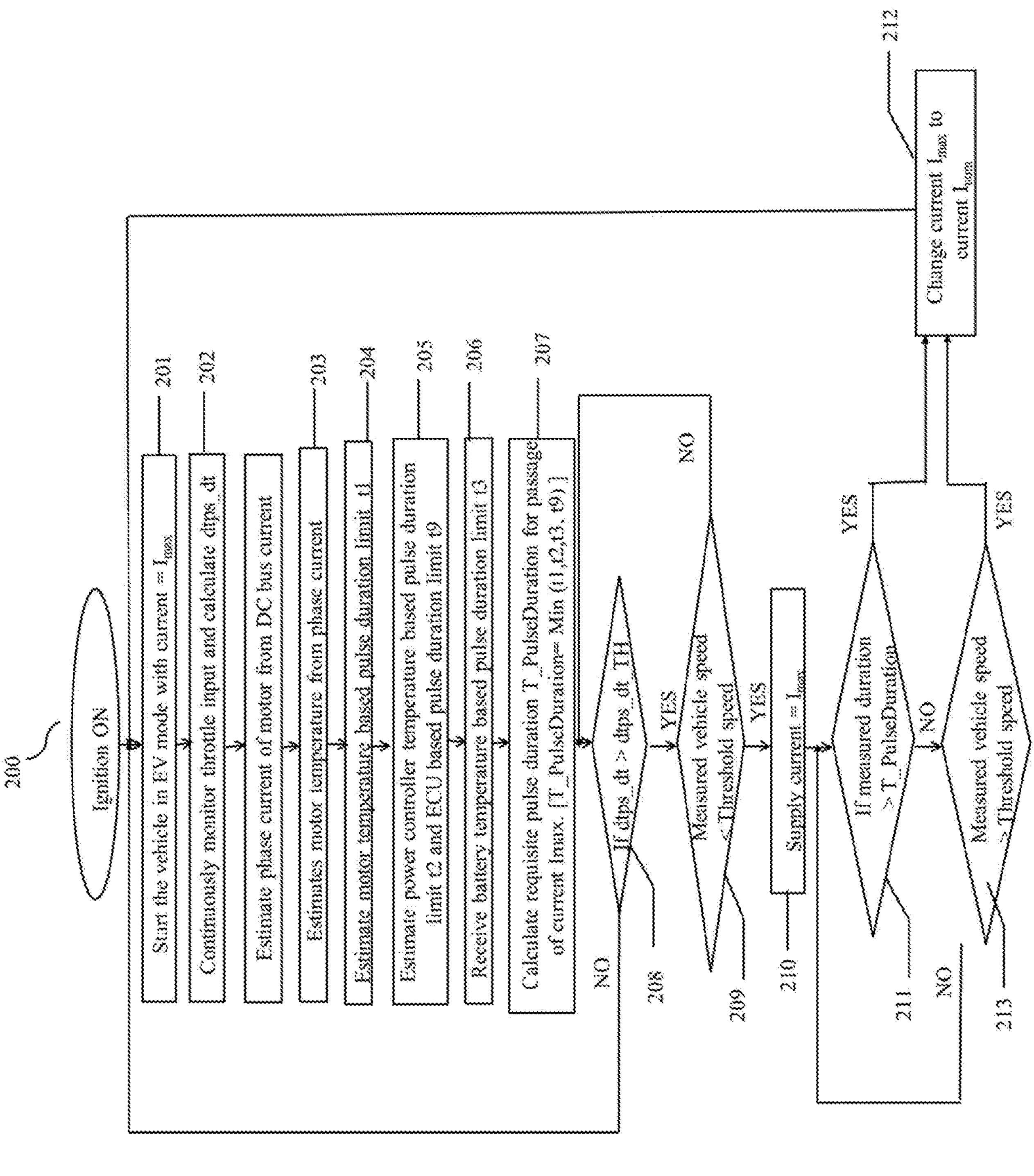
200
Ignition ON
Start the vehicle in EV mode with current = I_{max}
201
Continuously monitor throttle input and calculate dtps_dt
202
Estimate phase current of motor from DC bus current
203
Estimates motor temperature from phase current
204
Estimate motor temperature based pulse duration limit t1
205
Estimate power controller temperature based pulse duration limit t2 and ECU based pulse duration limit t9
206
Receive battery temperature based pulse duration limit t3
207
Calculate requisite pulse duration T_PulseDuration for passage of current Imax. [T_PulseDuration= Min (t1,t2,t3, t9)]
If dtps_dt > dtps_dt_TH
208
NO
YES
Measured vehicle speed < Threshold speed
209
NO
YES
Supply current = I_{max}
210
If measured duration > T_PulseDuration
211
YES
NO
Measured vehicle speed > Threshold speed
213
YES
NO
Change current I_{max} to current I_{nom}
212

