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(54) **ELECTRIC VEHICLE AND CONTROL METHOD THEREFOR**

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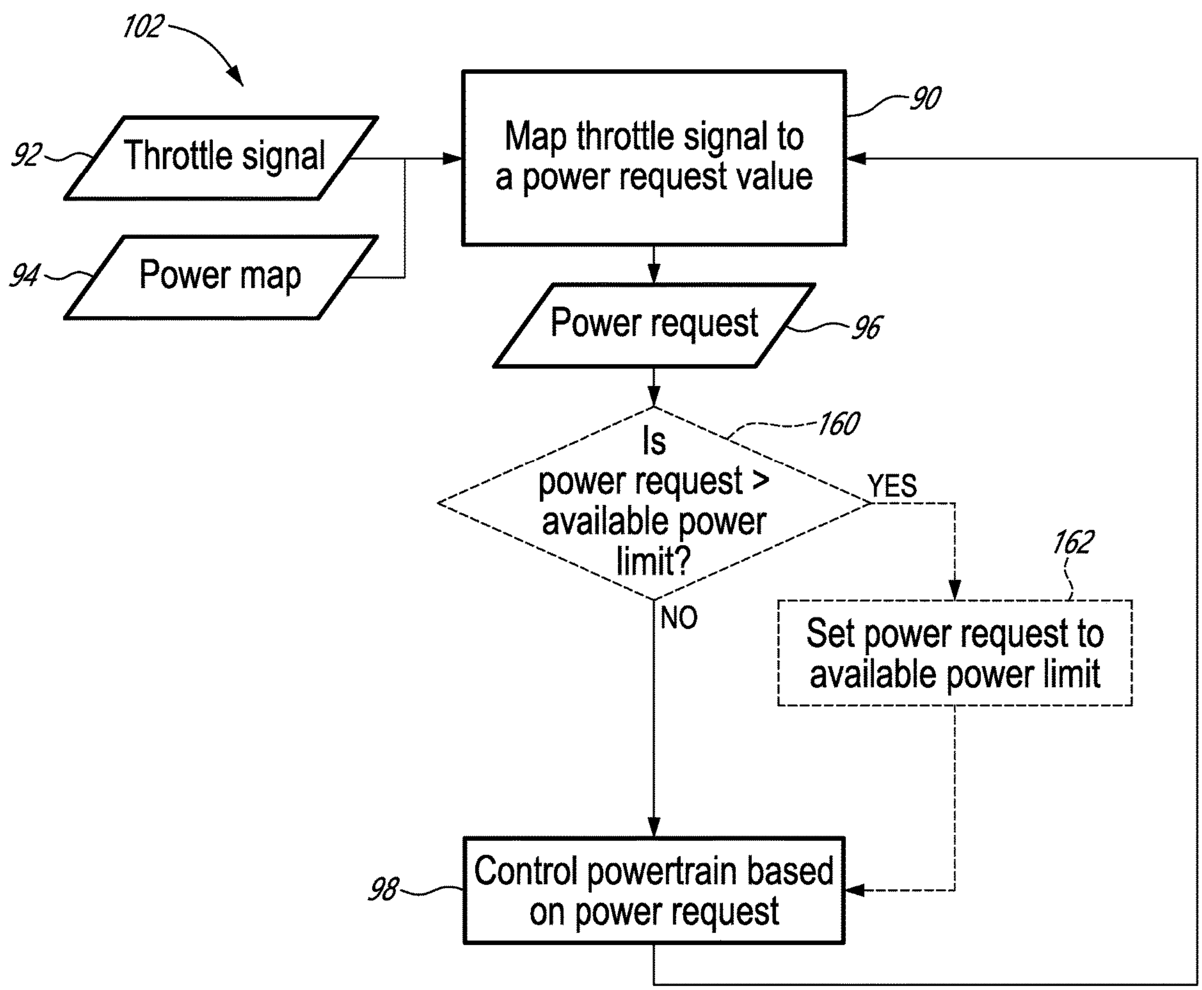
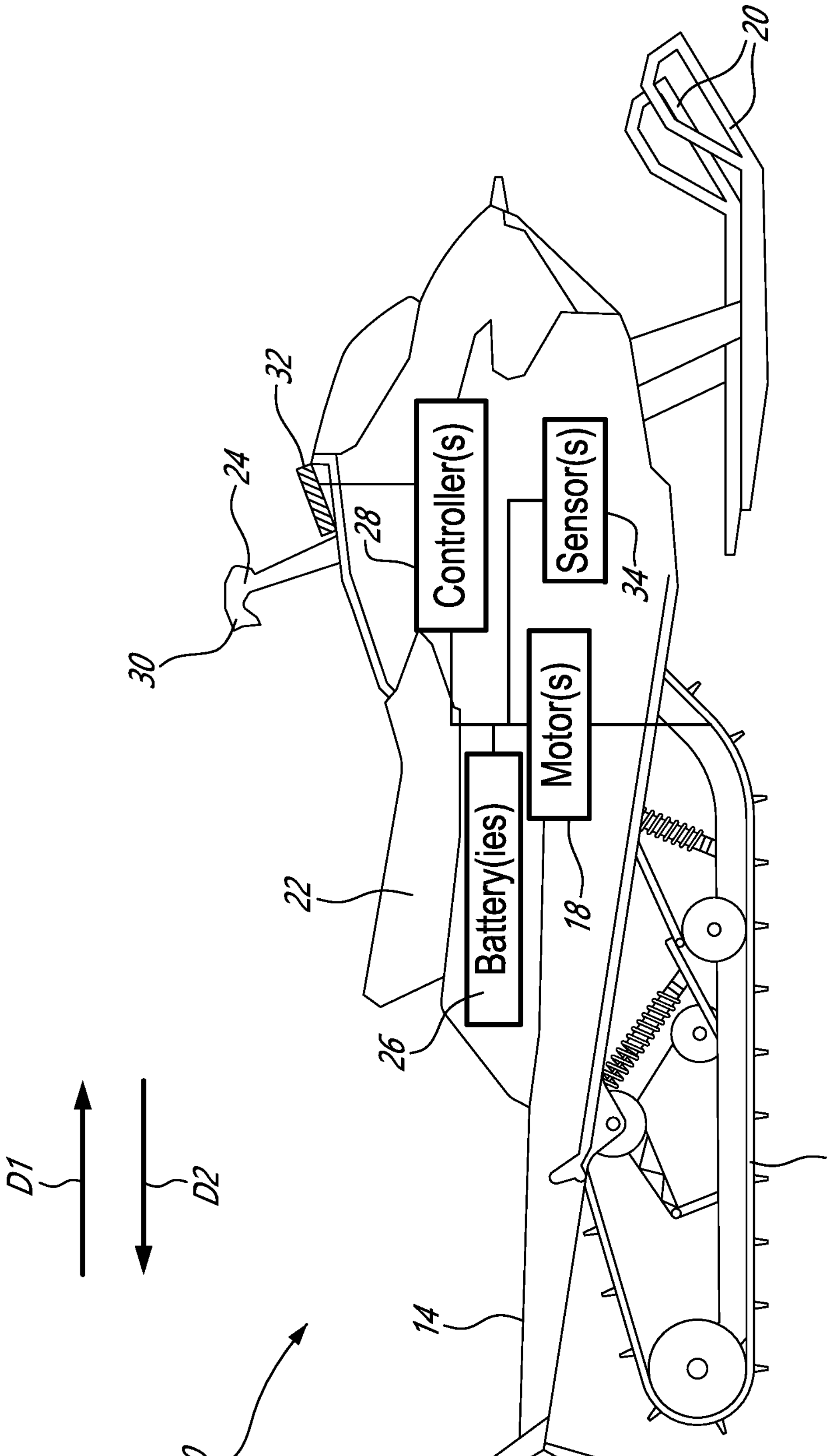
(57) **ABSTRACT**

A method of transitioning an electric snowmobile from a drive state to a reverse state comprising receiving at a controller a reverse request from a user interface of the electric snowmobile. Upon receipt of the reverse request, the controller transitions the electric snowmobile from a drive state to a reverse state when a speed signal associated with the electric snowmobile is below a predetermined speed threshold and transitions the electric snowmobile from a drive state to a reverse requested state when a speed signal associated with the electric snowmobile is above a predetermined speed threshold. In the reverse state, the controller drives the electric snowmobile in a reverse direction based on a throttle signal and in the reverse requested state, the controller does not drive operation of the electric snowmobile based on the throttle signal.





20
32
24
30
28
Controller(s)
Sensor(s)
34
Motor(s)
Battery(ies)
22
18
26
D1
D2
16
14
10

FIG. 1

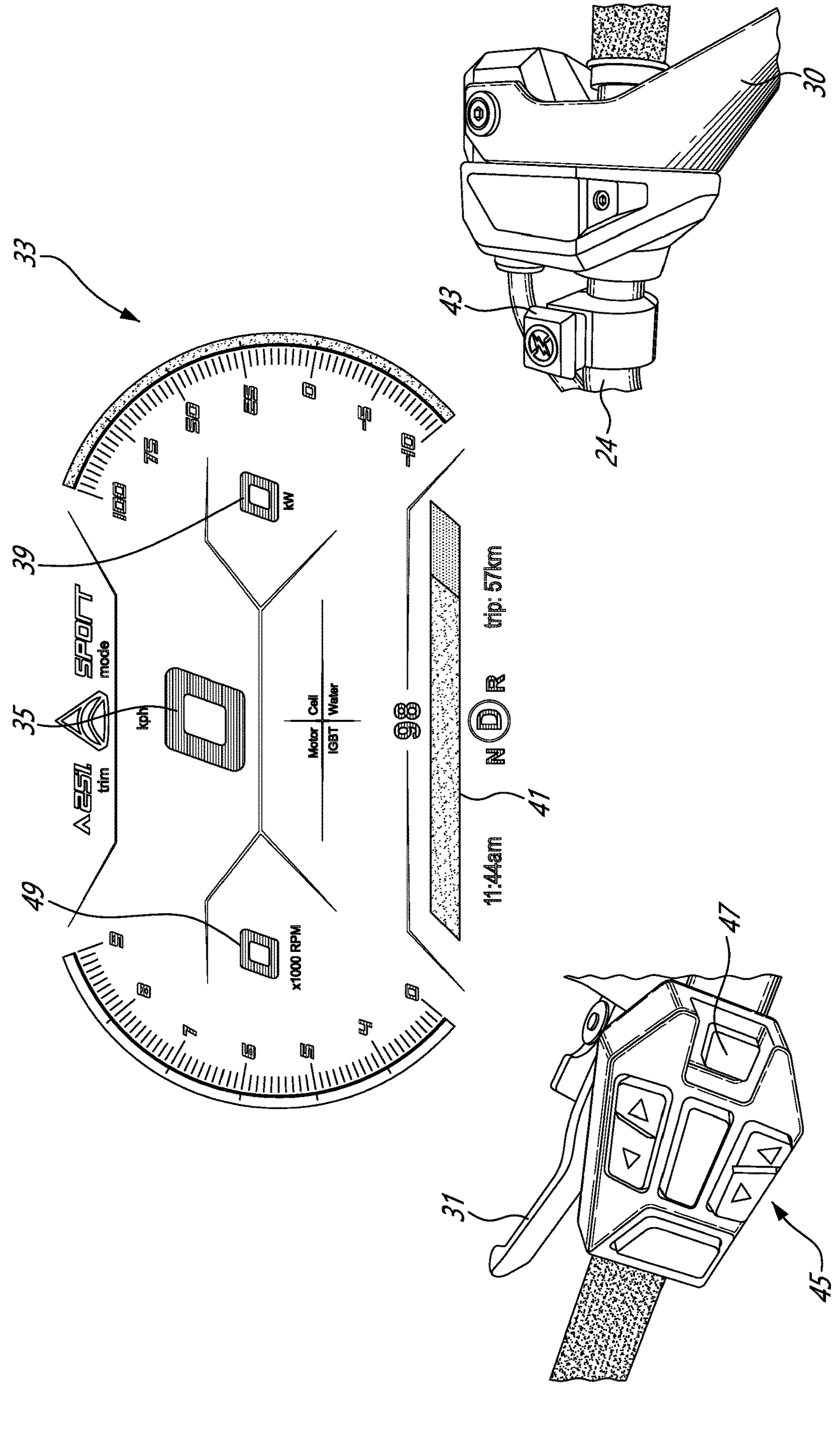

33
35
39
49
41
43
24
30
31
45
47
SPORT
mode
25L
trim
kph
kW
x1000 RPM
Motor
Cell
IGBT
Water
98
N D R
11:44am
trip: 57km

