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(54) **SYSTEM AND METHOD FOR POWER ALLOCATION TO HIGH-VOLTAGE THERMAL LOADS FROM MULTIPLE ENERGY SOURCES IN A HYBRID POWERTRAIN DURING COLD CONDITIONS**

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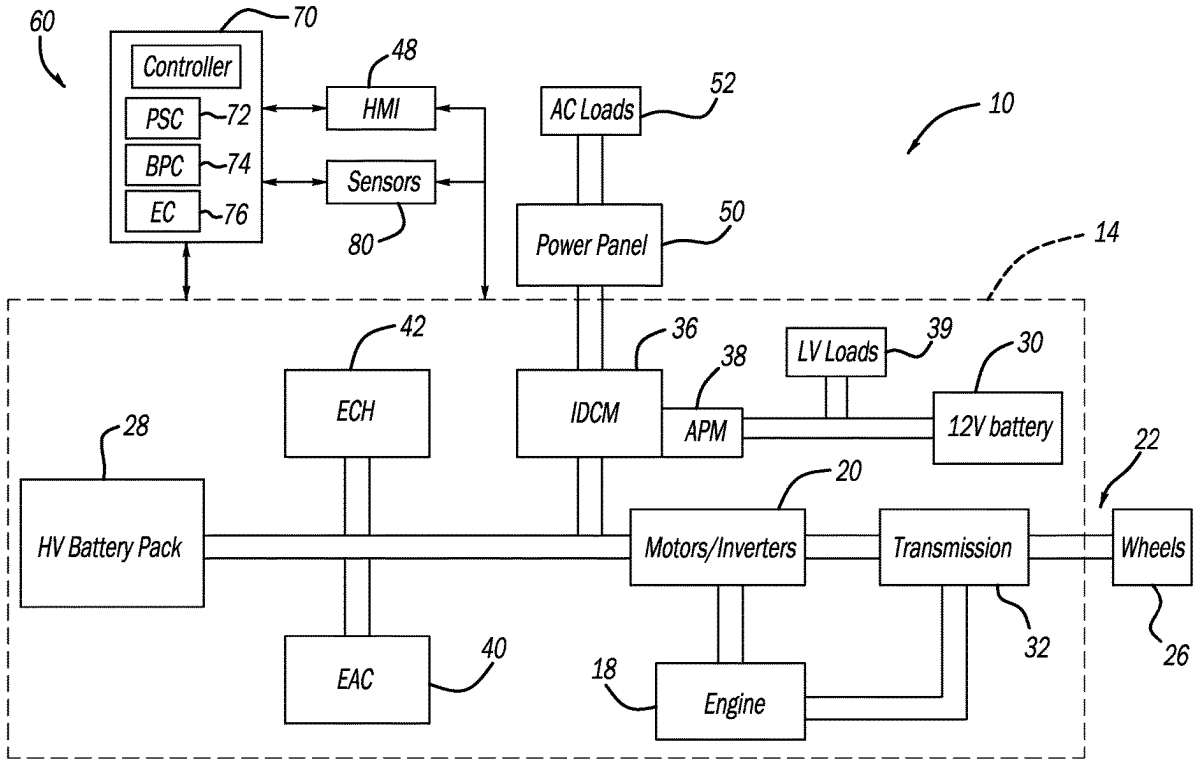
(57) **ABSTRACT**

A powertrain and control method that generates and transfers drive torque to a driveline of a hybrid electric vehicle is provided. The powertrain includes an internal combustion engine (ICE), at least one electric motor powered by a high-voltage battery, an integrated dual charge module (IDCM) and a controller. The controller is configured to: determine whether an external load is connected to the vehicle through the IDCM; determine an available engine-based power; determine whether the available engine-based power is above a threshold to support thermal loads; command power consumption from the high-voltage battery based on a determination that available engine-based power is not above the threshold; command power consumption from the ICE based on a determination that available engine-based power is above the threshold; and command a blending of power between the high-voltage battery and the ICE.