Fig.3

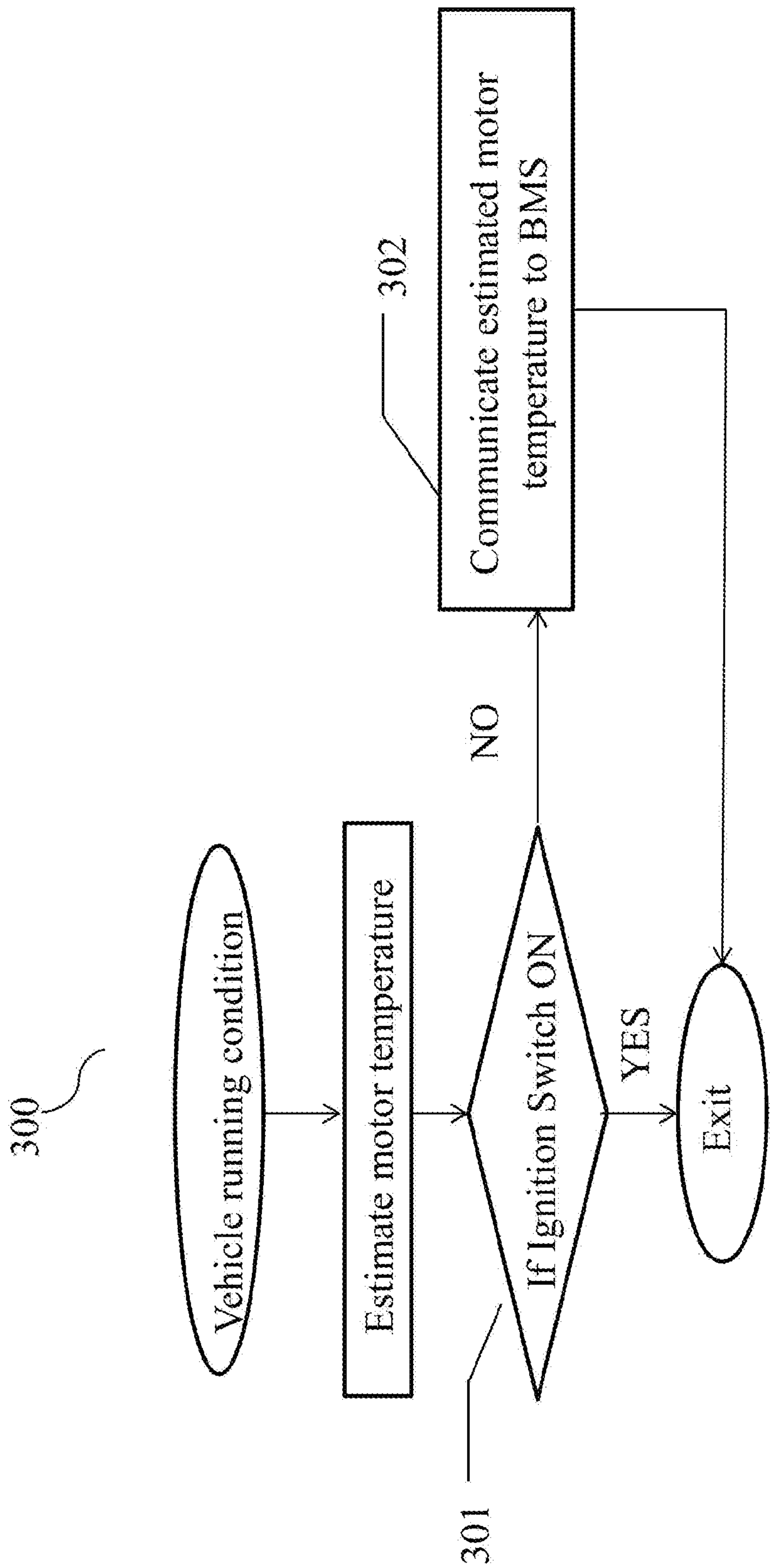
300
Vehicle running condition
Estimate motor temperature
If Ignition Switch ON
301
NO
YES
Exit
Communicate estimated motor temperature to BMS
302