FIG-2

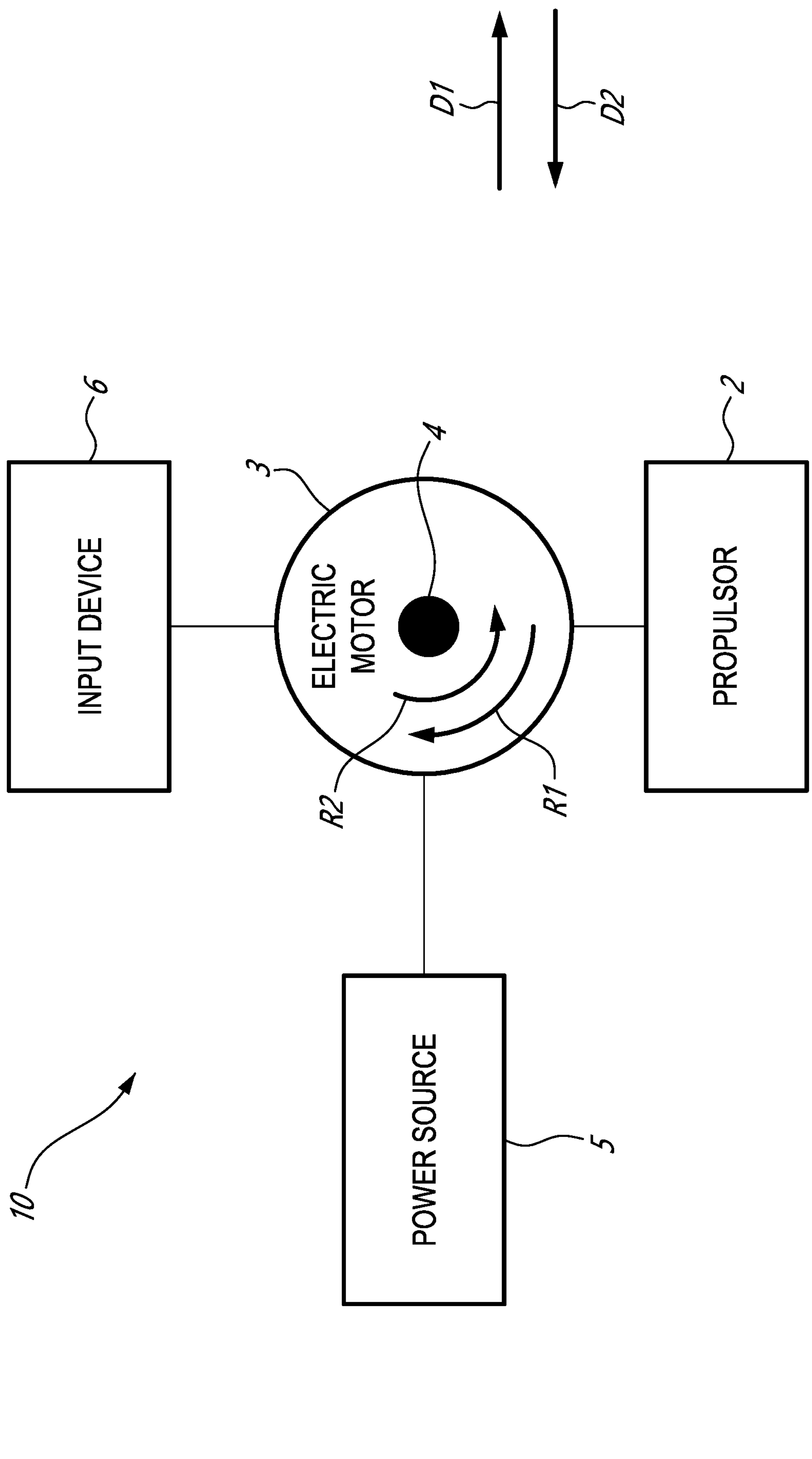

D1
D2
6
INPUT DEVICE
3
4
ELECTRIC
MOTOR
R2
R1
2
PROPULSOR
POWER SOURCE
5
10

FIG. 3

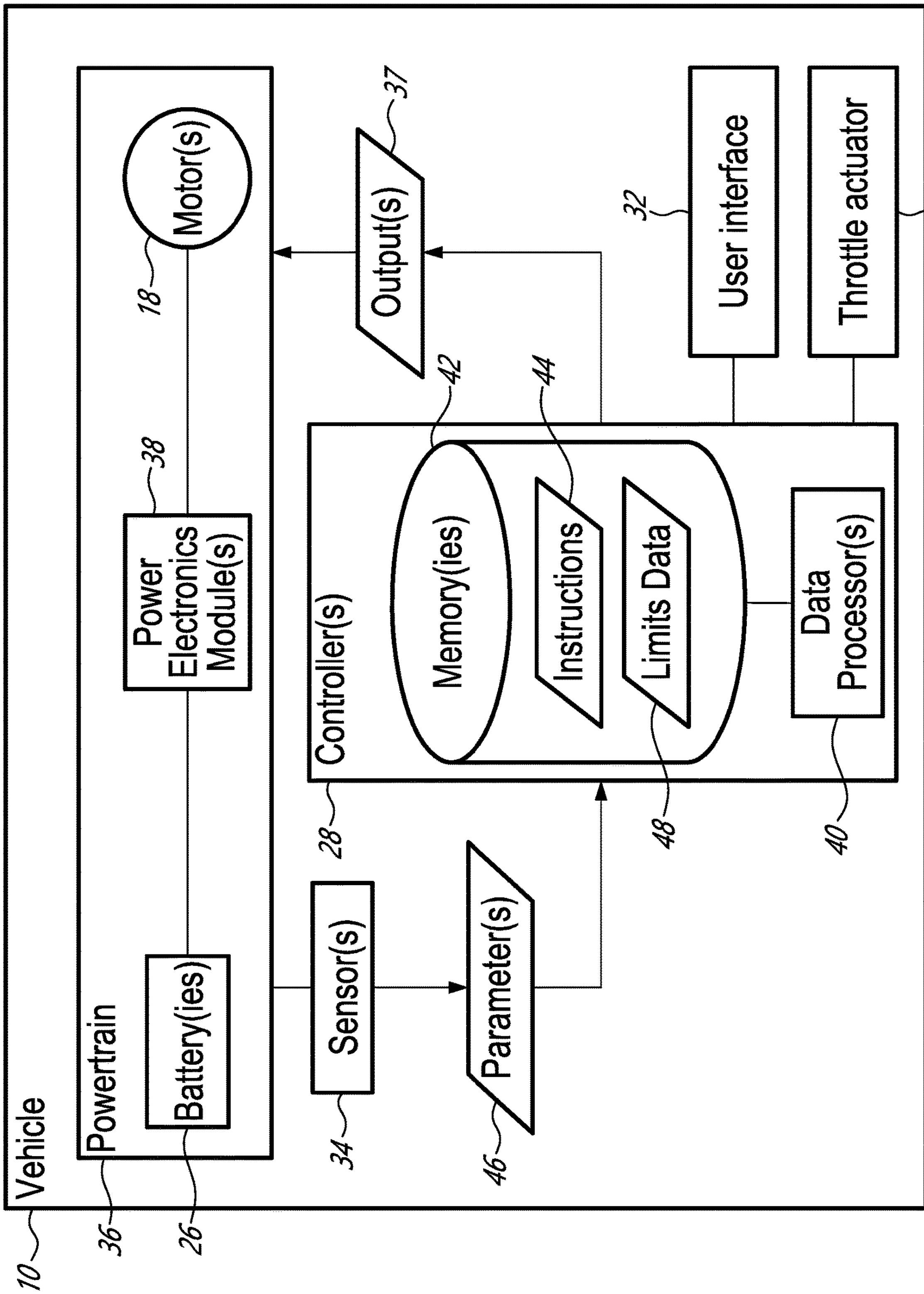

Vehicle
Powertrain
Battery(ies)
Power
Electronics
Module(s)
Motor(s)
Sensor(s)
Parameter(s)
Output(s)
Controller(s)
Memory(ies)
Instructions
Limits Data
Data
Processor(s)
User interface
Throttle actuator
10
36
26
34
46
28
48
40
18
38
37
42
44
32
30

FIG. 4

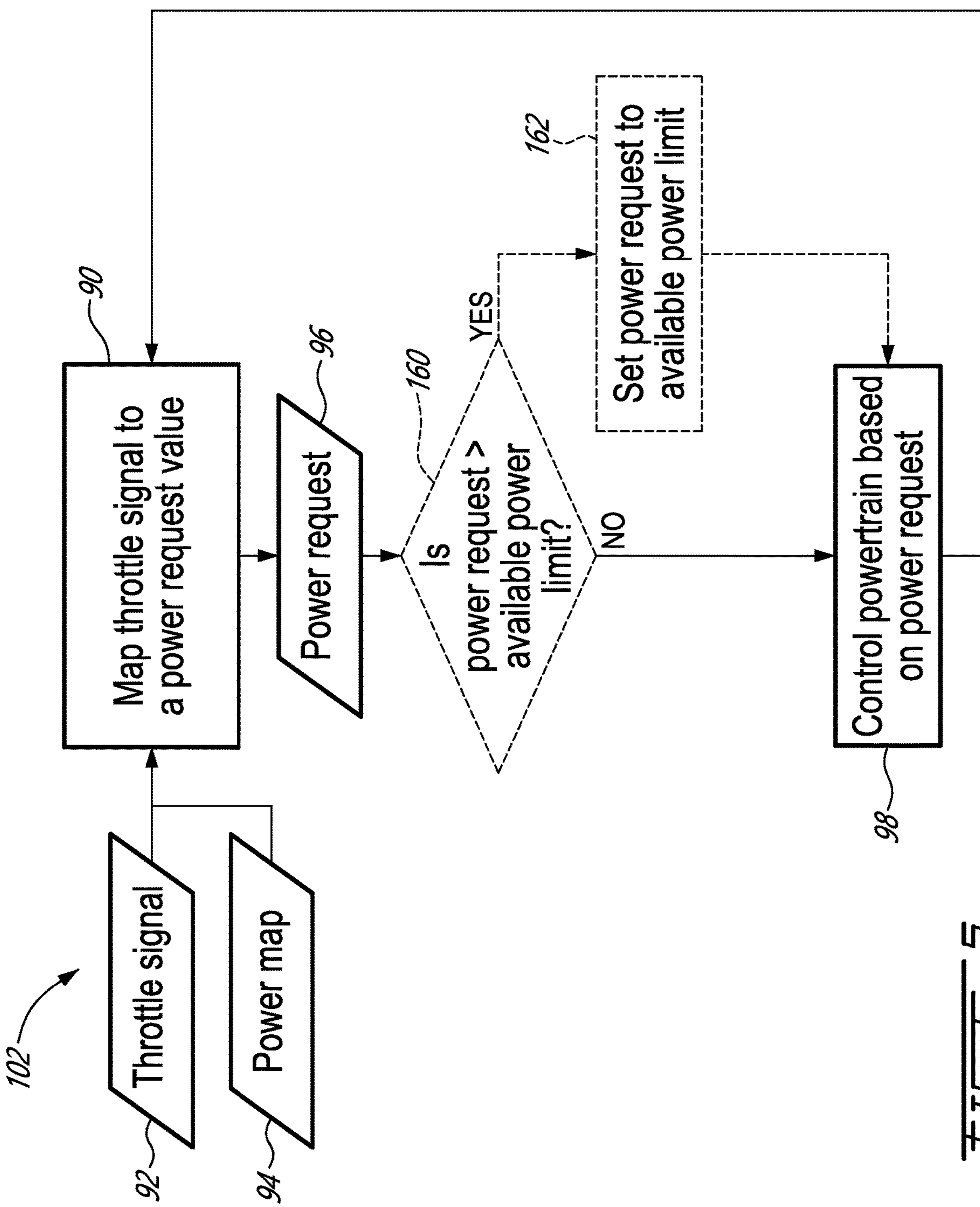

102
Throttle signal
92
Power map
94
Map throttle signal to a power request value
90
Power request
96
Is power request > available power limit?
160
YES
NO
Set power request to available power limit
162
Control powertrain based on power request
98