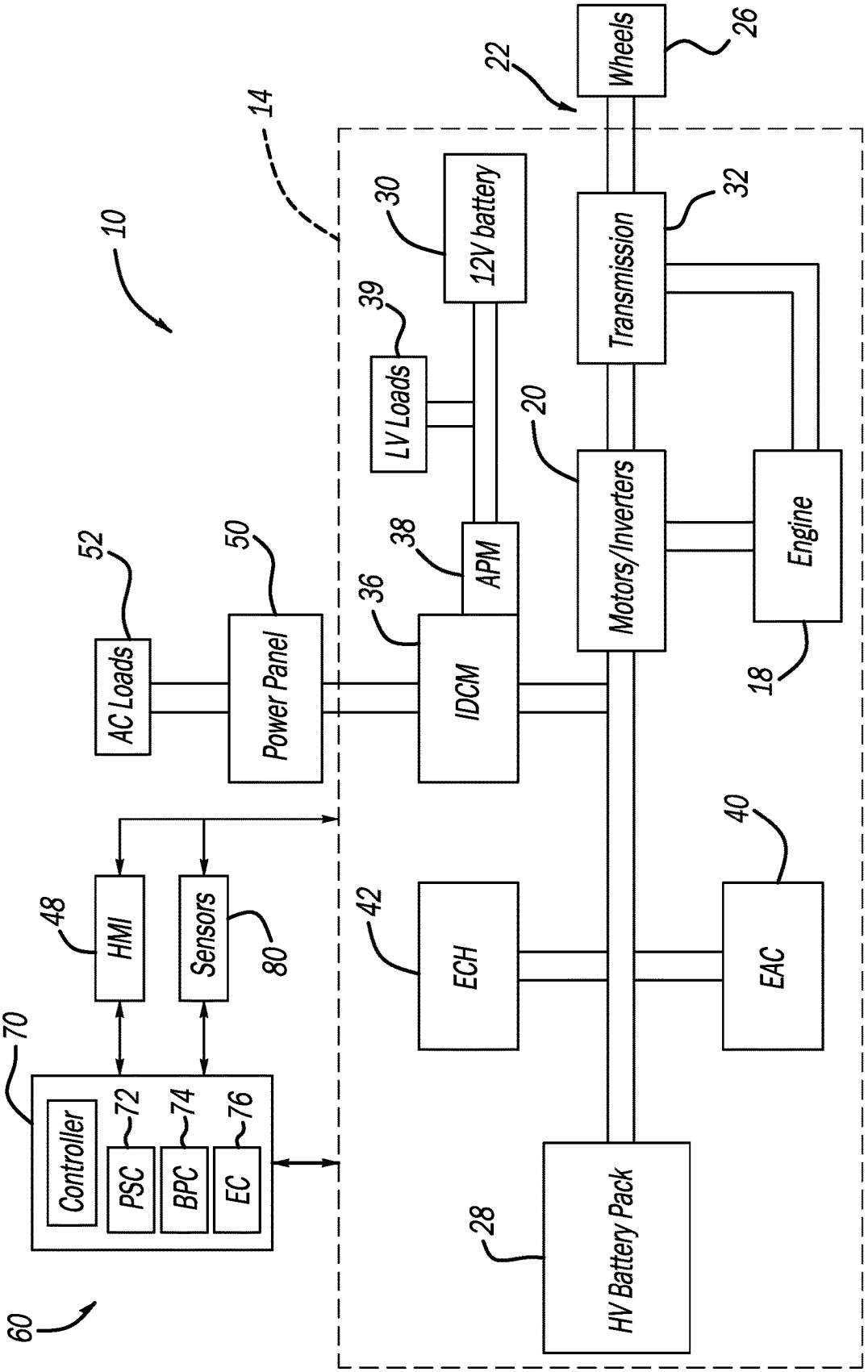

10
14
22
Wheels
26
12V battery
30
Transmission
32
39
LV Loads
20
Motors/Inverters
Engine
52
50
38
APM
36
AC Loads
Power Panel
IDCM
18
48
HMI
Sensors
80
42
ECH
40
EAC
70
Controller
72
PSC
74
BPC
76
EC
28
HV Battery Pack
60