Fig.4

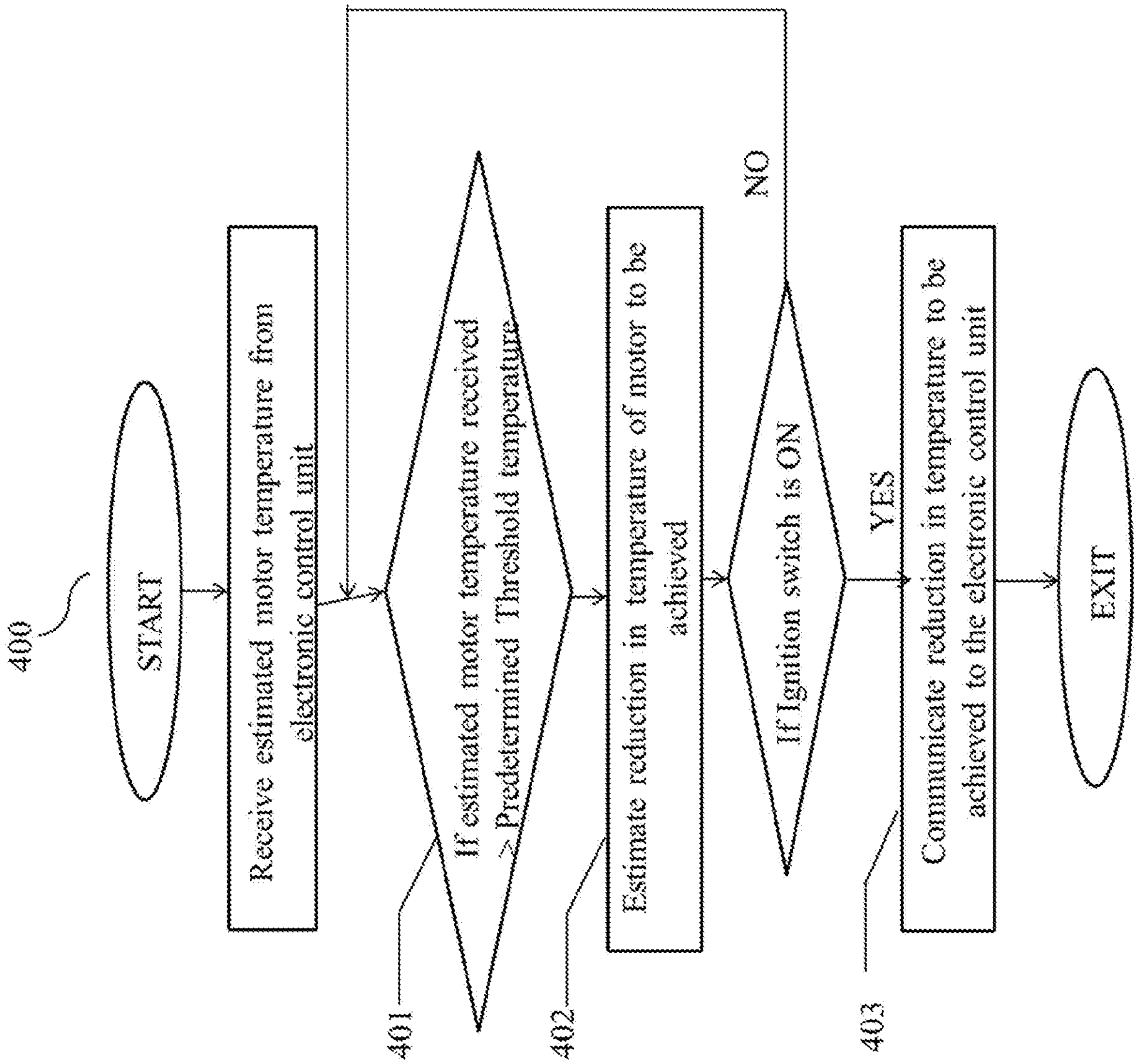
400
START
Receive estimated motor temperature from electronic control unit
401
If estimated motor temperature received > Predetermined Threshold temperature
402
Estimate reduction in temperature of motor to be achieved
If Ignition switch is ON
NO
YES
403
Communicate reduction in temperature to be achieved to the electronic control unit
EXIT