FIG. 5

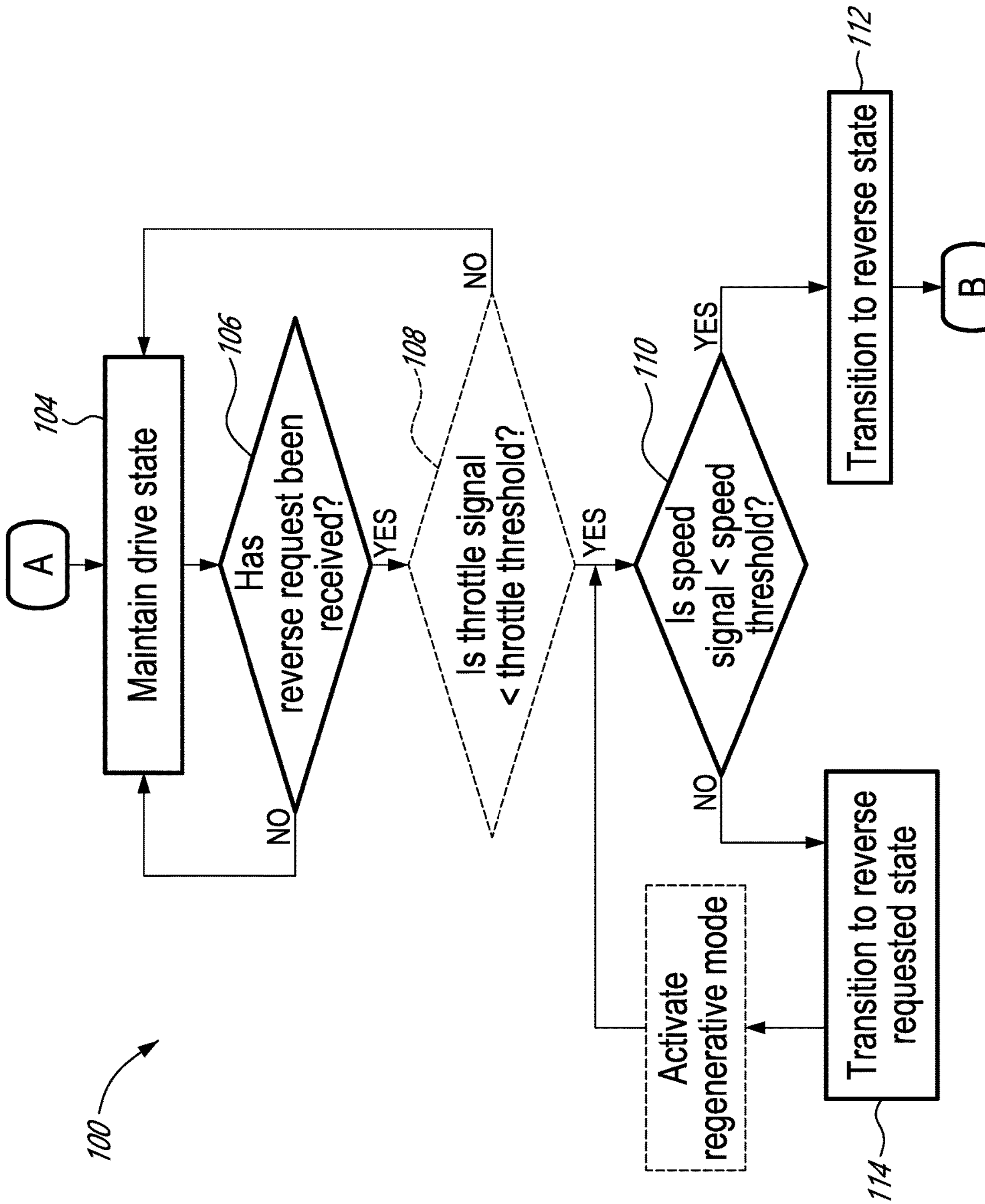

100
A
Maintain drive state
104
Has reverse request been received?
106
NO
YES
Is throttle signal < throttle threshold?
108
NO
YES
Is speed signal < speed threshold?
110
YES
NO
Transition to reverse state
112
B
Transition to reverse requested state
114
Activate regenerative mode

FIG. 6A

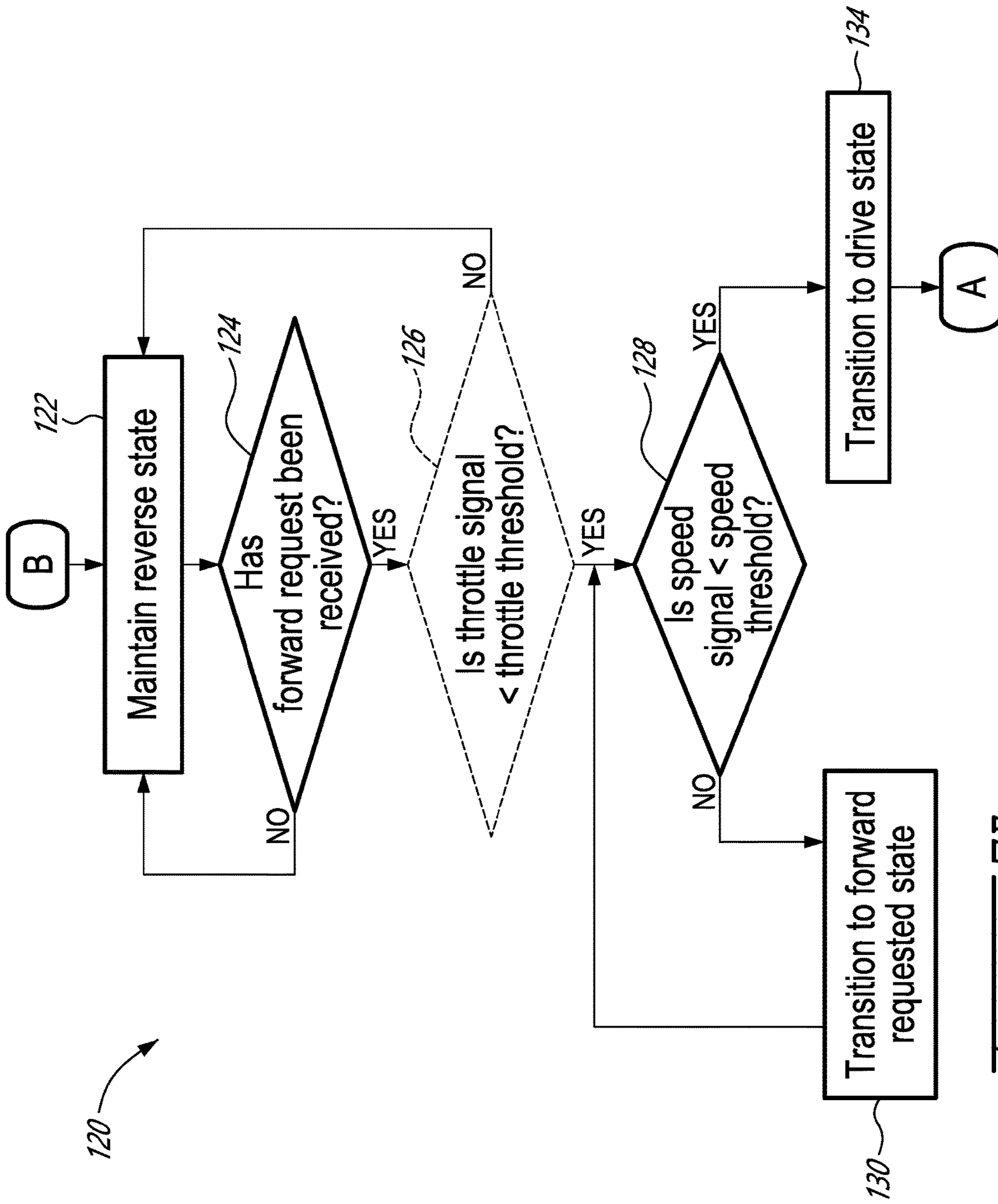

120
B
122
Maintain reverse state
124
Has forward request been received?
NO
YES
126
Is throttle signal < throttle threshold?
NO
YES
128
Is speed signal < speed threshold?
YES
NO
134
Transition to drive state
A
130
Transition to forward requested state