FIG. 1

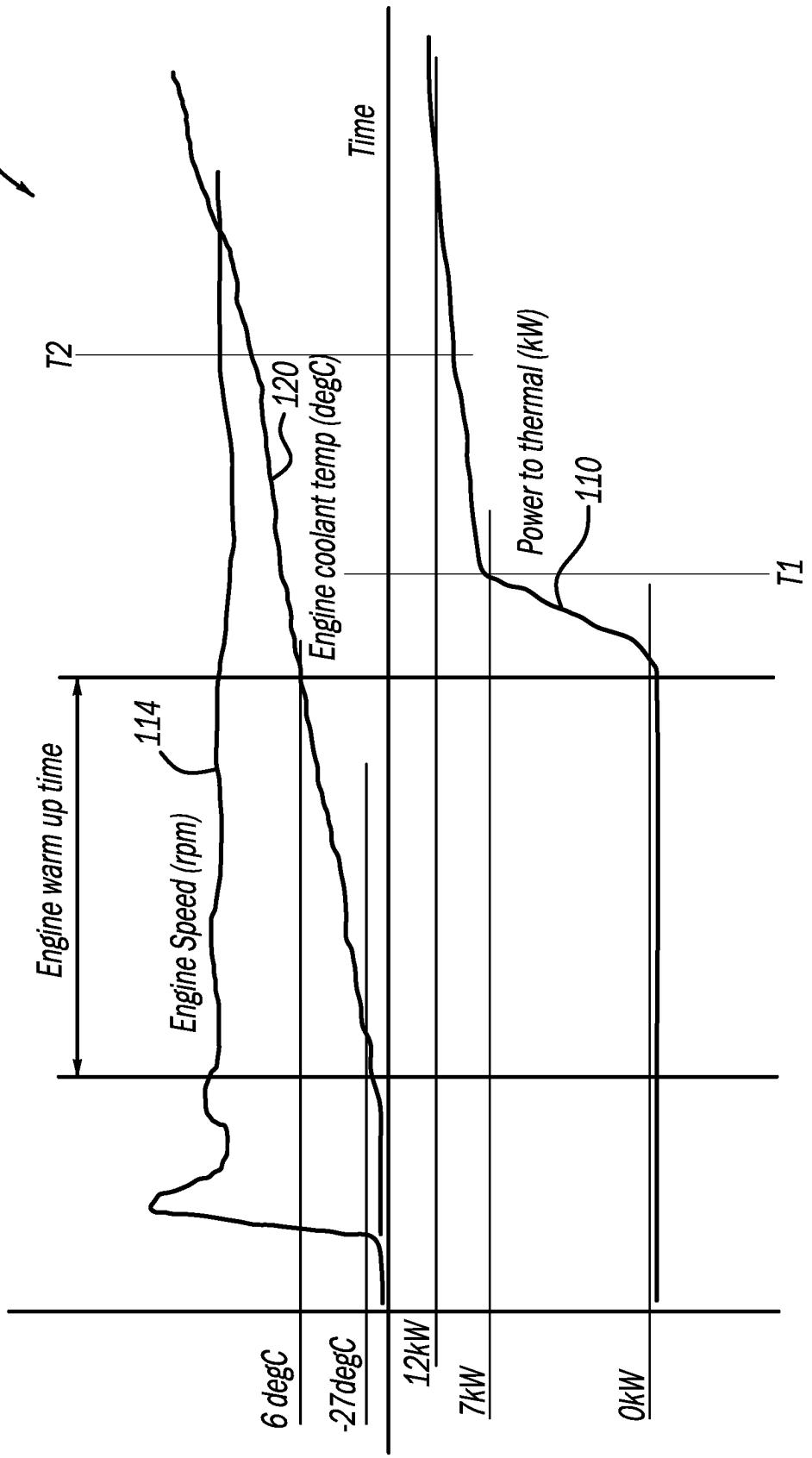

100
Time
T2
120
Engine coolant temp (degC)
Power to thermal (kW)
110
T1
Engine warm up time
114
Engine Speed (rpm)
6 degC
-27degC
12kW
7kW
0kW

FIG. 2

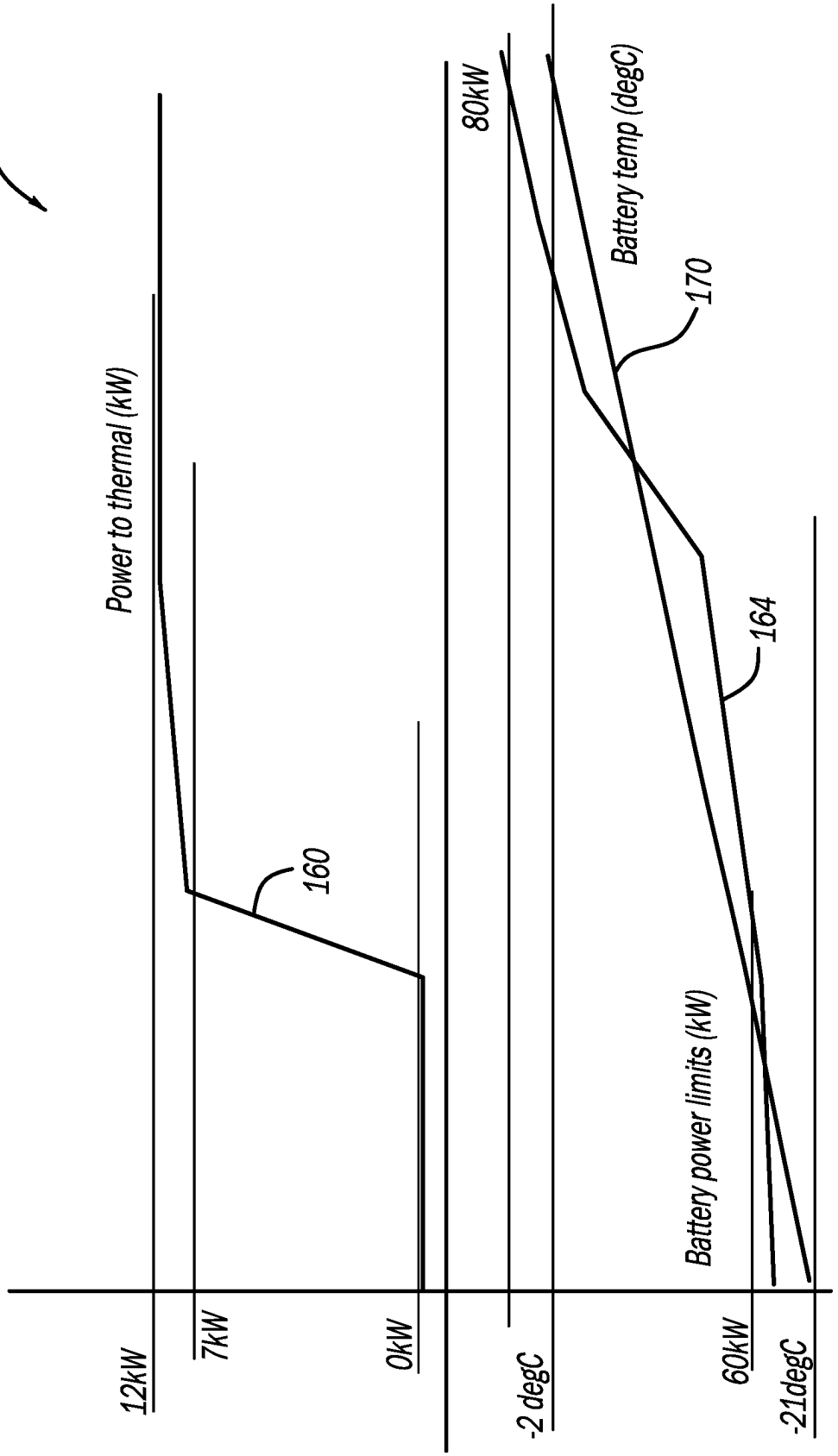

150
Power to thermal (kW)
12kW
7kW
0kW
160
80kW
Battery temp (degC)
-2 degC
170
164
Battery power limits (kW)
60kW
-21degC

