US 20250264072A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2025/0264072 A1

(43) Pub. Date: Aug. 21, 2025

PURSIFULL et al.

(54) SYSTEM AND METHOD FOR DETECTING A FUEL TANK VALVE STATE IN A FUEL CELL ELECTRIC VEHICLE

(71) Applicant: **Ford Global Technologies, LLC**, Dearborn, MI (US)

(72) Inventors: **Ross Dykstra PURSIFULL**, Dearborn, MI (US); **Michiel J. VAN NIEUWSTADT**, Ann Arbor, MI (US)

(21) Appl. No.: **18/443,476**

(22) Filed: **Feb. 16, 2024**

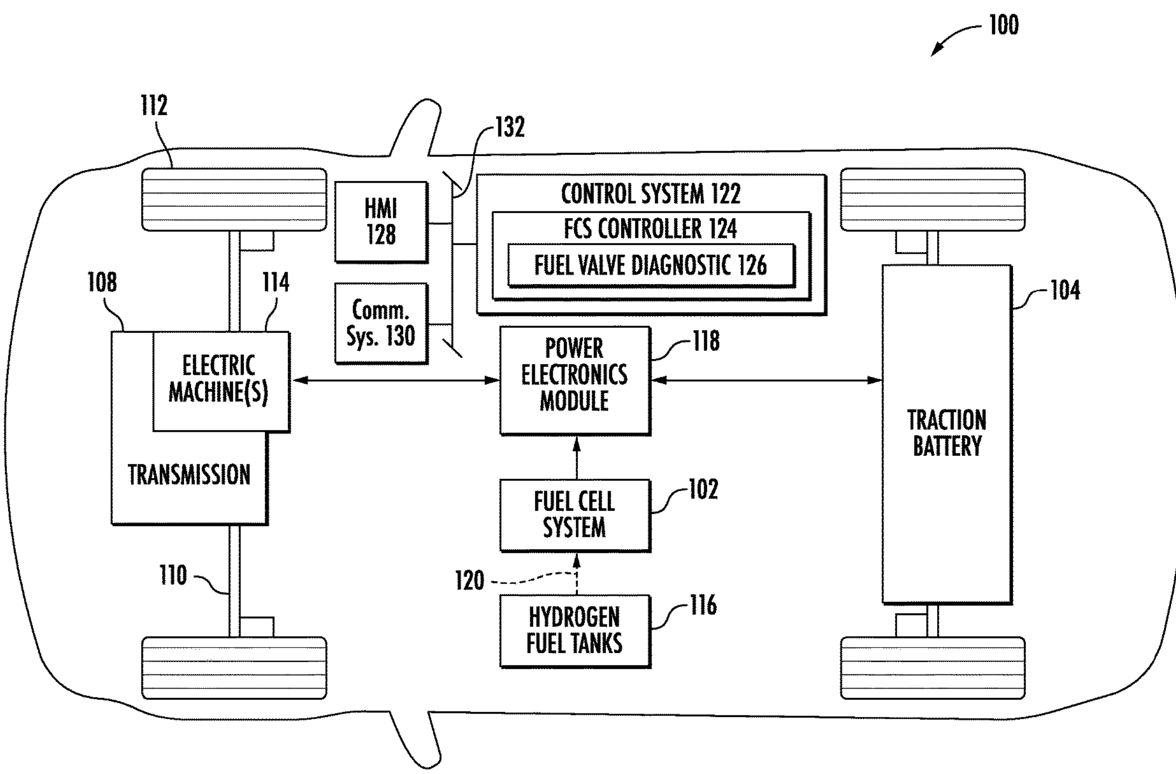
Publication Classification

(51) **Int. Cl.**
F02D 41/30 (2006.01)

(52) **U.S. Cl.**
CPC .. ***F02D 41/3082*** (2013.01); *F02D 2200/0602* (2013.01); *F02D 2200/0606* (2013.01)

(57) **ABSTRACT**

A control system for a fuel cell electric vehicle (FCEV) includes a controller that is configured to control a fuel delivery system to release fuel via an injector with a selected fuel tank valve among a plurality of fuel tank valves controlled to be in an open state and with the other fuel tank valves controlled to be in a closed state. The control is further configured to cause a corrective action in response to a fuel characteristic indicating the selected fuel tank valve is stuck closed.