FIG. 6B

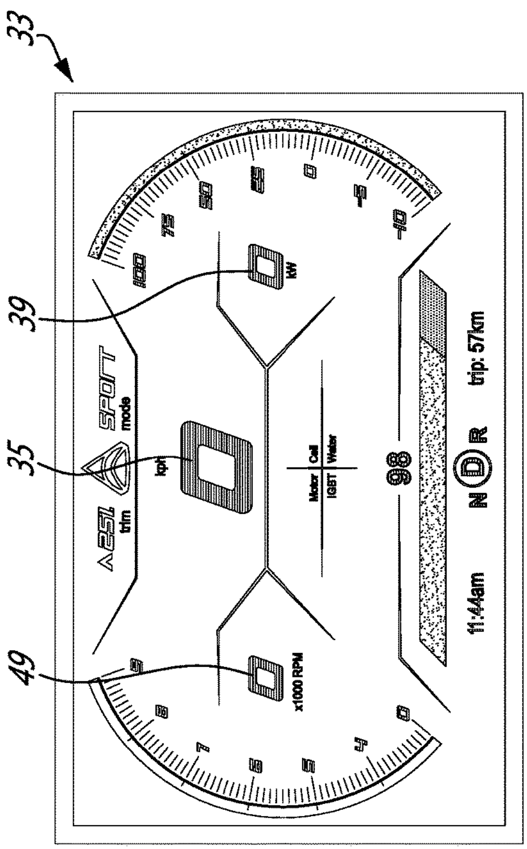


FIG. 7A

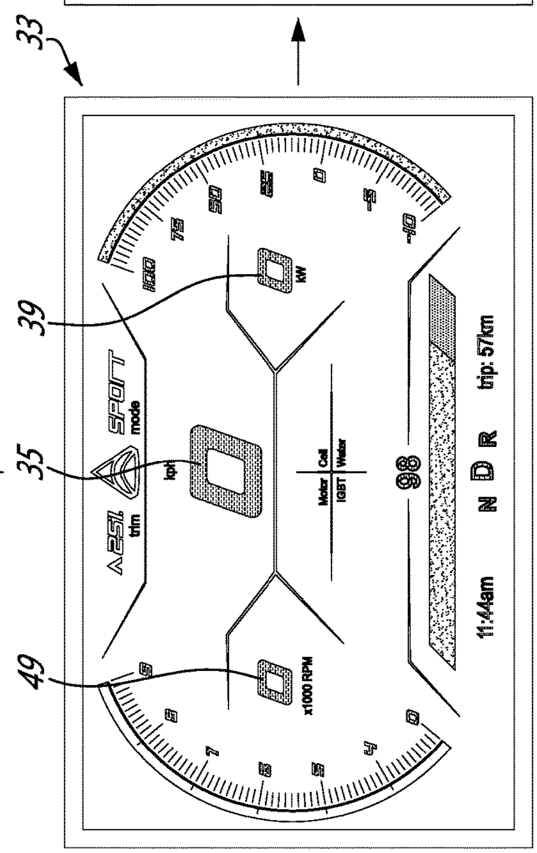


FIG. 7B

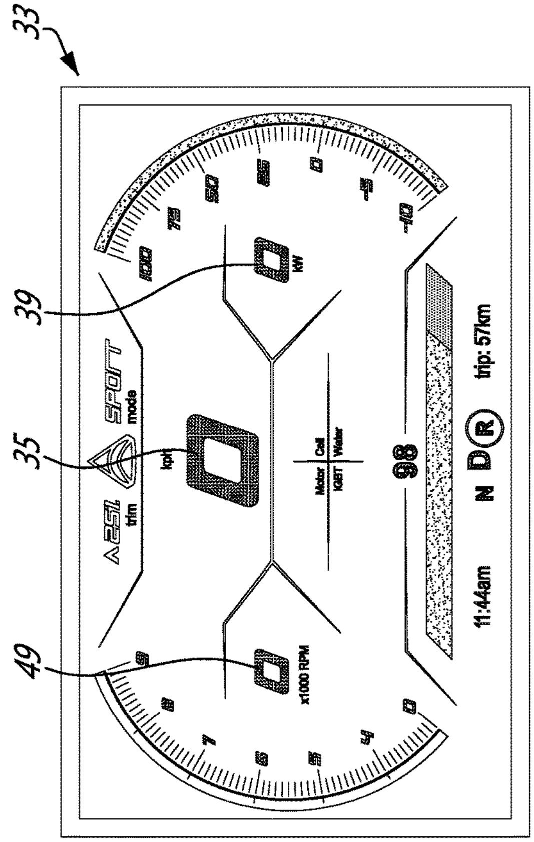


FIG. 7C

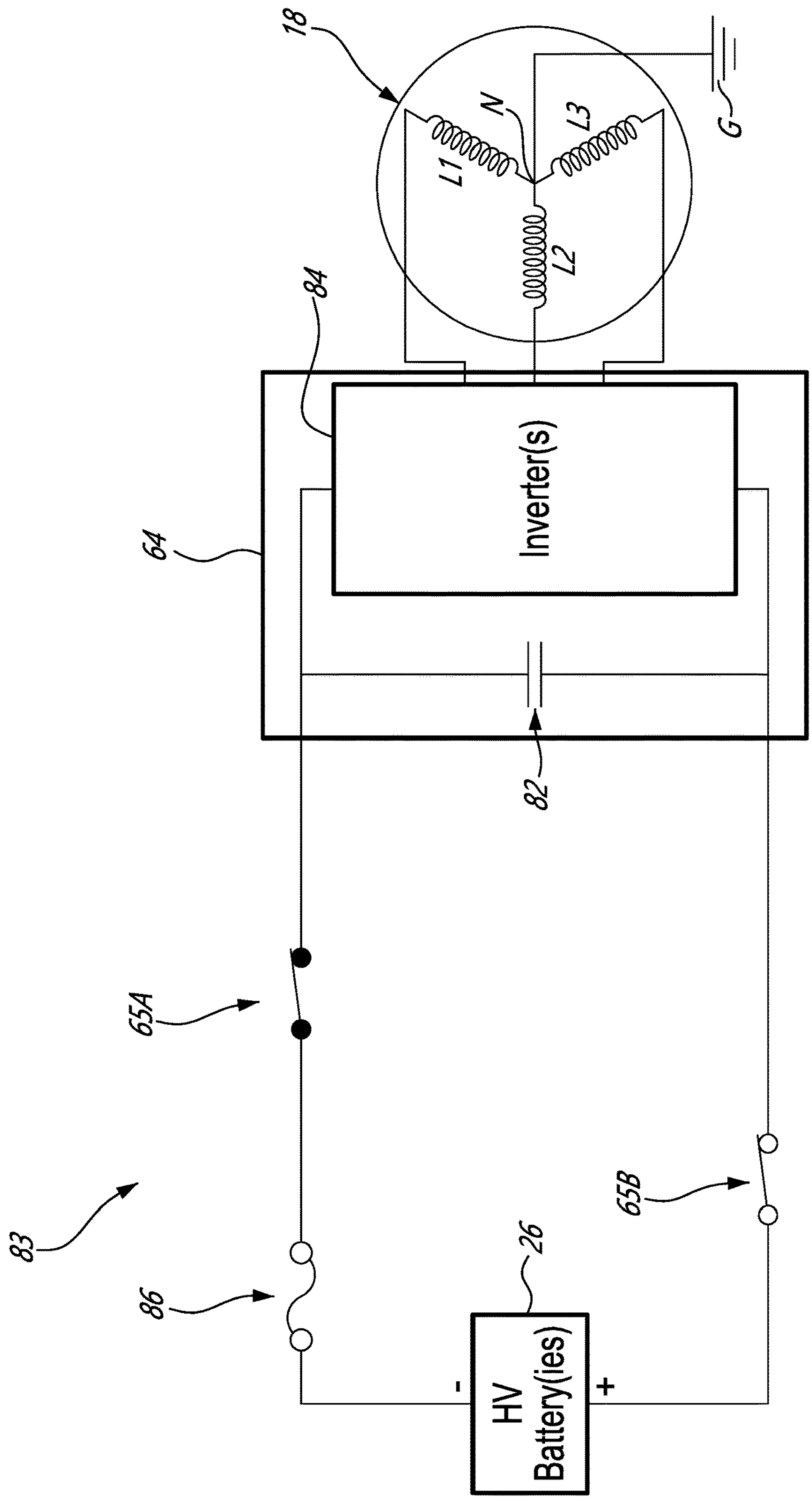


FIG-8

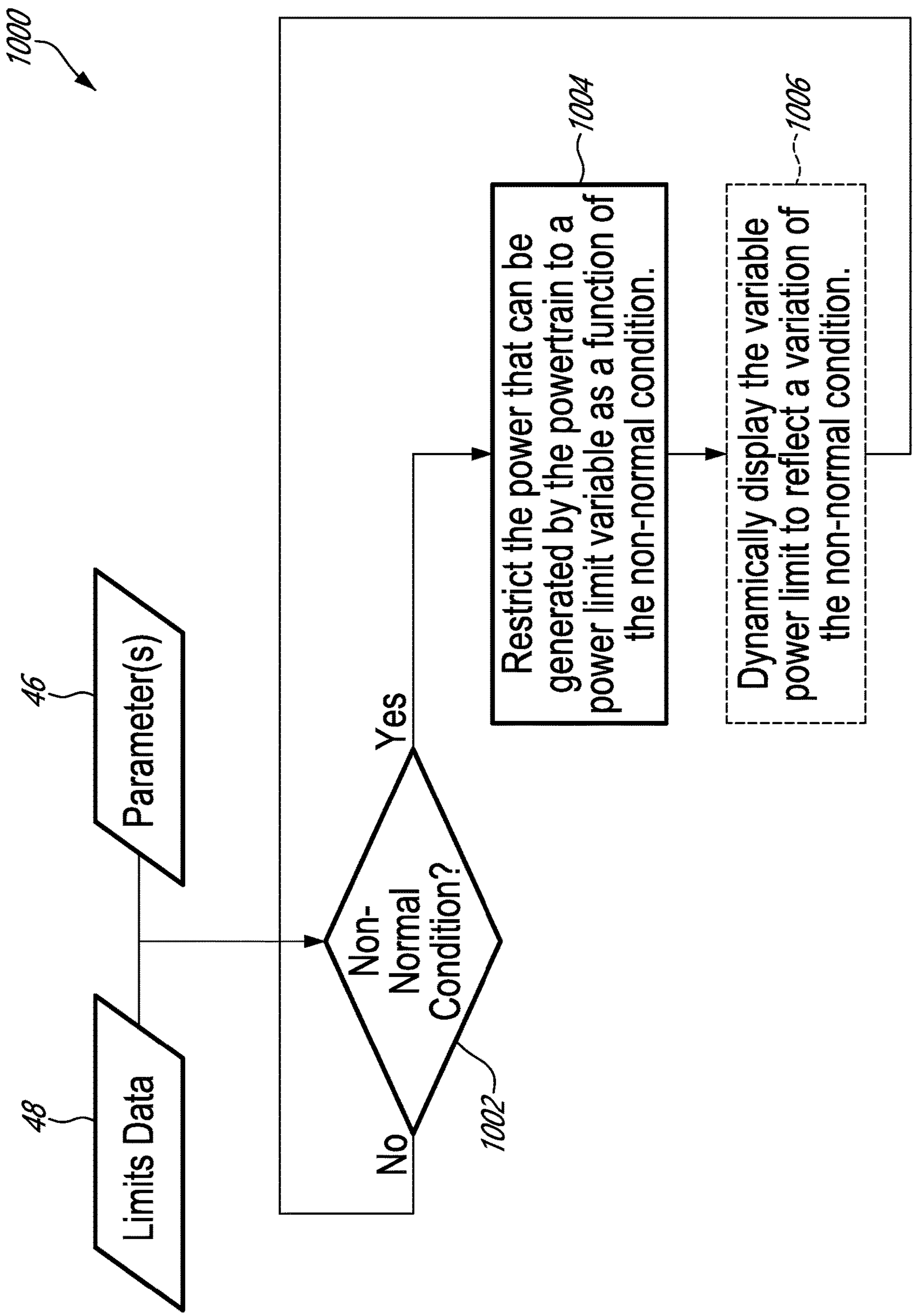

1000
48
Limits Data
46
Parameter(s)
Non-Normal Condition?
1002
No
Yes
1004
Restrict the power that can be generated by the powertrain to a power limit variable as a function of the non-normal condition.
1006
Dynamically display the variable power limit to reflect a variation of the non-normal condition.

Fig-9

ELECTRIC VEHICLE AND CONTROL METHOD THEREFOR

FIELD

[0001] This specification relates to electric vehicles and, more specifically, to a method of controlling operation of an electric snowmobile.

BACKGROUND

[0002] Heat engine based snowmobiles have been around for many decades and have become a very popular sport with amateurs and professionals, as well as a valued utility vehicle. Increased environmental awareness, as well as other factors, motivate the use of electric engines instead of heat engines. Electric engines have several differences from heat engines, both in terms of energy supply, power delivery, and general behavior. For instance, electric engines typically generate significantly less noise than heat engines and have full torque at zero RPM. While earlier technologies have been satisfactory to a certain degree, there always remains room for improvement, including in terms of providing a better user experience in relation with the reverse function in an electric snowmobile.

SUMMARY

[0003] In one aspect, the disclosure describes a method of transitioning an electric snowmobile from a drive state to a reverse state, the method comprising: receiving at a controller a reverse request from a user interface of the electric snowmobile; wherein, upon receipt of the reverse request, the controller being operative to: transition the electric snowmobile from a drive state to a reverse state when a speed signal associated with the electric snowmobile is below a predetermined speed threshold, wherein in the reverse state, the controller drives the electric snowmobile in a reverse direction based on a throttle signal; and, transition the electric snowmobile from a drive state to a reverse requested state when a speed signal associated with the electric snowmobile is above a predetermined speed threshold, wherein in the reverse requested state, the controller does not drive operation of the electric snowmobile based on the throttle signal.

[0004] In some embodiments, when the electric snowmobile is in the reverse requested state, the controller is further operative to: transition the electric snowmobile from the reverse requested state to the reverse state when the speed signal transitions from above the speed threshold to below the speed threshold.

[0005] In some embodiments, when the electric snowmobile is in the drive state, the controller drives the electric snowmobile in a forward direction based on the throttle signal.

[0006] In some embodiments, the transition from the drive state to the reverse state is contingent upon determining that a throttle signal is below a throttle threshold.

[0007] In some embodiments, the transition from the drive state to the reverse requested state includes changing an indicator configuration in a user interface of the electric snowmobile.

[0008] In some embodiments, the changing the indicator configuration includes at least one of changing a configuration of a visual indicator and changing a configuration of an audible indicator.

[0009] In some embodiments, when the electric snowmobile is in the reverse requested state, the controller is further operative to: transition the electric snowmobile from the reverse requested state to the reverse state when the speed signal transitions from above the speed threshold to below the speed threshold, and the transition from the reverse requested state to the reverse state includes changing an indicator configuration in the user interface.

[0010] In some embodiments, the reverse request can be generated upon operator interaction with a user input on a user interface of the electric snowmobile.

[0011] In some embodiments, the speed signal comprises at least one of a vehicle speed and a motor speed.

[0012] In some embodiments, driving the electric snowmobile in the reverse direction includes mapping a throttle signal to a corresponding power request based on a power map, and applying the power request to an electric motor of the electric snowmobile.

[0013] In some embodiments, when the electric snowmobile is in the reverse requested state, the controller is further operative to: transition the electric snowmobile from the reverse requested state to the drive state when a throttle signal above a throttle threshold value is received.

[0014] In some embodiments, when in the reverse requested state, the controller drives the electric motor in a regenerative mode to actively decelerate the electric snowmobile.

[0015] Embodiments may include combinations of the above features.

[0016] In another aspect, the disclosure describes a snowmobile having a powertrain including an electric motor mechanically engaged with a track, a motoring battery configured for supplying the electric motor with electrical power, a throttle actuator operable to provide a throttle signal changing as a function of a position of the throttle actuator, a speed sensor operable to provide a speed signal associated with the electric snowmobile, a user interface operable to receive a reverse request from a driver of the snowmobile, and a controller having a processor and a non-transitory memory, the non-transitory memory having instructions stored thereon, the instructions being executable by the processor for enabling the controller to: when the controller is in a drive state, operate an electric motor of the electric snowmobile in a forward angular direction based on the throttle signal, and, when the reverse request has been received, transition from the drive state to a reverse requested state; when the controller is in the reverse requested state, negate control of the electric motor on a basis of the throttle signal, and, transition to a reverse state when the speed signal transitions from above a speed threshold to below the speed threshold; and when the controller is in the reverse state, operate the electric motor in the reverse angular direction based on the throttle signal.

[0017] In some embodiments, the transitioning from the drive state to a reverse requested state is contingent upon determining that the throttle signal is below a throttle threshold value.

[0018] In some embodiments, the transitioning from the drive state to the reverse requested state includes changing an indicator configuration in the user interface of the electric snowmobile.

[0019] In some embodiments, the transitioning from the reverse requested state to the reverse state includes changing an indicator configuration in the user interface.

[0020] Embodiments may include combinations of the above features.

[0021] In a further aspect, the disclosure describes a method of transitioning an electric vehicle from a drive state to a reverse state, the method comprising: receiving at a controller a reverse request from a user interface of the electric vehicle; wherein, upon receipt of the reverse request, the controller being operative to: transition the electric vehicle from a drive state to a reverse state when a speed signal associated with the electric vehicle is below a predetermined speed threshold, wherein in the reverse state, the controller drives the electric vehicle in a reverse direction based on a throttle signal; and, transition the electric vehicle from a drive state to a reverse requested state when a speed signal associated with the electric vehicle is above a predetermined speed threshold, wherein in the reverse requested state, the controller does not drive operation of the electric vehicle based on the throttle signal.

[0022] In some embodiments, when the electric vehicle is in the reverse requested state, the controller is further operative to: transition the electric vehicle from the reverse requested state to the reverse state when the speed signal transitions from above the speed threshold to below the speed threshold.

[0023] In a further aspect, the disclosure describes a method of transitioning an electric snowmobile from a drive state to a reverse state, the method comprising: receiving at a controller a reverse request from a user interface of the electric snowmobile; wherein, upon receipt of the reverse request, the controller being operative to: transition the electric snowmobile from a drive state to a reverse state when a speed signal associated with the electric snowmobile is below a predetermined speed threshold, wherein in the reverse state, the controller drives an electric motor of the electric snowmobile in a reverse direction based on a throttle signal; and, transition the electric snowmobile from a drive state to a reverse requested state when a speed signal associated with the electric snowmobile is above a predetermined speed threshold, wherein in the reverse requested state, the controller drives the electric motor in a regenerative mode to actively decelerate the electric snowmobile.

[0024] In some embodiments, in the reverse requested state, the controller sustains the regenerative mode until the speed signal reaches the predetermined speed threshold.

[0025] Embodiments may include combinations of the above features.

[0026] Many further features and combinations thereof concerning the present improvements will appear to those skilled in the art following a reading of the instant disclosure.

DESCRIPTION OF THE FIGURES

[0027] In the figures,

[0028] FIG. **1** is a schematic side elevation view of an example electric vehicle including a power indicator as described herein;

[0029] FIG. **2** is a schematic representation of a user interface of the electric vehicle of FIG. **1**;

[0030] FIG. **3** is another schematic representation of the electric vehicle of FIG. **1**;

[0031] FIG. **4** is another schematic representation of the electric vehicle of FIG. **1** is another schematic illustration of the vehicle of FIG. **1**;

[0032] FIG. **5** is a flow chart of a method of operating the electric vehicle of FIG. **1**;

[0033] FIGS. **6**A-**6**B are flow charts of methods of operating the electric vehicle of FIG. **1**;

[0034] FIGS. **7**A-**7**C provide an example of successive changes in an indicator configuration of a user interface corresponding to successive controller state transitions;

[0035] FIG. **8** shows a configuration of an example circuit of the electric vehicle of FIG. **1**;

[0036] FIG. **9** is a flow chart presenting a method of determining power limits to the electric vehicle of FIG. **1**.