FIG. 3

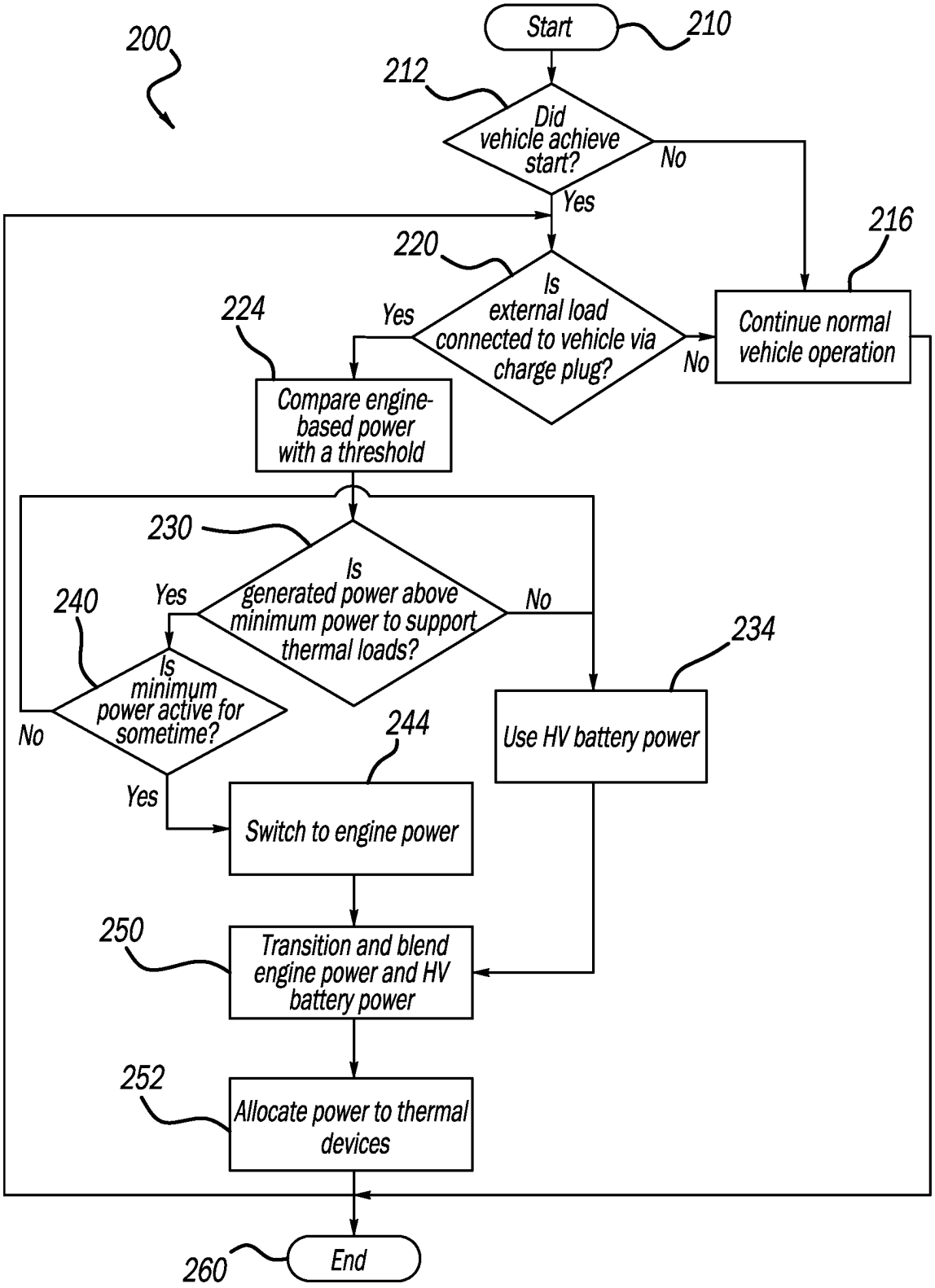

200
Start
210
212
Did vehicle achieve start?
No
Yes
216
220
Is external load connected to vehicle via charge plug?
Yes
No
224
Continue normal vehicle operation
Compare engine-based power with a threshold
230
Is generated power above minimum power to support thermal loads?
Yes
No
240
234
Is minimum power active for sometime?
No
Use HV battery power
244
Yes
Switch to engine power
250
Transition and blend engine power and HV battery power
252
Allocate power to thermal devices
260
End