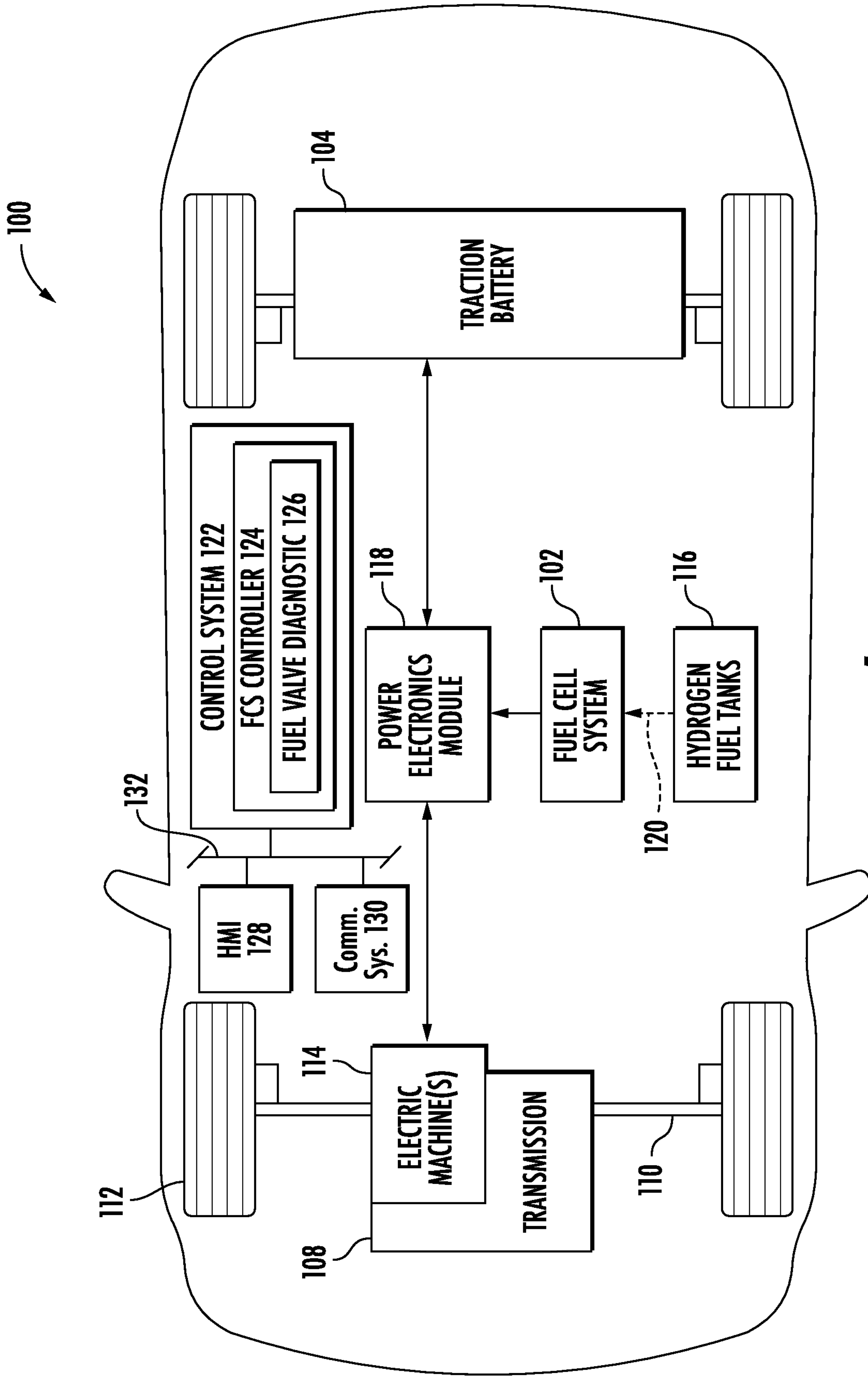

100
104
TRACTION BATTERY
CONTROL SYSTEM 122
FCS CONTROLLER 124
FUEL VALVE DIAGNOSTIC 126
118
POWER ELECTRONICS MODULE
102
FUEL CELL SYSTEM
116
HYDROGEN FUEL TANKS
120
132
HMI 128
Comm. Sys. 130
114
ELECTRIC MACHINE(S)
TRANSMISSION
110
112
108