DETAILED DESCRIPTION

[0037] The following disclosure relates to systems and associated methods for controlling the operation of electric vehicles. In some embodiments, the systems and methods described herein may be particularly suitable for electric powersport vehicles. Examples of suitable electric powersport vehicles include snowmobiles, all-terrain vehicles (ATVs), and (e.g., side-by-side) utility task vehicles (UTVs). In some embodiments, the systems and methods described herein may provide a relatively user-friendly forward to reverse transition sequence. In some embodiments, the systems and methods described herein may promote the operator's awareness of the state of the electric vehicle, facilitate human/machine interaction, and promote operator experience. In some embodiments, the systems and methods described herein may promote a safe operation of an electric vehicle by reducing a risk of the electric vehicle being inadvertently placed in a reverse state and/or being inadvertently caused to be propelled in a reverse direction.

[0038] Indeed, in addition to potentially limiting the torque or power output to appropriate levels, it can be desired for a controller of an electric snowmobile to prevent sudden reversals of torque or power output. However, traditional combustion engine based snowmobiles can typically be switched from forward to reverse via a mechanical transmission actuator independently of the movement of the vehicle in the forward direction, which some combustion engine snowmobile operators may have come to appreciate in some driving conditions. Accordingly, snowmobile operators accustomed to combustion engine snowmobiles who want to transition to an electric snowmobile, may not appreciate the experience of a controller which prevents them from switching to reverse while the vehicle is still moving. In some embodiments, such inconveniences may be alleviated by introducing an intermediary state, which may be referred to as a "reverse requested" state, into which the operator may transition the controller while the vehicle is still moving. In the intermediary state, the reverse operation of the motor can be prevented. The controller may be configured to automatically transition from the reverse requested state into a reverse state, based on detecting that the vehicle speed has transitioned from above to below a speed threshold. Once in the reverse state, reverse operation of the motor can be allowed based on the throttle signal. Indeed, this can allow the reverse request from the operator to be "remembered" by the controller until conditions are deemed appropriate for its execution.

[0039] The terms "connected" and "coupled" may include both direct connection and coupling (where two elements contact each other) and indirect connection and coupling (where at least one additional element is located between the two elements).

[0040] The term "substantially" as used herein may be applied to modify any quantitative representation which could permissibly vary without resulting in a change in the basic function to which it is related.

[0041] Aspects of various embodiments are described through reference to the drawings.

[0042] FIG. **1** is a schematic side elevation view of an exemplary electric snowmobile **10** (referred hereinafter as "vehicle **10**"). As illustrated in FIG. **1**, vehicle **10** may be a snowmobile but it is understood that controller and control methods described herein may also be used with other types of electric off-road vehicles including utility task vehicles (UTVs), such as side-by-side vehicles and all-terrain vehicles (ATVs) for instance.

[0043] Vehicle **10** may include a frame (also known as a chassis) which may include tunnel **14**, track **16** having the form of an endless belt for engaging the ground and disposed under tunnel **14**, one or more electric motors **18** (referred hereinafter in as "motor **18**") mounted to the frame and configured to drive track **16**. The vehicle **10** may further include left and right skis **20** disposed in a front portion of vehicle **10**, straddle seat **22** disposed above tunnel **14** for accommodating an operator of vehicle **10** and optionally one or more passengers. Skis **20** may be pivotally connected to the frame via a steering column interconnecting handlebar **24** with skis **20** to permit steering of vehicle **10** via a steering assembly including.

[0044] Motor **18** may be drivingly connected to track **16** via a drive shaft to cause propulsion of vehicle **10**. Motor **18** may be in torque-transmitting engagement with the drive shaft via a belt/pulley drive. However, motor **18** may be in torque-transmitting engagement with the drive shaft via other arrangements such as a chain/sprocket drive, or shaft/gear drive for example. The drive shaft may be drivingly connected to track **16** via one or more toothed wheels or other means so as to transfer motive power from motor **18** to track **16**.

[0045] Vehicle **10** may include a controller **28** and a throttle actuator **30**. The controller **28** may include more than one control unit communicatively coupled to one another, one or more of which may be a computer. The operation of motor **18** may be controlled by the controller **28** based on an actuation of throttle actuator **30**, i.e. accelerator, by the operator. More specifically, the throttle actuator **30** can generate a throttle signal which varies over time as a function of variations in the position of the throttle actuator **30**. The controller **28** can have a function to map an amplitude of the throttle signal to a power request for the electric motor **18**, and to control the electric motor based on the power request. The mapping of the amplitude of the throttle signal to the power request may be subject to a current operating mode of the controller **28**. Vehicle may further include one or more sensors **34** for sensing one or more operating parameters of vehicle **10**. The power request communicated to the electric motor **18** may further be based on feedback from one or more sensors **34**.

[0046] Vehicle **10** may also include one or more batteries **26** (referred hereinafter in the singular as "battery **26**") for providing electric power to motor **18** and driving motor **18**. Battery **26** may be a main battery pack used for propelling vehicle **10**, and may be referred to as a motoring battery. Battery **26** may be disposed under seat **22**. In some embodiments, battery **26** may be a rechargeable lithium ion or other type of battery. In some embodiments, battery **26** may be configured to output electric power at a voltage of between 300-400 volts, or up to 800 volts, for example. The controller **28** can have a function to control the delivery of electrical power from the battery **26** to the electric motor **18**. Vehicle may further include a utility battery, e.g. 12 volt battery, configured for powering the controller and any electrically powered accessories of the vehicle **10**, but not the motor **18**.

[0047] Vehicle **10** may also include one or more brakes (referred to below in the singular) that may be applied or released by an actuation of a suitable brake actuator (e.g., brake lever **31** presented in FIG. **2**) by the operator for example. Brake may be operable as a main brake for the purpose of slowing and stopping vehicle **10** during motion of vehicle **10**. Alternatively or in addition, brake may be operable as a parking brake, sometimes called "e-brake" or "emergency brake", of vehicle **10** intended to be used when vehicle **10** is stationary. In various embodiments, such main and parking brake functions may use separate brakes, or may use a common brake. For example, brake may have a friction-type brake including a master cylinder operatively connected to a brake calliper that urges bake pads against a brake rotor or disk that is coupled to the powertrain of vehicle **10**. In some embodiments, such brake rotor may be secured to and rotatable with drive shaft of motor **18**.

[0048] Actuation of the brake actuator (e.g. lever **31**) may cause one of, or both, tractive braking and regenerative braking. Regenerative braking can be controlled via controller **28**. In some embodiments, regenerative braking may be used such that the battery **26** is supplied with electric energy generated by motor **18** operating as a generator when the brake actuator (e.g. lever) is applied, and/or when the operator releases throttle actuator **30**. Such torque operating in a direction contrary to the current direction of movement of the vehicle in decelerating the vehicle can be referred to as negative torque.

[0049] In some embodiments, system **12** may include an operator key (not shown) permitting the operation of vehicle **10** when key is received into receptacle of vehicle **10**, or when key is in sufficient proximity to vehicle **10** for example. The engagement of key with receptacle or the proximity of key to vehicle **10** may be communicated to controller **28** so that controller **28** may authorize the operation of vehicle **10**. Key may be attached to one end of tether (e.g., lanyard). The opposite end of tether may be attached to the vehicle operator's clothing or belt during operation of vehicle **10**. The use of tether and key may allow system **12** to automatically stop propulsion of vehicle **10** by, for example, shutting down or reducing the output of motor **18** to prevent vehicle runaway in an emergency situation such as where the operator would become separated from vehicle **10** and consequently key would become removed from receptacle for example. In some embodiments, separation of the key from the receptacle may prevent vehicle runaway in an emergency situation by preventing propulsion of vehicle **10** and/or activating (e.g. regenerative) braking of motor **18**.

[0050] Vehicle **10** may include a user interface **32** which can include one or more buttons (e.g. a button cluster), and one or more visual indicators. Visual indicators can be embodied in physical devices such as needle indicators, gauges, dials and digital readouts, and/or as virtual devices such as virtual needle indicator, gauges, dials, and digital readouts represented as corresponding elements of a graphical user interface on a display screen or touch screen. Similarly, buttons can be embodied as physical (hardware) devices such as movable press buttons in a button cluster which trigger electrical contacts, or as virtual devices involving both hardware and software, such as portions of a touch screen delimited by graphical elements displayed when the screen is powered. The user interface **32** may include a liquid crystal display (LCD) screen, thin-film-transistor (TFT) LCD screen, light-emitting diode (LED), a button cluster, or other suitable display device operatively connected to controller **28** and/or to one or more other systems of vehicle **10**.

[0051] In an embodiment, the user interface **32** can include a graphical user interface **33** displayed on a display screen such as presented in FIG. **2**. The graphical user interface **33** can be configured for displaying some or all of the values measured by sensors **34** to a user. The graphical user interface may include a speedometer **35** indicating a current speed of vehicle based on a speed sensor. In this embodiment, the speedometer **35** is embodied as a digital readout. The graphical user interface **33** can further include a tachometer **49** indicating a current angular rotation speed of motor **18** in revolutions-per-minute (RPM), including in an embodiment both a digital readout and a virtual dial, a power indicator indicating an amount of power being generated by a powertrain of vehicle **10**, including in an embodiment both a digital readout and a virtual dial, a battery state of charge (SoC) indicator **41** associated with battery **26**, and/or other indicators such as analog or digital readouts, based on corresponding sensors. In particular, controller operating mode indicators (e.g. "Eco", "Normal" and "Sport") can be provided in this example at a top portion of the display screen, and controller drive state (e.g. Drive "D", Neutral "N", Reverse "R") indicator can be provided at a bottom portion of the display screen. One or more of the elements of the graphical user interface **33** can have variable colors. The controller can be said to change an indicator configuration of the user interface **33** when changing either one, or more than one of the operating mode indicator, a controller drive state indicator, and/or a variable color of one or more elements of the graphical user interface **33**.

[0052] In an embodiment, the user interface **32** further includes a plurality of user inputs (e.g. buttons, dials, switches, toggles, levers, etc.). In one embodiment, the user inputs can be embodied as hardware buttons and can include a button cluster **45** disposed on a left handlebar adjacent a brake lever **31** and an emergency stop button **43** disposed on a right handlebar adjacent a throttle actuator **30**. The button cluster can include a reverse/forward button **47** and additional buttons. Additional user inputs can be provided to allow a user to change between controller operating modes such as driving modes (e.g. Sport, Eco, etc.), regenerative braking modes (e.g. regen off, low regen, high regen), handlebar heating activation and headlight activation, among other possibilities. Changes stemming from user input can be reflected in corresponding portions of the graphical user interface. In an embodiment, the user interface **32** further includes an audible indicator including a speaker.

[0053] Referring to FIG. **3**, a schematic diagram of components of vehicle **10** is shown. The vehicle **10** has a propulsor **2** (e.g. track **16**). At least one electric motor **3** (e.g. motor **18**) is drivingly engaged to the propulsor **2** and operatively connectable to a power source **5** (e.g. battery **26**). At least one input device **6** (e.g. throttle actuator **30**) is operatively connected to the electric motor **3**. The electric motor **3** has a forward configuration in which a motor output **4** (e.g. a rotor) of the electric motor **3** rotates in a first direction R**1**. The electric motor **3** has a rearward configuration in which the motor output **4** of the electric motor **3** rotates in a second direction R**2** opposite the first direction R**1**. The input device **6** is engageable to operate the electric motor **3** in a selected one of the forward configuration and the rearward configuration. In the forward configuration, the motor output **4** of the electric motor **5** engages the propulsor **2** in such a way that the propulsor **2** propels the vehicle **10** in a forward direction D**1**. In the rearward configuration, the motor output **4** of the electric motor **3** engages the propulsor **2** in such a way that the propulsor **2** propels the straddle seat vehicle **10** in a rearward direction D**2** opposite the forward direction D**1** (also represented relative the vehicle in FIG. **1**).

[0054] FIG. **4** is another schematic representation of vehicle **10**. Motor **18** may provide propulsive power to vehicle **10** and may be part of powertrain **36** of vehicle **10**. In various embodiments, motor **18** may be a permanent magnet synchronous motor or a brushless direct current motor for example.

[0055] Motor **18** may be drivingly connected to track **16** (shown in FIG. **1**) in embodiments where vehicle **10** is a snowmobile for example. For UTVs and ATVs, motor **18** may be drivingly connected to ground-engaging wheels. Powertrain **36** may also include battery **26** for providing electric power to motor **18**. The operation of motor **18** and the delivery of electric power to motor **18** may be controlled by controller **28** via output(s) **37** and power electronics module **38** (referred hereinafter as "PEM **38**"). PEM **38** may include suitable electronic switches (e.g., insulated gate bipolar transistor(s)) to provide motor **18** with electric power having the desired voltage, current, waveform, etc. to implement the desired performance of vehicle **10** based on an actuation of throttle actuator **30** by the operator to indicate a command to propel vehicle **10**A. In some embodiments, PEM **38** may include a power inverter for example.

[0056] One or more of sensors **34** may be operatively connected to component(s) of powertrain **36** and configured to sense one or more parameters of powertrain **36**. Controller **28**, via the control of PEM **38** and using feedback from sensor(s) **34**, may control the amount of motive power that may be output from powertrain **36** during propulsion of vehicle **10**, and also control the amount of electric power that may be delivered to battery **26** during regenerative braking. Controller **28** may include one or more data processors **40** (referred hereinafter as "processor **40**") and non-transitory machine-readable memory **42**. Controller **28** may be operatively connected to sensor(s) **34** via wired or wireless connections for example so that one or more parameters acquired via sensor(s) **34** may be received at controller **28** and used by processor **40** in one or more procedures or steps defined by machine-readable instructions **44** stored in memory **42** and executable by processor **40**.