FIG. 4

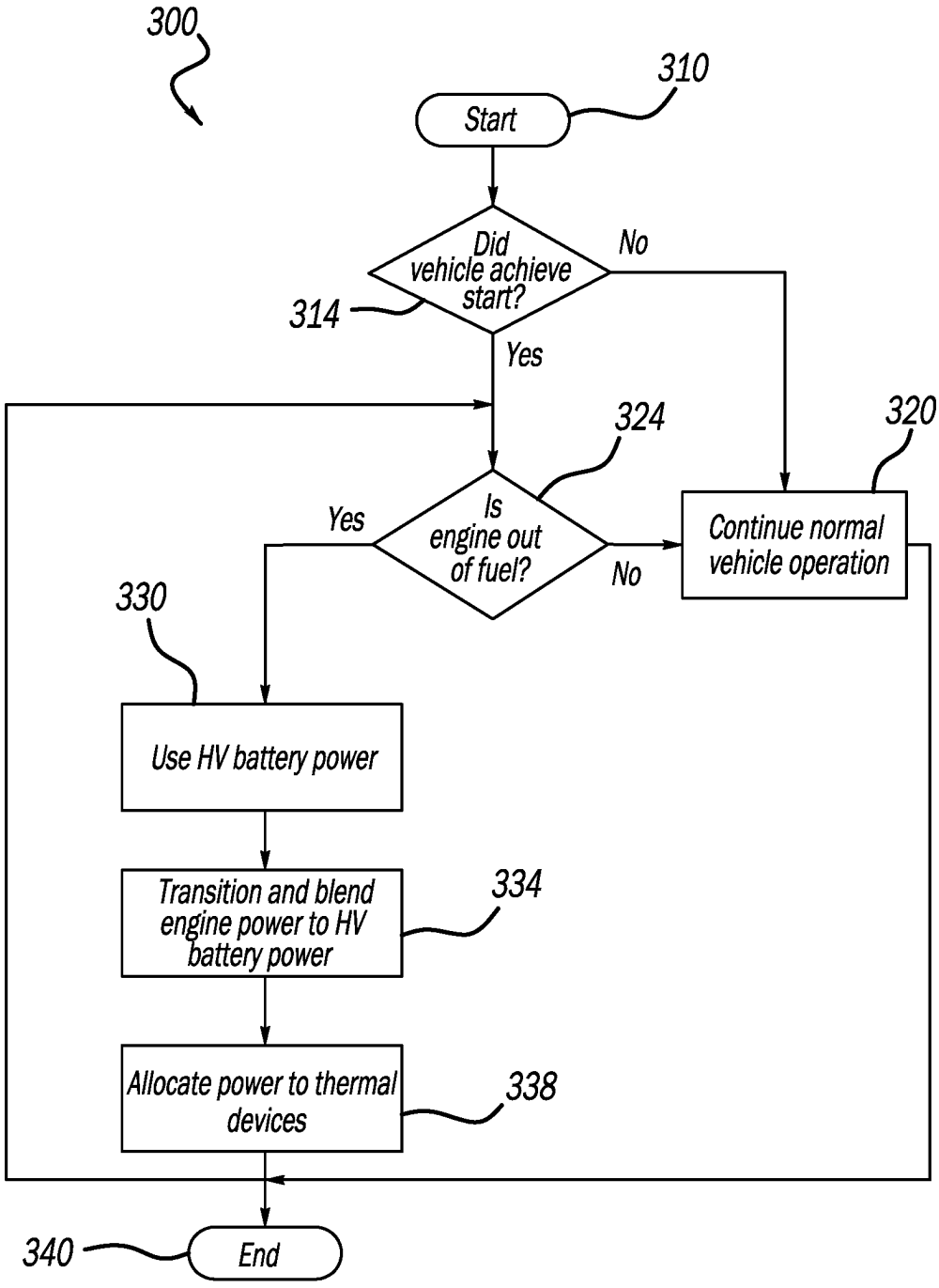

300
310
Start
Did vehicle achieve start?
No
314
Yes
324
320
Is engine out of fuel?
Yes
No
Continue normal vehicle operation
330
Use HV battery power
Transition and blend engine power to HV battery power
334
Allocate power to thermal devices
338
340
End

FIG. 5

SYSTEM AND METHOD FOR POWER ALLOCATION TO HIGH-VOLTAGE THERMAL LOADS FROM MULTIPLE ENERGY SOURCES IN A HYBRID POWERTRAIN DURING COLD CONDITIONS

FIELD

[0001] The present application generally relates to hybrid electric vehicles and, more particularly, to a system and method for allocating power from multiple energy sources during cold conditions.

BACKGROUND

[0002] A hybrid electric vehicle (HEV) is a type of hybrid vehicle that combines a conventional internal combustion engine system with an electric propulsion system. The engine in the HEV can be stopped and started multiple times during a drive cycle. The engine start-stop functionality in HEV's is a feature that automatically turns off the internal combustion engine when the vehicle comes to a stop, such as at traffic lights or in congested traffic, and restarting it when vehicle propulsion is needed again. Unlike a conventional 12 volt starter to crank the internal combustion engine, HEV's generally use high-voltage electric machines such a belt starter generator motor or integrated motors within a transmission to start the internal combustion engine.

[0003] In some HEV configurations, a power panel can be connected to a charge port of the HEV. An integrated dual charge module (IDCM) can use the energy from the high-voltage battery and engine to convert DC power to support AC loads connected to the power panel such as, but not limited to, power tools, appliances, computers and the like. It is generally difficult to observe and manage the selection of power source (battery or engine) while the HEV is supporting these external loads. Accordingly, while such HEV's do work well for their intended purpose, there is a desire for improvement in the relevant art.

SUMMARY

[0004] According to one example aspect of the invention, a powertrain that generates and transfers drive torque to a driveline of a hybrid electric vehicle is provided. The powertrain includes an internal combustion engine (ICE), at least one electric motor powered by a high-voltage battery, an integrated dual charge module (IDCM) and a controller. The controller is configured to: determine whether an external load is connected to the vehicle through the IDCM; determine an available engine-based power; determine whether the available engine-based power is above a threshold to support thermal loads; command power consumption from the high-voltage battery based on a determination that available engine-based power is not above the threshold; command power consumption from the ICE based on a determination that available engine-based power is above the threshold; and command a blending of power between the high-voltage battery and the ICE.

[0005] In some implementations, the controller is further configured to determine available engine-based power based upon a coolant temperature of the ICE.

[0006] In some implementations, the controller is further configured to determine available engine-based power based on a lookup table.

[0007] In some implementations, the controller is further configured to command power consumption from the ICE based on the determination that available engine-based power is above the threshold; and determine whether minimum power is active for a predetermined time.

[0008] In some implementations, the controller is further configured to command power consumption from the ICE based on a determination that the minimum power has been active for the predetermined time.

[0009] In additional aspects, the controller is further configured to determine whether fuel is out in the vehicle; and command power consumption from high-voltage battery based on a determination that the fuel is out in the vehicle.

[0010] In additional features, the controller is further configured to transition and blend power from the ICE to the high-voltage battery.

[0011] In other features, the powertrain further includes an electric air compressor (EAC) and an electric coolant heater (ECH), wherein the controller is further configured to allocate power to the EAC and the ECH.