FIG. 1

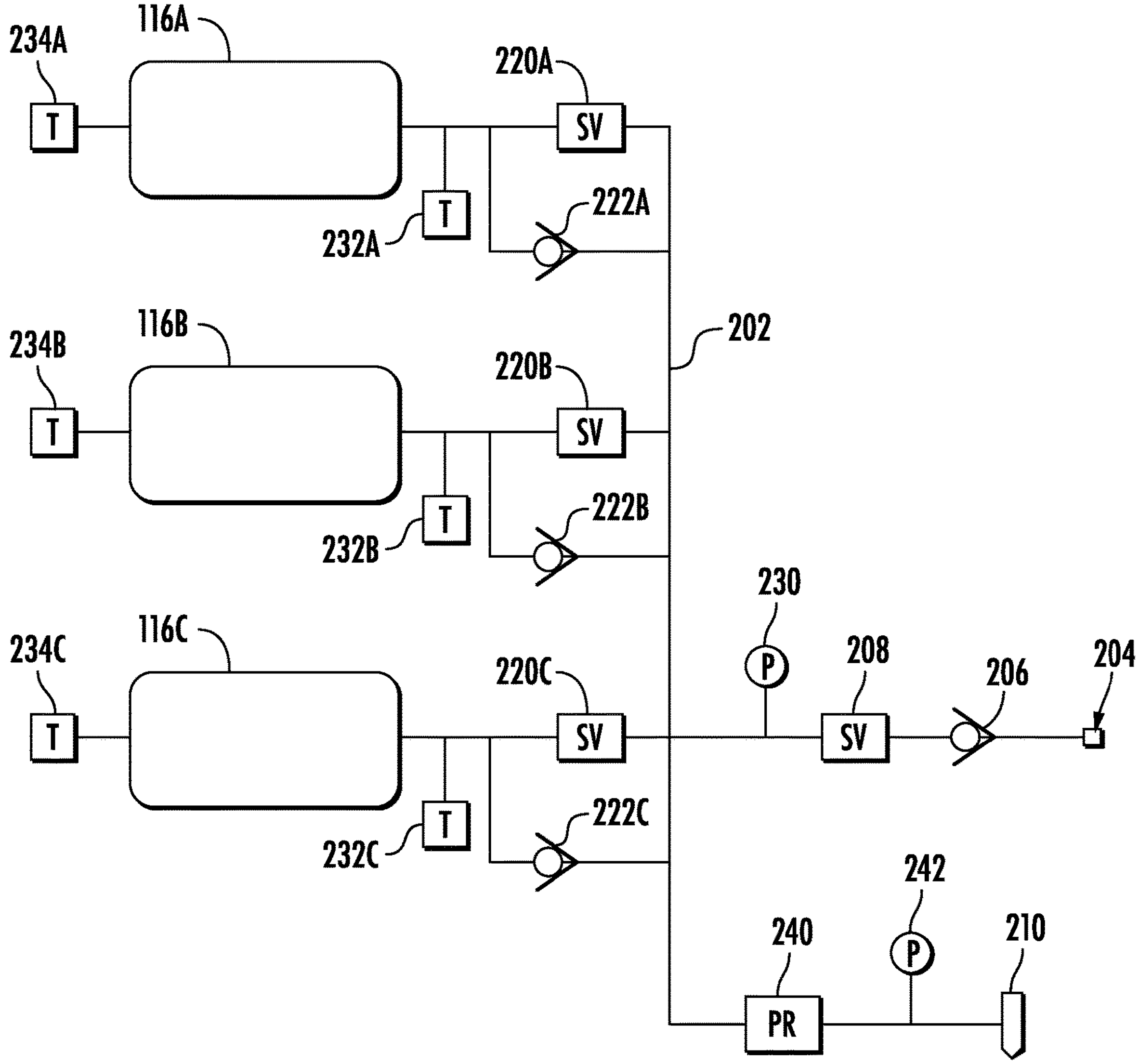

234A
116A
220A
SV
T
T
232A
222A
202
234B
116B
220B
SV
T
T
232B
222B
234C
116C
220C
SV
T
T
232C
222C
230
P
208
SV
206
204
240
PR
242
P
210