[0057] Controller **28** may carry out additional functions than those described herein. Processor **40** may include any suitable device(s) configured to cause a series of steps to be performed by controller **28** so as to implement a computer-implemented process such that instructions **44**, when executed by controller **28**, may cause the functions/acts to be executed.

[0058] Processor **40** may include, for example, any type of general-purpose microprocessor or microcontroller, a digital signal processing (DSP) processor, an integrated circuit, a field programmable gate array (FPGA), a reconfigurable processor, other suitably programmed or programmable logic circuits, or any combination thereof.

[0059] Memory **42** may include any suitable machine-readable storage medium. Memory **42** may include non-transitory computer readable storage medium such as, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. Memory **42** may include a suitable combination of any type of machine-readable memory that is located either internally or externally to controller **28**. Memory **42** may include any storage means (e.g. devices) suitable for retrievably storing machine-readable instructions executable by processor **40**.

[0060] Sensor(s) **34** may include one or more current sensors and/or one or more voltage sensors operatively connected to battery **26** and/or operatively connected to PEM **38**. Sensor(s) **34** may include a position sensor (e.g., encoder) operatively coupled to motor **18** to measure a position and/or rotational speed of a rotor of motor **18**. Sensor(s) **34** may include a speed sensor (e.g., revolution counter) operatively coupled to motor **18** to measure the rotational speed of motor **18** and generate a speed signal indicative of a current rotation speed of the electric motor as it changes over time. Sensor(s) **34** may include a torque sensor operatively coupled to motor **18** to measure an output torque of motor **18**. Alternatively, the output torque of motor **18** may be inferred by controller **28** based on an amount of electric current being delivered to motor **18**. Sensor(s) **34** may include one or more temperature sensors such as one or more thermocouples or resistance temperature detectors (RTD) suitable for measuring a temperature of one or more cells of battery **26**, and/or for measuring a temperature of a component of motor **18** for example. Sensor(s) **34** may acquire one or more signals indicative of, or useful in inferring, one or more operating parameters **46** of powertrain **36**. For example, sensor(s) **34** may acquire one or more signals indicative of, or useful in inferring, an amount of electric power being discharged from battery **26** during propulsion of vehicle **10**, an amount of electric power being received into battery **26** to charge battery **26** during regenerative braking of vehicle **10**, an amount of motive power being generated by motor **18** during propulsion of vehicle **10**, and/or an amount of electric power being generated by motor **18** when motor **18** is operating as a generator during regenerative braking of vehicle **10**. Sensor(s) **34** may acquire one or more signals indicative of, or useful in inferring, a state of charge (SoC) of battery **26** and/or other parameters of powertrain **36**. The SoC may be expressed as a percentage of the capacity of battery **26** (e.g., 0%=empty; 100%=full), or as any other suitable indication. Sensor(s) **34** may include one or more potentiometers for obtaining a throttle signal indicative of a position of throttle actuator **30**, and/or obtaining a brake signal indicative of a position of a brake lever **31**, for instance. In an alternative embodiment, sensor(s) **34** may include one or more limit switches for sensing activation of brake lever **31**.

[0061] The throttle actuator **30** may be operatively connected (e.g. in electronic communication, wired) to controller **28** so that controller **28** may control some aspects of operation of the powertrain **36** based on instructions **44**. For example, the throttle actuator **30** may be a source of a throttle (i.e. acceleration) signal which can vary over time based on changes in a position of a throttle actuator **30**. The change can be a change in amplitude or a change in a frequency of the throttle signal for instance. The controller **28** can map a given value of the throttle signal to a given power request from the motor **18** based on the instructions. The mapping may be constant throughout operating conditions, or various mappings can be defined in the instructions **44** and be adapted to different driving modes or driving conditions. For instance, a sports mode mapping may be defined as more aggressively mapping smaller changes in the throttle signal to larger changes in requested power, whereas an eco mode mapping may be defined as less aggressively mapping corresponding changes in the throttle signal to smaller changes in requested power. More than two driving modes, and associated mappings, may be provided for. The controller **28** can be configured to allow the operator to switch from one driving mode to another via one or more elements of the user interface **32**, such as switching buttons and a visual indication of the current state for instance. The mapping may be the same, or different, between forward and reverse states of operation, with a significant difference being that the motor **18** can be driven to rotate in different orientations between the forward and reverse states of operation.

[0062] User interface **32** may be operatively connected (e.g., in electronic communication, wired) to controller **28** so that controller **28** may control some aspects of operation of user interface **32** or of the power electronics module **38** based on instructions **44**. For example, based on one or more sensed parameters **46** of powertrain **36**, controller **28** may determine, based on limits data **48**, whether or not the operation of vehicle **10** needs to be restricted to mitigate a non-normal operating condition or for another reason. The limits data **48** may be used to identify an available power limit based on the operating conditions determined by the sensed parameters **46** at a given time. The available power limit may vary over time as the operating conditions of the vehicle **10** change. Controller **28** may be configured to restrict operation of vehicle **10** based on limits data **48** and also cause user interface **32** to visually display one or more applied limits. Such one or more applied limits may limit the power request outputted from the controller **28** to the powertrain **36**. For instance, if the power request determined from the mapping of the throttle signal is lower than the one or more applied limits, the mapped power request can be directly outputted from the controller **28** to the powertrain **36**, whereas if the mapped power request is greater than the one or more applied limits, the power request outputted from the controller **28** to the powertrain **36** may be reduced compared to the mapped power request based on the one or more limits. The power request outputted from the controller **28** to the powertrain **36** can be executed via the power electronics module **38** which can control an amount of power delivered to the motor from the batteries **26**. In an alternate embodiment, the power electronics module **38** can be considered to form part of controller **28**.

[0063] The drive state can be defined as a mode of operation in which the electric motor **18** will be controlled in a manner to drive in a forward direction D**1** of the vehicle **10**. In a direct drive configuration, rotating the electric motor **18** in a forward angular direction R**1** drives the electric snowmobile **10** in a forward direction D**1**, and rotating the electric motor **18** in a rear angular direction R**2** drives the electric snowmobile **10** in the rear direction D**2**. Similarly, the reverse state can be defined as a mode of operation in which the electric motor **18** will be driven in a rear angular direction R**2** corresponding to a rear direction D**2** of the vehicle **10**.

[0064] Presented in FIG. **5**, is a method **102** of controlling the vehicle **10**. Broadly stated, controller **28** may map (block **90**) the throttle signal **92** to a power request **96** at least in part on a basis of a power map **94**, and subsequently control (block **98**) the electric motor **18** based on the power request **96**. Power map **94** may vary depending on a vehicle drive mode (Eco, Normal, Sport) as well as depending on whether the vehicle **10** is in drive state vs. a reverse state, for example. Controller **28** may enable changing of the power map **94** during operation of the vehicle **10**, such as upon operator intervention such as by interacting with user interface **32** (e.g. switching drive mode between Eco, Sport, etc,) or automatically (e.g. by providing a different map for the reverse state than for the drive state). In some embodiments, in the reverse state, the mapping between the throttle signal **92** and the power request **96** can be different, or the same, than in the drive state.

[0065] Upon determination of the power request **96**, controller **28** may determine (decision block **160**) whether the value of the power request **96** is above an available power limit. As described above, the available power limit may be determined based on the limits data **48** and the operational condition of the vehicle **10** as determined based on sensed parameters **46**. If the value of the power request **96** is above the available power limit, the power request **96** may be set (block **162**) to the available power limit before being applied to control the electric motor **18** (block **98**). If the value of the power request **96** is below the available power limit, the power request **96** may be directly applied to control the electric motor **18** (block **98**). The power request **96** is thus applied to the powertrain by the controller **28** to control propulsion of the vehicle.

[0066] The method **102** presented in FIG. **5** may be adapted to both operation in the drive state and to operation in the reverse state. The power request **96** may be applied to the powertrain by controller **28** to drive the propulsion of the vehicle in both the forward direction D**1** and the rear direction D**2**.

[0067] Turning now to FIG. **6**A, an example method **100** of transitioning between a drive state (forward operation) and a reverse state is presented. Prior to receiving a reverse request, controller **28** maintains vehicle **10** in the drive state (block **104**), such as by executing method **102** described in FIG. **5**, for example. While in the drive state, controller **28** determines (decision block **106**) whether a reverse request has been received. A reverse request may be received via the forward/reverse button **47** of user interface **32**, for example, or another user input. A reverse request may be received based on a short press activation of the forward/reverse button **47**, or alternatively a long press (e.g. 2 or more seconds) of the forward/reverse button **47**. In an alternate embodiment, forward/reverse button **47** may mechanically remain depressed following activation and generate the reverse request until it is pressed again to revert to its initial state. So long as a reverse request is not received, controller **28** maintains vehicle **10** in the drive state (block **104**).

[0068] If controller **28** determines that a reverse request has been received, controller **28** may verify that the throttle signal is below a given throttle threshold (block **108**). In some embodiments, this may be an optional step. The throttle threshold may correspond to a position of the throttle actuator **30**, such as less than 3% or 5% of an actuation range of throttle actuator **30**, for example. In some embodiments, the throttle threshold may be substantially 0, such that method **100** does not proceed towards transitioning from the drive state to the reverse state unless the throttle actuator **30** is in a zero position (i.e. un-actuated). This verification may be performed as a safety check to ensure that the forward/reverse button **47** was not pressed inadvertently. If a throttle signal from throttle actuator **30** is above the throttle threshold (e.g. the throttle actuator **30** is being actuated) when a reverse request is received (e.g. forward/reverse button **47** is actuated), then the reverse request may be ignored and vehicle **10** is caused to maintain the drive state (block **104**).

[0069] Upon receipt of the reverse request and any additional conditions being satisfied, such as the optional condition of the throttle signal being below the throttle threshold, controller **28** determines whether a speed signal from the vehicle is below a predetermined speed threshold (decision block **110**). A sudden transition of direction at speeds above the threshold may be undesirable in a snowmobile. It is preferable to dampen a transition between directions to prevent harm to an operator and/or damage to the vehicle. More particularly, it may be damaging to components of the powertrain for the vehicle **10** to transition from a drive state to a reverse state when motor **18** is rotating in the forward angular direction R**1** at relatively high speeds. Controller **28** may thus prevent motor **18** and/or vehicle **10** from switching to the reverse state when one or both of the motor speed and/or the vehicle speed are above a predetermined speed threshold in the forward direction. A speed check against the predetermined speed threshold is performed before allowing the vehicle **10** to transition from a drive state to a reverse state (decision block **110**).

[0070] In one embodiment, the speed signal associated with vehicle **10** received at controller **28** may be indicative of a motor speed (rpm). In another embodiment, the speed signal associated with vehicle **10** received at controller **28** may be indicative of a vehicle speed. The vehicle speed may be determined from a Global Positioning System (GPS), for example, or alternatively may be inferred or calculated from a motor speed (rpm). For example, in an electric snowmobile **10** having a direct drive configuration, a rotation speed (rpm) of electric motor **18** can be considered suitably proportional to vehicle speed to enable vehicle speed to be derived, calculated, or inferred.

[0071] In accordance with some non-limiting examples, the speed threshold for vehicle speed may be in the order of 1, 2 or 5 km/h, for example, but other values, including values above or below these examples, may be preferred in alternate embodiments. In accordance with some non-limiting examples, the speed threshold for motor speed (rpm) may be between 30 and 250 RPM, such as less than or approximately 30 RPM, 60 RPM, 100 RPM, 150 RPM or 250 RPM for instance, but other values, including values above or below this range may be preferred in alternative embodiments. In some examples, the speed threshold may be configurable and/or selectable by an operator, while being constrained within certain safety limits. Furthermore, a ramp down rate of the motor speed and/or vehicle speed towards the predetermined speed threshold may also be user selectable and configurable. The speed threshold and ramp down rate may be different for each of the vehicle drive modes (e.g. Eco, Normal, Sport).

[0072] While it may be undesirable to transition from the drive state to the reverse state when vehicle **10** is operating at relatively high speeds, it may also be undesirable to require that an operator waits until vehicle **10** and/or motor **18** have come to a complete stop before allowing an operator to convey their desire to transition directions. Accordingly, it may be desirable to allow an operator to provide a reverse request (e.g. press the reverse button **47**) even while the vehicle is in motion and operating at high speeds. However, upon receipt of the reverse request, the actual transition from the drive state to the reverse state should be avoided until a speed signal is below the speed threshold. In such cases, controller **28** may place vehicle **10** into an intermediate state for a time period between receiving a reverse request and vehicle **10** and/or motor **18** achieving a speed at or below the speed threshold. This intermediate state may serve the function of enabling controller **28** to override any throttle signal to zero so that vehicle **10** is forced to slow down to below the speed threshold before vehicle **10** enters the reverse state (i.e. before the reverse state is activated).