[0012] According to one example aspect of the invention, a method for controlling a powertrain that generates and transfers drive torque to a driveline of a hybrid electric vehicle is provided. The powertrain includes an internal combustion engine (ICE), and at least one electric motor powered by a high-voltage battery, and an integrated dual charge module (IDCM). The method includes: determining, at a controller, whether an external load is connected to the vehicle through the IDCM; determining, at the controller, available engine-based power; determining, at the controller, whether available engine-based power is above a threshold to support thermal loads; commanding power consumption from high-voltage battery based on a determination that available engine-based power is not above the threshold; commanding power consumption from the ICE based on a determination that available engine-based power is above the threshold; and commanding a blending of power between the high-voltage battery and the ICE.

[0013] In additional features, the method includes determining the available engine-based power based upon a coolant temperature of the ICE.

[0014] In other features, determining the available engine-based power based on a lookup table.

[0015] In additional features, the method includes commanding power consumption from the ICE based on the determination that available engine-based power is above the threshold; and determining whether minimum power is active for a predetermined time.

[0016] According to other implementations, the method includes commanding power consumption from the ICE based on a determination that the minimum power has been active for the predetermined time.

[0017] In other features, the method includes determining whether fuel is out in the vehicle; and commanding power consumption from high-voltage battery based on a determination that the fuel is out in the vehicle.

[0018] In other features, the method includes transitioning and blending power from the ICE to the high-voltage battery.

[0019] In other features, the method includes allocating power to an electric air compressor (EAC) and an electric coolant heater (ECH).

[0020] Further areas of applicability of the teachings of the present application will become apparent from the detailed

description, claims and the drawings provided hereinafter, wherein like reference numerals refer to like features throughout the several views of the drawings. It should be understood that the detailed description, including disclosed embodiments and drawings referenced therein, are merely exemplary in nature intended for purposes of illustration only and are not intended to limit the scope of the present disclosure, its application or uses. Thus, variations that do not depart from the gist of the present application are intended to be within the scope of the present application.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] FIG. **1** is a schematic diagram of an exemplary HEV having a control system that allocates power from the internal combustion engine and the high-voltage battery based on operating conditions according to various principles of the present application;

[0022] FIG. **2** is a plot illustrating coolant temperature for the internal combustion engine versus power according to various principles of the present application;

[0023] FIG. **3** is a plot illustrating battery temperature versus power limits according to various principles of the present application;

[0024] FIG. **4** is a logic flow diagram illustrating a method for operating the control system of FIG. **1** according to various principles of the present application; and

[0025] FIG. **5** is a logic flow diagram illustrating a method for operating the control system of FIG. **1** according to other features of the present application.

DESCRIPTION

[0026] As discussed above, in some HEV configurations, a power panel can be connected to a charge port of the HEV. An integrated dual charge module (IDCM) can use the energy from the high-voltage battery and engine to convert DC power to support AC loads connected to the power panel such as, but not limited to, power tools, appliances, computers and the like. It is generally difficult to observe and manage the selection of power source (battery or engine) while the HEV is supporting these external loads as HEV's typically do not have a human machine interface (HMI) dedicated to such task. In this regard, it is challenging to communicate details of vehicle behavior (status of operation, power consumption, time remaining, etc.) while the HEV is supporting such external loads. In some known prior art configurations, a user can select whether the engine can turn on or off as needed, or never to allow the engine to come on. In circumstances where the user has selected no engine operation, the sole energy source is the high-voltage battery.

[0027] The system and methods described herein determines power allocation (engine or battery) based on operating conditions such as engine coolant temperature and high-voltage load requirements. A control strategy determines when to switch to high-voltage battery power and transition back to engine power once available power is sufficient to meet the high-voltage load request. The control strategy also considers low fuel condition to default to high-voltage battery power.

[0028] Referring now to FIG. **1**, a functional block diagram of an example HEV **10** (also referred to herein as "vehicle **10**") according to the principles of the present application is illustrated. The vehicle **10** is a plug in hybrid electric vehicle and includes an electrified powertrain **14** generally having an internal combustion engine **18** and an electric motor **20**. While one electric motor **20** is shown in the functional block diagram of FIG. **1**, the vehicle **10** can have various configurations having various electric motors. The electrified powertrain **14** is configured to deliver drive torque from the engine **18**, from the electric motor **20**, or any combinations thereof, through a driveline **22** and to drive wheels **26**. The electrified powertrain **14** can be configured to drive rear drive wheels through a first driven axle however, the electrified powertrain **14** can be configured to alternatively or additionally drive front drive wheels through a second driven axle. The electric motor(s) **20** are powered by a high-voltage battery pack **28** (e.g., such as a 16 kilowatt-hour (kWh) lithium-ion battery pack). A low-voltage battery **30** (e.g., 12 volt) can be disposed in the vehicle **10** that is generally configured to power low voltage components of the vehicle **10**.

[0029] The electrified powertrain **14** includes a transmission **32**. A clutch (not shown) selectively disengages an output of the engine **18** from a remainder of the electrified powertrain **14**. In examples, the electric motor **20** can include a starting motor for the engine **18** or belt starter generator (BSG), connected to the engine **18** via a belt system. The electric motor **20** can also represent traction motors that can be used to deliver drive torque to the drive wheels **26** (such as during electric mode). As can be appreciated the electric motor **20** can be disposed at different positions in the powertrain **14**. In general, the position of the motor(s) represents the type of hybrid architecture.