FIG. 2

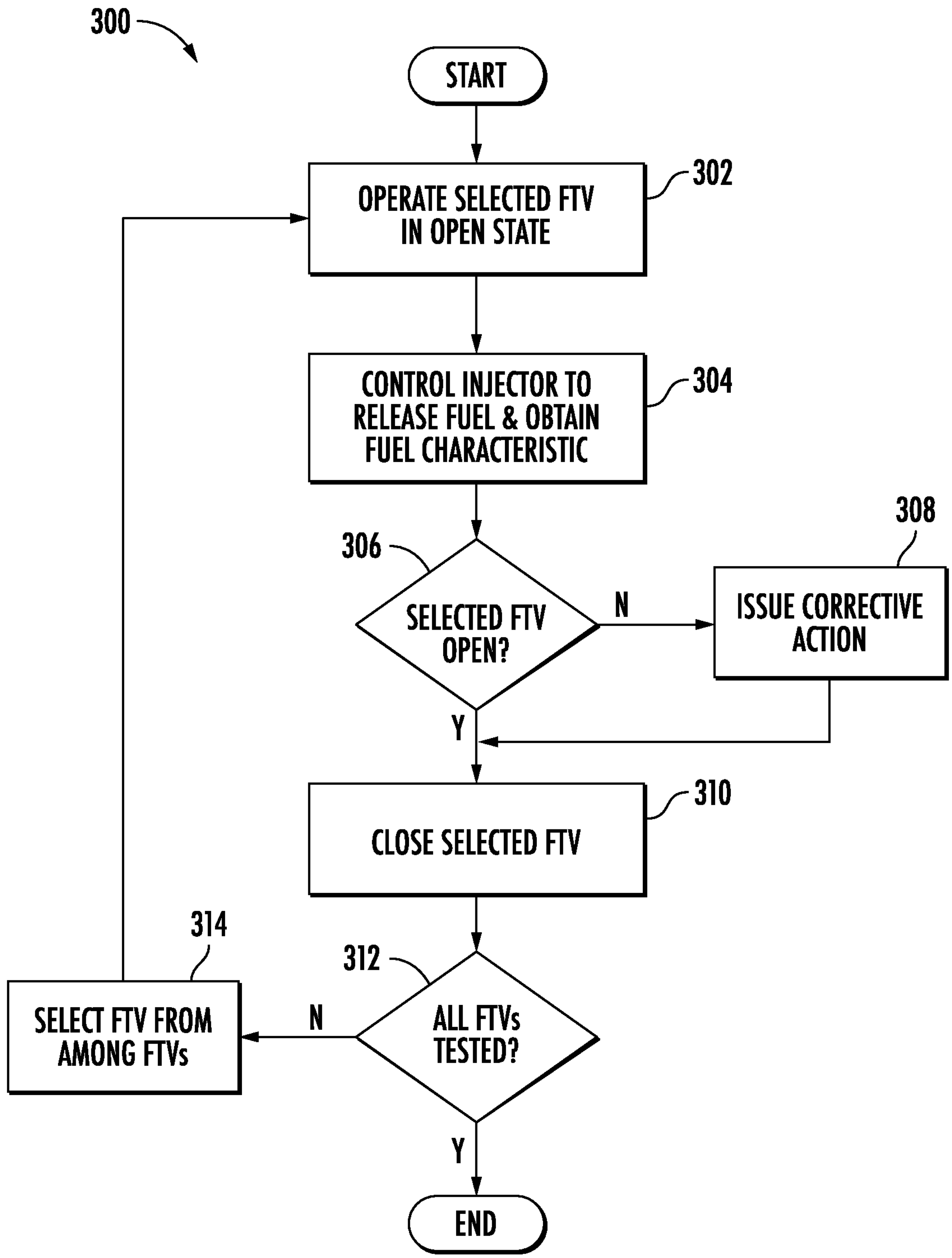

300
START
OPERATE SELECTED FTV IN OPEN STATE
302
CONTROL INJECTOR TO RELEASE FUEL & OBTAIN FUEL CHARACTERISTIC
304
306
SELECTED FTV OPEN?
N
ISSUE CORRECTIVE ACTION
308
Y
CLOSE SELECTED FTV
310
312
ALL FTVs TESTED?
N
SELECT FTV FROM AMONG FTVs
314
Y
END