[0073] Accordingly, upon receipt of the reverse request, controller **28** determines if the speed signal received is below the speed threshold (decision block **110**). If the speed signal is indicative that the speed of the motor **18** and/or vehicle **10** is below the speed threshold, controller **28** transitions vehicle **10** to a reverse state (block **112**). As such, if the reverse request is received when vehicle **10** is stationary or operating at a suitably low speed (i.e. below the speed threshold), controller **28** transitions vehicle **10** directly to the reverse state (block **112**) such that subsequent operation of throttle actuator **30** will cause motor **18** to rotate in the rear angular direction R**2** such that vehicle **10** is propelled in the reverse direction D**2**.

[0074] However, if the speed signal is indicative that the speed of motor **18** and/or vehicle **10** is above the speed threshold, controller **28** transitions vehicle **10** to an intermediate, reverse requested state (block **114**). In other words, if the reverse request is received when vehicle **10** is operating at a relatively fast speed (i.e. above the speed threshold), where abrupt transition between states could be undesirable to an operator and/or cause damage to vehicle components, controller **28** transitions vehicle **10** to an intermediate, reverse requested state.

[0075] The reverse requested state provides an intermediate state where vehicle **10** is enabled to slow down to acquire an operational condition where controller **28** can transition vehicle **10** to the reverse state safely. Accordingly, in one embodiment, while in the reverse requested state, controller **28** may not accept throttle signals **92** received from throttle actuator **30** for controlling motor **18**. In other words, controller **28** ignores throttle signals **92** received from throttle actuator **30** while vehicle **10** is in the reverse requested state. In still other words, controller **28** overrides any throttle signal **92** to zero while in the reverse requested state. As such, an operator is prevented from accelerating vehicle **10**, so as to enable vehicle **10** and/or motor **18** to reduce speed to below the speed threshold.

[0076] In an alternative embodiment, actuation of the throttle actuator **30** during the intermediate, reverse requested state causes the reverse request to be voided, and controller **28** returns vehicle **10** to the drive state.

[0077] In the reverse requested state, controller **28** may provide an operator-perceptible indication (e.g. indicator scheme) to the operator via the user interface **33**, to clearly convey to an operator that vehicle **10** is in the reverse requested state. This indication to the operator may be distinguishable from the drive state and/or distinguishable from the reverse state. Such user feedback may improve user experience by conveying to the operator the current operational condition of the vehicle. In this manner, the operator will not expect actuation of throttle actuator **30** to generate propulsion, thereby avoiding puzzlement and frustration. In one embodiment, such an indication can include changing a color of one or more portions of the graphical user interface **33** in a manner to produce a noticeable change compared with the previous state, e.g. the drive state. In one embodiment, one or more portions of the graphical user interface **33** may be switched to a different color in the reverse requested state than the color used in the drive state or the reverse state. In one embodiment, such an indication can include activating an audible indication such as a repeating beep. The one or more changes can reflect a difference between an indicator scheme of the drive state and an indicator scheme of the reverse state.

[0078] While the vehicle is in the reverse requested state, controller **28** may continuously and/or intermittently monitor the speed signal (block **110**), such that when vehicle **10** and/or motor **18** drop to speeds below the speed threshold, controller **28** transitions vehicle **10** to the reverse state (block **112**). In other words, controller **28** maintains vehicle **10** in the reverse requested state while the vehicle speed is above the speed threshold (block **114**) and transitions vehicle **10** to the reverse state when the speed signal drops below the speed threshold (block **112**). Controller **28** may monitor the speed signal in a manner to affect the transition when the speed signal transitions from above the speed threshold to below the speed threshold.

[0079] Depending on the embodiment, one or more timers may be used as a basis for one or more additional conditions. For instance, a first timer may be activated upon transitioning into the reverse requested state (block **114**) and when the first timer reaches a first time limit, controller **28** may automatically transition from the reverse requested state back to the drive state if the speed signal has not been reduced below the speed threshold within the first time limit. In some embodiments, controller **28** may also transition back into the drive state if a drive request is received. In an embodiment, the drive request can be identical to the reverse request (i.e. an input received from pressing of a forward/reverse button **47** by the operator). As another example, a timer can be activated upon determining that the speed is already below the speed threshold at an initial check (block **110**), and the controller **28** may delay the transition into the reverse state based on reaching a predetermined time limit.

[0080] In an embodiment, controller **28** may trigger an operator-perceptible indication (e.g. indicator scheme) in the user interface **33** upon the transition to the reverse state, which can signify to the operator that activation of the throttle actuator **30** will now lead to delivering rearward acceleration. In an embodiment, the indication in the user interface **33** may include a further change in a color of one or more portions of the graphical user interface **33**. Alternatively, or in addition, the indication may include a perceptible change in an audible signal (e.g. change a frequency of an audible beep). In an embodiment, the indication to the operator corresponding to the reverse state can be distinguishable from both the indication corresponding to the drive state and the indication corresponding to the reverse requested state.

[0081] In some embodiments, additional functions may be triggered when in the reverse requested state. For instance, in an embodiment, when in the reverse requested state, controller **28** may change a mode of operation of the electric motor **18** to a zero-torque mode, where controller **28** commands the motor **18** to acquire a zero torque state (i.e. a no-load operating state). In other words, the no-load operating state may correspond to substantially no torque being output from motor **18** or being input into motor **18** operating as a generator. As motor **18** is operated at no load, the total input power to motor **18** may be relatively low and substantially equal to (e.g., iron, friction and windage) losses of motor **18**.

[0082] Alternately, when in the reverse requested state, controller **28** may change a mode of operation of the electric motor **18** to a regenerative mode where motor braking is applied (negative torque relative the direction of movement) to reduce the vehicle speed more quickly than it would reduce in a zero torque scenario. In the regenerative mode, electric power generated by motor **18** is provided to battery **26**. In one embodiment, the regenerative mode can be sustained until one or more conditions are met, such as until the speed signal reaches or goes below the speed threshold for instance. Various alternatives exist in ways to embody a regenerative mode, one of which is to control negative torque in a manner to lead to a target power recovery value corresponding, for example, with a recharging capacity of the battery **26**. Other ways to embody a regenerative mode specific to a reverse requested state may be to limit the amount of regenerative braking to a different value below the recharging capacity of the battery **26**. In still another embodiment, in the reverse requested state, the throttle signal and/or the brake signal may be mapped by controller **28** to a negative value of torque (i.e. a value of regenerative braking).

[0083] Turning now to FIG. **6**B, an example method **120** of transitioning between the reverse state and the drive state (forward operation) is presented. Prior to receiving a forward request, controller **28** maintains vehicle **10** in the reverse state (block **122**). While in the reverse state, controller **28** determines (decision block **124**) whether a forward request has been received, or in alternative embodiments, whether a reverse request has ceased to be received. A forward request may be received via the reverse/forward button **47** of user interface **32**, for example, or another user input. A forward request may be received based on a short press activation of the reverse/forward button **47**, or alternatively a long press (e.g. 2 or more seconds) of the reverse/forward button **47**., So long as no forward request is received, controller **28** maintains vehicle **10** in the reverse state (block **122**).

[0084] In an alternative embodiment, if while in the reverse state the vehicle **10** is turned "off", the vehicle **10** may default back to the drive state (forward operation) when it is turned back "on". In a further alternative embodiment, if while in the reverse state the vehicle **10** is put into an "awake" state where it is "on" but does not respond to throttle signals from throttle actuator **30**, vehicle **10** may default back to the drive state when it is returned to an "active" state where the controller **28** responds to throttle signals from throttle actuator **30** to propel vehicle **10**.

[0085] Returning to FIG. **6**B, if controller **28** determines that a forward request has been received, controller **28** may optionally verify that the throttle signal is below a given throttle threshold (block **126**). The throttle threshold may correspond to a position of the throttle actuator **30**, such as less than 3% or 5% of actuation range of throttle actuator **30**, for example. In some embodiments, the throttle threshold may be substantially 0, such that method **120** does not proceed towards transitioning from the reverse state to the drive state unless the throttle actuator **30** is in a zero position (i.e. un-actuated). This verification may be performed as a safety check to ensure that the reverse/forward button **47** was not pressed inadvertently. If a throttle signal from throttle actuator **30** is above the throttle threshold (e.g. the throttle actuator **30** is being actuated) when a forward request is received (e.g. reverse/forward button **47** is actuated), then the forward request may be ignored and vehicle **10** is caused to maintain the reverse state (block **122**).

[0086] Upon receipt of the forward request and any additional conditions being satisfied, such as the optional condition of the throttle signal being below the throttle threshold, controller **28** determines whether a speed signal from the vehicle is below a predetermined speed threshold (decision block **128**).

[0087] The speed threshold for transitioning from the reverse state to the drive state may be the same or different than the speed threshold for transitioning form the drive state to the reverse state, as described above. In some embodiments, the speed threshold for transitioning from the reverse state to the drive state may be the less than the speed threshold for transitioning form the drive state to the reverse state.

[0088] While it may be undesirable to transition from the reverse state to the drive state when the vehicle is operating at relatively high speeds, it may also be undesirable to require that an operator waits until vehicle **10** and/or motor **18** have come to a complete stop before allowing an operator to convey their desire to transition directions. Accordingly, it may be desirable to allow an operator to provide a forward request (e.g. press the reverse/forward button **47**) even while vehicle **10** and/or motor **18** is in motion and operating at high speeds. However, upon receipt of the forward request, the actual transition from the reverse state to the drive state should be avoided until a speed signal is below the speed threshold.

[0089] Accordingly, upon receipt of the forward request, the controller determines if the speed signal received is below the speed threshold (decision block **128**). If the speed signal is indicative that the speed of motor **18** and/or vehicle **10** is below the speed threshold, the controller transitions vehicle **10** to a drive state (block **134**). In other words, if the forward request is received when vehicle **10** is stationary or operating at a suitably low speed (i.e. below the speed threshold), controller **28** transitions vehicle **10** directly to the forward state (block **134**) such that subsequent operation of throttle actuator **30** will cause motor **18** to rotate in the forward angular direction R**1** such that vehicle **10** is propelled in the forward direction D**1**.

[0090] However, if the speed signal is indicative that the speed of the motor **18** and/or vehicle **10** is above the speed threshold, the controller transitions vehicle **10** to an intermediate, forward requested state (block **130**). In other words, if the forward request is received when the vehicle **10** is operating at a relatively fast speed (i.e. above the speed threshold), where abrupt transition between states could be undesirable to an operator and/or cause damage to vehicle components, controller **28** transitions vehicle **10** to the intermediate, forward requested state.

[0091] The forward requested state provides an intermediate state where vehicle **10** is enabled to slow down to acquire an operational condition where controller **28** can transition vehicle **10** to the forward state safely. Accordingly, in one embodiment, while in the forward requested state, controller **28** may not accept throttle signals **92** received from throttle actuator **30** for controlling motor **18**. In other words, controller **28** ignores throttle signals **92** received from throttle actuator **30** while in the forward requested state. As such, an operator is prevented from accelerating vehicle **10**, so as to enable vehicle **10** and/or motor **18** to reduce speed to below the speed threshold.

[0092] In an alternative embodiment, actuation of the throttle actuator **30** during the intermediate, forward requested state causes the forward request to be voided, and controller **28** returns vehicle **10** to the reverse state.

[0093] While in the forward requested state, controller **28** may provide an operator-perceptible indication (e.g. indicator scheme) to the operator, via the user interface **33**, to clearly convey to an operator that vehicle **10** is in the forward requested state. This indication to the operator may be distinguishable from the drive state and/or distinguishable from the reverse state. Such user feedback may improve user experience by conveying to the operator the current operational condition of the vehicle. In this manner, the operator will not expect actuation of the throttle actuator **30** to generate propulsion, thereby avoiding puzzlement and frustration. In one embodiment, such an indication can include changing a color of one or more portions of the graphical user interface **33** for instance, in a manner to produce a noticeable change compared with the previous state, e.g. the reverse state. In one embodiment, one or more portions of the graphical user interface **33** may be switched to a different color in the forward requested state than the color used in the drive state or the reverse state. In one embodiment, such an indication can include activating an audible indication such as a repeating beep. The one or more changes can reflect a difference between an indicator scheme of the drive state and an indicator scheme of the reverse state.

[0094] The operator-perceptible indication that the vehicle **10** is in the forward requested state may be the same or different than the operator-perceptible indication that the vehicle is in the reverse requested state.

[0095] While the vehicle is in the forward requested state, controller **28** may continuously and/or intermittently monitor the speed signal (block **128**), such that when vehicle **10** and/or motor **18** speed drops below the speed threshold, controller **28** transitions vehicle **10** to the drive state (block **134**). In other words, controller **28** can maintain the vehicle in the forward requested state while the vehicle speed is above the speed threshold (block **130**) and transition vehicle **10** to the drive state when the speed signal transitions to below the speed threshold (block **134**). Controller **28** may monitor the speed signal in a manner to affect the transition when the speed signal transitions from above the speed threshold to below the speed threshold.

[0096] Depending on the embodiment, one or more timers may be used as a basis for one or more additional conditions. For instance, a first timer may be activated upon transitioning into the forward requested state (block **130**) and when the first timer reaches a first time limit, controller **28** may automatically transition from the reverse requested state back to the reverse state if the speed signal has not been reduced below the speed threshold within the first time limit. As another example, a timer can be activated upon determining that the speed is already below the speed threshold at an initial check (block **128**), and the controller **28** may delay the transition into the drive state based on reaching a predetermined time limit.