Fig. 5

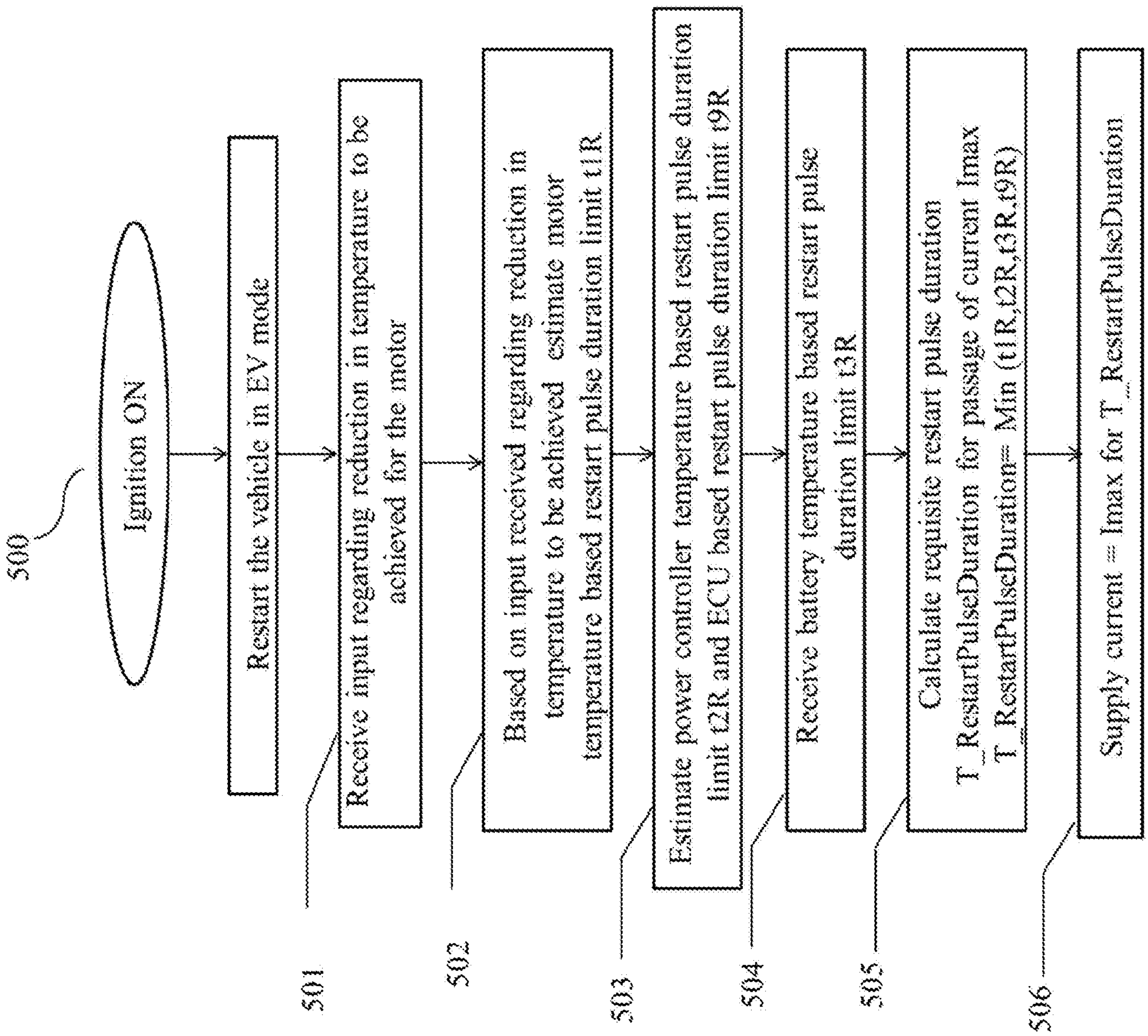
500
Ignition ON
Restart the vehicle in EV mode
Receive input regarding reduction in temperature to be achieved for the motor
Based on input received regarding reduction in temperature to be achieved estimate motor temperature based restart pulse duration limit t1R
Estimate power controller temperature based restart pulse duration limit t2R and ECU based restart pulse duration limit t9R
Receive battery temperature based restart pulse duration limit t3R
Calculate requisite restart pulse duration T_RestartPulseDuration for passage of current Imax
T_RestartPulseDuration= Min (t1R,t2R,t3R,t9R)
Supply current = Imax for T_RestartPulseDuration
501
502
503
504
505
506