FIG. 3

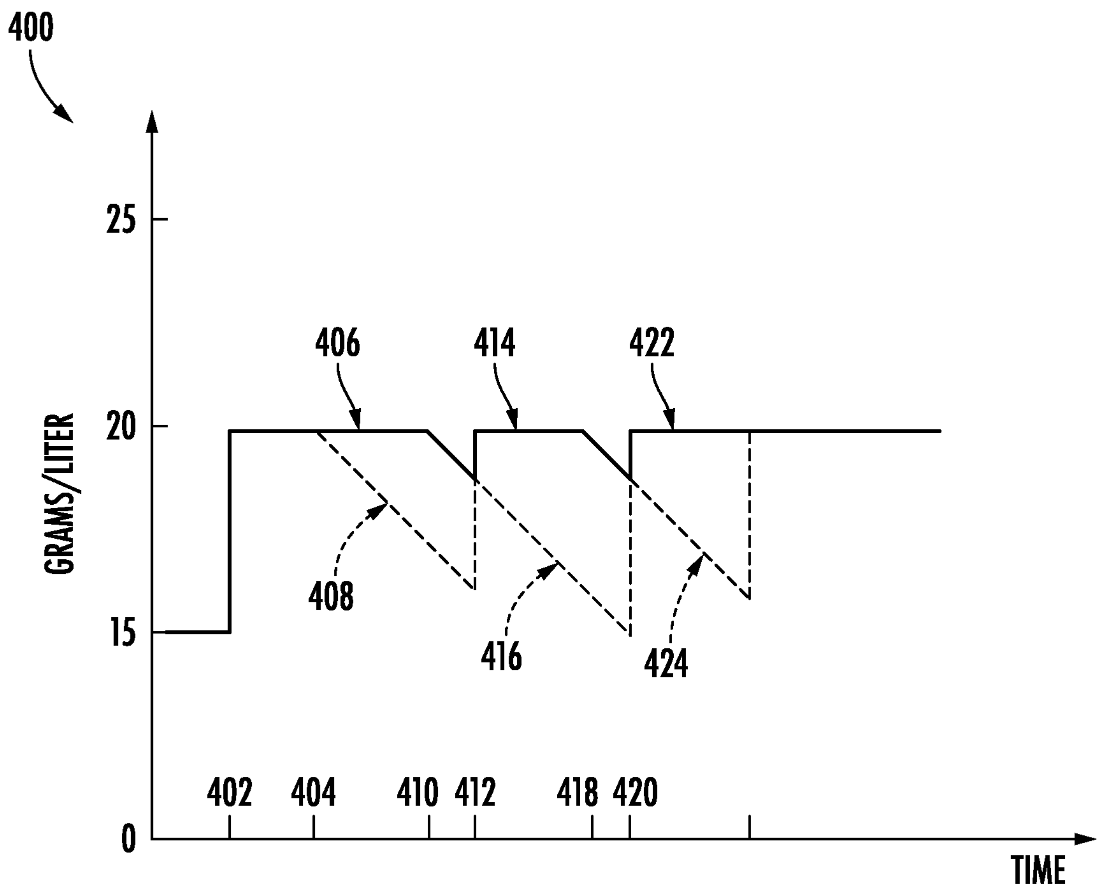

400
25
20
15
0
GRAMS/LITER
406
414
422
408
416
424
402
404
410
412
418
420
TIME

FIG. 4

SYSTEM AND METHOD FOR DETECTING A FUEL TANK VALVE STATE IN A FUEL CELL ELECTRIC VEHICLE

TECHNICAL FIELD

[0001] The present disclosure is generally directed to detecting a state of a fuel tank valve of a fuel cell electric vehicle.

BACKGROUND

[0002] A fuel cell is an electrochemical device that converts chemical energy of a fuel (e.g., hydrogen) and an oxidizing agent (e.g., oxygen) into electrical energy, with water as a byproduct. A fuel cell stack is a connected group of fuel cells. A fuel cell system including one or more fuel cell stacks may be used in a FCEV to provide electrical power for FCEV propulsion.

SUMMARY

[0003] In one form, the present disclosure is directed to a control system for a fuel cell electric vehicle (FCEV). The control system includes a controller that is configured to control a fuel delivery system to release fuel via an injector with a selected fuel tank valve among a plurality of fuel tank valves controlled to be in an open state and with the other fuel tank valves controlled to be in a closed state. The controller is further configured to cause a corrective action in response to a fuel characteristic indicating the selected fuel tank valve is stuck closed.

[0004] In one form, the present disclosure is directed to a method that includes controlling a fuel delivery system of a fuel cell electric vehicle (FCEV) to release fuel via an injector with a selected fuel tank valve among a plurality of fuel tank valves controlled to be in an open state and with the other fuel tank valves controlled to be in a closed state; and causing a corrective action in response to the selected tank valve being stuck closed as indicated by a fuel characteristic that is decreasing as fuel is being released.