[0030] An integrated dual charge module (IDCM) **36** includes an auxiliary power module (APM) **38** that functions as a DC-DC converter. The IDCM **36** can convert AC to DC power during external charging from an electric vehicle supply equipment to charge the battery pack **28**. The IDCM **26** can further convert DC to AC power to discharge from the battery pack **28** to support low voltage DC loads **39**. In addition, the IDCM **26** can convert DC to DC power to charge and maintain the 12V battery **30**.

[0031] Thermal devices in the vehicle **10** include an electric air compressor (EAC) **40** and an electric coolant heater (ECH) **42**. The EAC **40** and the ECH **42** are used to condition (heat or cool) the vehicle and its components including the battery **28** and vehicle passenger components (cabin, windshield, etc.). A human machine interface (HMI) **48** can be used to interface with the vehicle. The HMI **48** can be an instrument cluster, an infotainment device, a heads-up display, a handheld device (e.g., cellular phone) or any other device capable of communicating a message to a driver indicative of a drive state or other condition of the vehicle **10**.

[0032] An off-board power panel **50** is a hybrid vehicle device that can be externally connected to a vehicle charge port by way of the IDCM **36** similar to a charger plug connected during external charging. The power panel **50** can provide 120V, 30A outlets to power AC loads **52** like power tools, cellular phones, computers and the like.

[0033] A control system **60** for controlling operation of the electrified powertrain **14** includes a controller **70** that provides various inputs to the electrified powertrain **14**. The controller **70** is shown having a powertrain supervisory controller (PSC) **72**, a battery pack controller (BPC) **74**, and an engine controller (EC) **76**. It is appreciated that the controller **70** can include additional distinct controllers. Furthermore, while the controllers **72**, **74** and **76** are

described as unique controllers, the controller **70** can be configured to provide all control functionality.

[0034] The PSC **72** can be referred to as a hybrid control processor and can supervise all controllers in the controller **70**. The BPC **74** controls the high-voltage battery pack **28**. The BPC **74** manages the high-voltage battery pack **28** and monitors measurements and parameters from sensors **80** including parameters such as state of charge (SOC), state of health (SOH), voltage, temperature, current and power limits of the high-voltage battery pack **28**. The EC **76** controls the engine **18**. The EC **76** manages and monitors measurements and parameters from sensors **80** including fuel level, engine coolant temperature, speed, torque, engine status (start, stop, running, fault, etc.). The information is communicated with the PSC **72** and collectively the EC **76** and PSC **72** can determine when to start and stop the engine **18** depending upon vehicle conditions. The IDCM **36** also communicates with the PSC **72** and provides information when an external connection is established and whether it is for charging or discharging purposes.

[0035] With reference now to FIG. **2**, a plot **100** illustrating coolant temperature (for the engine **18**) versus power is shown. In particular, the plot **100** illustrates the relationship between engine power **110**, engine speed **114** and engine coolant temperature **120** over time is shown. In particular, access to engine power **110** is restricted based on coolant temperature **120**. In other words, under cold conditions, the operation of the engine **18** is constrained until the engine **18** can overcome the cold surroundings and produce steady power without the risk of stalling (which can occur at idle speed coupled with high load).

[0036] With reference now to FIG. **3**, a plot **150** illustrating battery temperature versus power limits. In particular, the plot **150** illustrates power available to thermal **160**, battery power limits **164** and battery temperature **170**. In general, as battery temperature **170** rises, so too does the battery power limit **164**. The power available to thermal **160** represents the power available for components such as the EAC **40** and ECH **42**. Again, as temperature rises in the battery **28**, so too does the available power.

[0037] In a cold operating scenario example of-**21** degrees Celsius, where power limits from the high-voltage battery pack **28** are sufficient to run thermal loads (such as, for example, 5 kW) but may not be sufficient to sustain power to the remainder of the powertrain **14**, the thermal devices **40**, **42** can consume this power to condition the high-voltage battery pack **28** which in turn will open up the battery power limits. The temperature of the high-voltage battery pack **28** rises, which means the vehicle **10** can utilize more battery power as the high- voltage battery pack **28** warms up. In this regard, under conditions where the power panel **50** is connected and the operating conditions are cold, the engine **18** cannot run effectively to provide power to the power panel **50**. As a result, the HV loads like thermal will not have any access to power to support conditioning in the vehicle **10**.

[0038] Another example where existing prior art controls simplistic design does not provide access to HV battery power is during cold conditions when the engine **18** has an out of fuel event or transitions to an out of fuel scenario. The engine coolant temperature based power does not work even though conditions are good for the engine **18** to start. If the HV battery **28** has enough state of charge to propel the vehicle **10**, cold conditions could mean that the windshield is icy and defrost functionality will not be available since there is no access to HV power for thermal loads (EAC **40**, ECH **42**, etc.), which is undesirable.

[0039] With additional reference now to FIG. **4**, a method for operating the control system of FIG. **1** according to examples of the present disclosure is shown and generally identified at reference numeral **200**. The method starts at **210**. At **212** control determines whether the vehicle **10** has started (for example, engine **18** has started and/or the vehicle **10** is in an operating state). If not, control continues normal vehicle operation at **216**. If the vehicle **10** has started at **212**, control determines whether there is an external load **52** connected to the vehicle **10** via the power panel or charge plug **50**. If yes, control compares engine based power to a threshold at **224**.

[0040] In examples, control compares the power that can be expected out of the engine **18** based on engine coolant temperature to a minimum power required to operate high-voltage loads such as thermal devices at **230**. In examples, the temperature-based engine power can be a look up table where below a certain temperature, there is no power available, i.e., 0 KW. Explained further, only when the engine **18** runs for some amount of time with the engine coolant temperature rise to a point where engine power (to support thermal loads) will slowly increase and reach a state where it is sufficient to support the thermal loads. The engine based power and threshold can be in the form of a lookup table.