Fig.6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2017/058095

A. CLASSIFICATION OF SUBJECT MATTER
B60L5/00,B60W20/00 Version=2018.01

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B60L, B60W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Databases: TotalPatent One, IPO Internal database
Keywords: Control system, Electric vehicle

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN103448570A (BOSCH AUTOMOTIVE COMPONENTS (SUZHOU) CO. LTD.), 18 December 2013 (18-12-2013); Claims 1, 4-7; Paragraphs [0005]-[0006], [0018], [0020]-[0023], [0032]-[0033], [0036]-[0038],	1-8, 11-18
Y	[0040]-[0050]; [0058]-[0068]; Figures 3-7; Abstract	9-10
Y	US4721894A (MOTORS LIQUIDATION CO.), 26 January 1988 (26-01-1988); Claims 8, 10; Column 1, lines 13-14; Column 1, line 58 to Column 2, line 2; Column 3, lines 60-64; Figures 1-2	9-10
A	KR1020150108137A (LSIS CO. LTD.), 25 September 2015 (25-09-2015); Whole document	1-18

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26-04-2018	26-04-2018
Name and mailing address of the ISA/ Indian Patent Office Plot No.32, Sector 14,Dwarka,New Delhi-110075 Facsimile No.	Authorized officer Md. Tanveer ur Rahman Telephone No. +91-1125300200

International application No.
PCT/IB2017/058095

Citation	Pub.Date	Family	Pub.Date
CN 103448570 A	18-12-2013	CN 103448570 B	13-04-2016
KR 1020150108137 A	25-09-2015	CN 104924919 A	23-09-2015
		CN 104924919 B	23-02-2018
		EP 2921337 A2	23-09-2015
		EP 2921337 A3	30-09-2015
		JP 6034428 B2	30-11-2016
		JP 2015177741 A	05-10-2015
		US 9559626 B2	31-01-2017
		US 2015263662 A1	17-09-2015
US 4721894 A	26-01-1988	DE 3818722 A1	05-01-1989
		DE 3818722 C2	07-06-1990
		JP S63316652 A	23-12-1998
		JP H0697822 B2	30-11-1994