[0097] In an embodiment, controller **28** may trigger an operator-perceptible indication (e.g. indicator scheme) in the user interface **33** upon the transition to the drive state, which can signify to the operator that activation of the throttle actuator **30** will now lead to delivering forward acceleration. In an embodiment, the indication in the user interface **33** may include a further change in a color of one or more portions of the graphical user interface **33**. Alternatively, or in addition, the indication may include a perceptible change in an audible signal (e.g. change a frequency of an audible beep). In an embodiment, the indication to the operator corresponding to the drive state can be distinguishable from both the indication corresponding to the reverse state and the indication corresponding to the forward requested state.

[0098] FIGS. **7**A, **7**B and **7**C present one of numerous possible examples of a change in an indicator scheme between different drive states. In this example, FIG. **7**A presents a graphical user interface **33** in a first indicator scheme when the controller is in a drive state. The first indicator scheme includes illustrating various display items (e.g. the numerical values of motor speed (RPM) **49**, vehicle speed (kph) **35** and motor power **39**) in a first color, e.g. green, and providing a circle around the D to indicate the drive state. FIG. **7**B presents a second indicator scheme corresponding to the reverse requested state. In the reverse requested state, various display items (e.g. the numerical values of motor speed **49**, vehicle speed **35** and motor power **39**) can appear in a second color, e.g. grey or purple. At this stage, the circle around the D can have disappeared such as illustrated, or remain around the D to name an example variant. Optionally, or additionally, an audible indicator can be activated in parallel. FIG. **7**C presents a third indicator scheme corresponding to the reverse state. In the reverse state, various display items (e.g. the numerical values of motor speed **49**, vehicle speed **35** and motor power **39**) can remain in the second color as illustrated, or change to yet another color, e.g. orange, to name a possible variant. At this stage, the circle can appear around the R to indicate the reverse state. Optionally, or additionally, an audible indicator can be activated or, if it was already activated in the reverse requested state, it can be perceptibly changed such as by changing its pitch or frequency.

[0099] In yet another embodiment, a change of indicator scheme can include a change in a background color as opposed to a change in a display item. In yet another embodiment, instead of a change of color, the different indicator schemes may provide a change of texture, pattern or emphasis of various display items or backgrounds. In one embodiment, in the reverse requested state (and/or forward requested state), a separate icon, text message, or graphical indication may appear on the graphical user interface **33**

covering various display items, such as one or all of the numerical values of motor speed **49**, vehicle speed **35** and motor power **39** either partially or completely. The icon, text message or graphical indication may make clear to an operator that a reverse or forward requested state has been entered and that functioning of the throttle actuator **30** may be temporarily unavailable.

[0100] FIG. **8** shows an exemplary circuit **83** for activating vehicle **10**. PEM **64** may be a non limiting example of Power Electronics Module **38** shown in FIG. **4**. As shown, PEM **64** may be operatively connected between HV battery **26** and motor **18** to control the delivery of electric power from HV battery **26** to motor **18**. Motor **18** may be a polyphase (e.g., 3-phase) synchronous motor and may include a plurality of armature (e.g., stator) windings such as armature windings L**1**, L**2**, L**3**. Armature windings L**1**, L**2**, L**3** may be connected in a wye or delta configuration. Neutral point N may be connected to ground G.

[0101] PEM **64** may include inverter **84** and capacitor **82**. Capacitor **82** may be electrically connected in parallel with inverter **84**. Capacitor **82** may be a smoothing capacitor within PEM **64**. Circuit **83** may also include fuse **86** operative to provide overcurrent protection for circuit **83**.

[0102] In preparation for propulsion of vehicle **10**, switches **65**A and **65**B are closed so that HV battery **26** can deliver electric power to motor **18**. Switches **65**A-**65**B may be operatively connected to be controlled via controller **28**. In some embodiments, switches **65**A, **65**B may be high power relays mounted to a frame or structure of a battery pack.

[0103] The configuration of circuit **83** shown in FIG. **8** may be adopted in both an "awake" state of vehicle **10** and an "active" drive state. As described above, in an "awake state", vehicle **10** is "on" but does not respond to throttle signals from throttle actuator **30**. In an "active" state vehicle **10** is also "on" and controller **28** responds to throttle signals from throttle actuator **30** to propel vehicle **10**. While in the "awake" state, HV battery **26** may be electrically connected to PEM **64**, but the propulsion of vehicle **10** may be prevented by preventing electric power from being delivered to motor **18** via inverter **84**. Preventing propulsion of vehicle **10** while switches **65**A and **65**B are closed may be done by controller **28** not executing (e.g., ignoring) propulsion commands that may be received via throttle actuator **30**. Ignoring propulsion commands may include controller **28** keeping the switches of inverter **84** in a configuration where electric power is not supplied to motor **18**. In other words, while in the "awake" state, controller **28** may be programmed not to control inverter **84** according to propulsion commands that may be received via throttle actuator **30**. When in the reverse requested state and/or the forward requested state, the configuration of circuit **83** may be adopted while controller **28** does not execute (e.g. ignores) commands originating from throttle actuator **30**.

[0104] FIG. **9** is a flow diagram of a method **1000** of controlling an electric vehicle such as vehicle **10**. Method **1000** may include other actions, or may be combined with other methods or actions disclosed. Method **1000** may be carried out using elements of vehicle **10**. Functions and other aspects of vehicle **10** may be incorporated into method **1000**. Method **100** may be computer-implemented. In various embodiments, method **100** may include: sensing parameter **46** of powertrain **36** of vehicle **10**, the powertrain including motor **18** for propelling vehicle **10** and battery **26** for powering motor **18**; when parameter **46** is indicative of a non-normal condition of powertrain **36** at decision block **1002** (e.g., using limits data **48**). Method **1000** may include: restricting the power that can be generated by powertrain **36** to an available power limit (block **1004**), the available power limit being variable as a function of the non-normal condition; and dynamically displaying (e.g., on instrument panel **32**) the available power limit to reflect a variation of the non-normal condition (block **1006**).

[0105] In some embodiments, the available power limit may be selected to mitigate the non-normal condition. For example, the available power limit may be selected to promote mitigation of the non-normal condition when the operation of vehicle **10** is restricted to the available selected power limit.

[0106] The dynamic display of the available power limit may display a variation of the power limit to reflect the variation of the non-normal condition substantially in real time. For example, the display of the available power limit may be substantially synchronized with one or more parameters **46** that are indicative of evolving or waning of the non-normal condition.

[0107] Returning now to FIG. **5**, any available power limit determined using the method **1000** can be applied as presented above.

[0108] In accordance with the present invention, while it is desirable to prevent sudden reversals of torque or power output by the electric vehicle, it is also desirable to allow an operator to request transition from the drive state to the reverse state, or vice versa, while the vehicle is in motion. This allows an operator to convey their desire to change vehicle directions at any time during riding, and not just when the vehicle is at rest or stationary. The reverse requested state (or forward requested state) where input commands from the throttle actuator **30** are not executed (e.g. ignored) allows the vehicle to acquire an intermediate state between receiving a reverse request (or forward request) and actually executing a change in direction of the motor **18**. Providing an operator-perceptible indication to an operator that the vehicle **10** is in the reverse requested state (or forward requested state) avoids confusion and or frustration at the vehicles' operation during this intermediate state.

[0109] As can be understood, the examples described above and illustrated are intended to be exemplary only. The technology presented herein may be used on other types of electric vehicles than snowmobiles in alternate embodiments, such as side-by-sides or other all terrain vehicles for instance. The scope is indicated by the appended claims.

What is claimed is:

1. A method of transitioning an electric snowmobile from a drive state to a reverse state, the method comprising:

receiving at a controller a reverse request from a user interface of the electric snowmobile;

wherein, upon receipt of the reverse request, the controller being operative to:

transition the electric snowmobile from a drive state to a reverse state when a speed signal associated with the electric snowmobile is below a predetermined speed threshold, wherein in the reverse state, the controller drives the electric snowmobile in a reverse direction based on a throttle signal; and,

transition the electric snowmobile from a drive state to a reverse requested state when a speed signal associated with the electric snowmobile is above a predetermined speed threshold, wherein in the reverse requested state, the controller does not drive operation of the electric snowmobile based on the throttle signal.

2. The method of claim **1** wherein, when the electric snowmobile is in the reverse requested state, the controller is further operative to: transition the electric snowmobile from the reverse requested state to the reverse state when the speed signal transitions from above the speed threshold to below the speed threshold.

3. The method of claim **1** wherein, when the electric snowmobile is in the drive state, the controller drives the electric snowmobile in a forward direction based on the throttle signal.

4. The method of claim **1** wherein the transition from the drive state to the reverse state is contingent upon determining that a throttle signal is below a throttle threshold.

5. The method of claim **1** wherein the transition from the drive state to the reverse requested state includes changing an indicator configuration in a user interface of the electric snowmobile.

6. The method of claim **5** wherein said changing the indicator configuration includes at least one of changing a configuration of a visual indicator and changing a configuration of an audible indicator.

7. The method of claim **1** wherein, when the electric snowmobile is in the reverse requested state, the controller is further operative to: transition the electric snowmobile from the reverse requested state to the reverse state when the speed signal transitions from above the speed threshold to below the speed threshold, and wherein the transition from the reverse requested state to the reverse state includes changing an indicator configuration in the user interface.

8. The method of claim **1** further comprising generating the reverse request upon operator interaction with a user input on a user interface of the electric snowmobile.

9. The method of claim **1** further comprising acquiring the speed signal associated with the electric snowmobile, the speed signal comprising at least one of a vehicle speed and a motor speed.

10. The method of claim **1** wherein driving the electric snowmobile in the reverse direction includes mapping a throttle signal to a corresponding power request based on a power map, and applying the power request to an electric motor of the electric snowmobile.

11. The method of claim **1**, wherein, when the electric snowmobile is in the reverse requested state, the controller is further operative to: transition the electric snowmobile from the reverse requested state to the drive state when a throttle signal above a throttle threshold value is received.

12. The method of claim **1**, wherein in the reverse requested state, the controller drives the electric motor in a regenerative mode to actively decelerate the electric snowmobile.

13. A snowmobile having a powertrain including an electric motor mechanically engaged with a track, a motoring battery configured for supplying the electric motor with electrical power, a throttle actuator operable to provide a throttle signal changing as a function of a position of the throttle actuator, a speed sensor operable to provide a speed signal associated with the electric snowmobile, a user interface operable to receive a reverse request from a driver of the snowmobile, and a controller having a processor and a non-transitory memory, the non-transitory memory having instructions stored thereon, the instructions being executable by the processor for enabling the controller to:

when the controller is in a drive state, operate an electric motor of the electric snowmobile in a forward angular direction based on the throttle signal, and, when the reverse request has been received, transition from the drive state to a reverse requested state;

when the controller is in the reverse requested state, negate control of the electric motor on a basis of the throttle signal, and, transition to a reverse state when the speed signal transitions from above a speed threshold to below the speed threshold; and

when the controller is in the reverse state, operate the electric motor in the reverse angular direction based on the throttle signal.

14. The snowmobile of claim **13** wherein said transitioning from the drive state to a reverse requested state is contingent upon determining that the throttle signal is below a throttle threshold value.

15. The snowmobile of claim **13** wherein said transitioning from the drive state to the reverse requested state includes changing an indicator configuration in the user interface of the electric snowmobile.

16. The snowmobile of claim **15** wherein said transitioning from the reverse requested state to the reverse state includes changing an indicator configuration in the user interface.

17. An electric vehicle comprising:

an electric motor;

a battery configured for supplying the electric motor with electrical power;

a throttle actuator operable to provide a throttle signal changing as a function of a position of the throttle actuator;

a controller having a processor and a non-transitory memory, the non-transitory memory having instructions stored thereon, the instructions being executable by the processor for enabling the controller to:

receive a reverse request from a user interface of the electric vehicle;

wherein, upon receipt of the reverse request, the controller being operative to:

transition the electric vehicle from a drive state to a reverse state when a speed signal associated with the electric vehicle is below a predetermined speed threshold, wherein in the reverse state, the controller drives the electric vehicle in a reverse direction based on the throttle signal; and,

transition the electric vehicle from a drive state to a reverse requested state when a speed signal associated with the electric vehicle is above a predetermined speed threshold, wherein in the reverse requested state, the controller does not drive operation of the electric vehicle based on the throttle signal.

18. The electric vehicle of claim **17**, wherein in the reverse requested state, the controller is further operative to: transition the electric vehicle from the reverse requested state to the reverse state when the speed signal transitions from above the speed threshold to below the speed threshold.

19. A method of transitioning an electric snowmobile from a drive state to a reverse state, the method comprising:

receiving at a controller a reverse request from a user interface of the electric snowmobile;

wherein, upon receipt of the reverse request, the controller being operative to:

transition the electric snowmobile from a drive state to a reverse state when a speed signal associated with the electric snowmobile is below a predetermined speed threshold, wherein in the reverse state, the controller drives an electric motor of the electric snowmobile in a reverse direction based on a throttle signal; and,

transition the electric snowmobile from a drive state to a reverse requested state when a speed signal associated with the electric snowmobile is above a predetermined speed threshold, wherein in the reverse requested state, the controller drives the electric motor in a regenerative mode to actively decelerate the electric snowmobile.

20. The method of claim **19** wherein in the reverse requested state, the controller sustains the regenerative mode until the speed signal reaches the predetermined speed threshold.

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