[0041] If the generated power is not above minimum power to support thermal loads at **230**, control uses high-voltage battery power **234**. If the generated power is above minimum power to support thermal loads at **230**, control determines whether minimum power is active for a period of time at **240**. Explained further, once the engine power meets the minimum threshold, there is a wait time to allow the engine **18** to ramp (warm) up to a state where the power produced is steady. If yes, control switches to engine power at **244**. If no, control loops to **234**. At **250**, control transitions and blends engine power and high-voltage battery power. At **252** control allocates power to thermal devices (such as the EAC **40** and ECH **42**). Control ends at **260**. The techniques disclosed herein ensures a smooth transition occurs between high-voltage battery power and engine power (or vice-versa) to avoid sudden loss (or jump) of power.

[0042] With additional reference now to FIG. **5**, a method **300** for determining an out of fuel condition and transitioning smoothly from engine power to high-voltage power will be described. The method **300** starts at **310**. At **314** control determines whether the vehicle **10** is started. If not, control continues normal vehicle operation at **320**. If yes, control determines whether the engine **18** is out of fuel at **324**. If not, control proceeds to **320**. If yes, control uses high-voltage battery power at **330**. At **334**, control transitions and blends engine power and high-voltage battery power. At **338** control allocates power to thermal devices. Control ends at **340**.

[0043] As used herein, the term controller or module refers to an application specific integrated circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group) and memory that executes one or more software or firmware programs, a combinational logic circuit, and/or other suitable components that provide the described functionality.

[0044] It will be understood that the mixing and matching of features, elements, methodologies, systems and/or functions between various examples may be expressly contem-

plated herein so that one skilled in the art will appreciate from the present teachings that features, elements, systems and/or functions of one example may be incorporated into another example as appropriate, unless described otherwise above. It will also be understood that the description, including disclosed examples and drawings, is merely exemplary in nature intended for purposes of illustration only and is not intended to limit the scope of the present application, its application or uses. Thus, variations that do not depart from the gist of the present application are intended to be within the scope of the present application.

What is claimed is:

1. A powertrain that generates and transfers drive torque to a driveline of a hybrid electric vehicle, the powertrain comprising:

an internal combustion engine (ICE);

at least one electric motor powered by a high-voltage battery;

an integrated dual charge module (IDCM); and

a controller that controls operation of the powertrain based on operating conditions, wherein the controller is configured to:

determine whether an external load is connected to the vehicle through the IDCM;

determine an available engine-based power;

determine whether the available engine-based power is above a threshold to support thermal loads;

command power consumption from the high-voltage battery based on a determination that available engine-based power is not above the threshold;

command power consumption from the ICE based on a determination that available engine-based power is above the threshold; and

command a blending of power between the high-voltage battery and the ICE.

2. The powertrain of claim **1**, wherein the controller is further configured to:

determine available engine-based power based upon a coolant temperature of the ICE.

3. The powertrain of claim **2**, wherein the controller is further configured determine available engine-based power based on a lookup table. to:

4. The powertrain of claim **1**, wherein the controller is further configured to:

command power consumption from the ICE based on the determination that available engine-based power is above the threshold; and

determine whether minimum power is active for a predetermined time.

5. The powertrain of claim **1**, wherein the controller is further configured to command power consumption from the ICE based on a determination that the minimum power has been active for the predetermined time.

6. The powertrain of claim **5**, wherein the controller is further configured to:

determine whether fuel is out in the vehicle; and

command power consumption from high-voltage battery based on a determination that the fuel is out in the vehicle.

7. The powertrain of claim **6**, wherein the controller is further configured to:

transition and blend power from the ICE to the high-voltage battery.

8. The powertrain of claim **1**, further comprising:

an electric air compressor (EAC);

an electric coolant heater (ECH); and

wherein the controller is further configured to allocate power to the EAC and ECH.

9. A method for controlling a powertrain that generates and transfers drive torque to a driveline of a hybrid electric vehicle, the powertrain including an internal combustion engine (ICE), and at least one electric motor powered by a high-voltage battery, and an integrated dual charge module (IDCM), the method comprising:

determining, at a controller, whether an external load is connected to the vehicle through the IDCM;

determining, at the controller, an available engine-based power;

determining, at the controller, whether the available engine-based power is above a threshold to support thermal loads;

commanding power consumption from the high-voltage battery based on a determination that available engine-based power is not above the threshold;

commanding power consumption from the ICE based on a determination that available engine-based power is above the threshold; and

commanding a blending of power between the high-voltage battery and the ICE.

10. The method of claim **9**, further comprising:

determining the available engine-based power based upon a coolant temperature of the ICE.

11. The method of claim **10**, further comprising:

determining the available engine-based power based on a lookup table.

12. The method of claim **9**, further comprising:

commanding power consumption from the ICE based on the determination that available engine-based power is above the threshold; and

determining whether minimum power is active for a predetermined time.

13. The method of claim **9**, further comprising:

commanding power consumption from the ICE based on a determination that the minimum power has been active for the predetermined time.

14. The method of claim **13**, further comprising:

determining whether fuel is out in the vehicle; and

commanding power consumption from high-voltage battery based on a determination that the fuel is out in the vehicle.

15. The method of claim **14**, further comprising:

transitioning and blending power from the ICE to the high-voltage battery.

16. The method of claim **1**, further comprising:

allocating power to an electric air compressor (EAC) and an electric coolant heater (ECH).

* * * * *