[0005] In one form, the present disclosure is directed to a fuel cell electric vehicle (FCEV) that includes a plurality of fuel tanks, a plurality of fuel tank valves, a fuel delivery system, and a control system. The fuel delivery system is fluidly coupled to the plurality of fuel tanks via the plurality of fuel tank valves, and includes a fuel line connecting the plurality of fuel tanks to an injector. The control system includes a controller that is configured to execute a fuel valve diagnostic during which the controller is configured to, for each fuel tank valve: control the fuel delivery system to release fuel via the injector with a selected fuel tank valve controlled to be in an open state and with the other fuel tank valves controlled to be in a closed state; and cause a corrective action in response to the selected tank valve being stuck closed as indicated by a fuel characteristic that is decreasing as fuel is being released.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. **1** illustrates an example fuel cell electric vehicle (FCEV) in accordance with the present disclosure;

[0007] FIG. **2** illustrates a fuel delivery system of the FCEV in accordance with the present disclosure;

[0008] FIG. **3** is a flowchart of an example fuel valve diagnostic in accordance with the present disclosure; and

[0009] FIG. **4** is a graph of density measurements for an open state valve and a stuck closed state valve in accordance with the present disclosure.

DETAILED DESCRIPTION

[0010] As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention that may be embodied in various and alternative forms. The figures are not necessarily to scale; some features may be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the present invention.

[0011] In gaseous fuel vehicles (e.g., H2 fuel cell), fuel tank valves, which may be provided as solenoid valves, can be used to control the flow of gaseous fuel from a tank to an injector supplying the gaseous fuel to fuel cell stacks. In some instances, the fuel tank valve may be stuck closed and thus, not providing fuel to the injector.

[0012] In one form, the present disclosure is directed to a system and/or method of detecting whether a fuel tank valve is stuck closed and, even, identifying the fuel tank valve that is stuck. Specifically, in one form, a control system of the FCEV is configured to control a fuel delivery system to release fuel via an injector with a selected fuel tank valve among a plurality of fuel tank valves controlled to be in an open state and with the other fuel tank valves controlled to be in a closed state. The controller obtains data related to a fuel characteristic of the fuel and causes a corrective action in response to the fuel characteristic indicating the selected fuel tank valve is stuck closed. The controller controls each fuel tank valve in a similar manner, and thus, is able to detect whether at least one of the fuel tank valves is stuck closed and identify which of the fuel tank valves is stuck closed. In addition, the system/method of the present disclosure is operable to accommodate any number of tanks and applicable to common fuel tank valves (i.e., should not be limited to solenoid valves).

[0013] Details regarding the method/system of the present disclosure is now described with reference to the figures.

[0014] Referring now to FIG. **1**, a block diagram of an example fuel cell electric vehicle (FCEV) **100** having a fuel cell system (FCS) **102** and a traction battery **104** is shown. The FCS **102** and the traction battery **104** are individually operable for providing electrical power for propulsion of the FCEV **100**.

[0015] In a non-limiting example, the FCEV **100** includes a transmission **108** that is mechanically connected to a drive shaft **110** that is further mechanically connected to wheels **112** of the FCEV **100**. The transmission **108** is mechanically connected to one or more electric machines **114** that are operable as motors and as generators. That is, as motors, the electric machines **114** propels and/or slows the FCEV **100**, and as generators, the electric machines **114** are operable to recover energy that may normally be lost as heat in a friction braking system (not shown).

[0016] The electric machines **114** receive power from the FCS **102**, which is operable to convert hydrogen to electrical power for powering the electric machines **114** and, thus, propelling the FCEV **100**. In one form, the FCS **102** includes one or more fuel cell stacks (not shown). Each fuel cell stack is comprised of a plurality of fuel cells (e.g., proton-exchange membrane fuel cells) electrically connected (usually) in series. In operation, hydrogen from one or more fuel tanks **116** storing high pressure hydrogen is injected into the fuel cell stack causing a chemical reaction within the fuel cell stack that further generates electrical power, which is employed to power the electric machines **114**.

[0017] In one form, the FCS **102** is electrically connected to the electric machine **114** via a power electronics module **118** of the FCEV **100**. Among other components, the power electronics module **118** may include an inverter to transfer electrical power from the FCS **102** into electrical power having a form compatible for operating electric machine **114**. For example, the FCS **102** may provide high-voltage (HV) direct current (DC) electrical power while the electric machine **114** may use three-phase alternating current (AC) electrical power to operate. In this way, FCEV **100** is configured to be propelled with use of electrical power from FCS **102**.

[0018] The traction battery **104** is configured to store electrical energy for use by the electric machines **114** for propelling FCEV **100**. The traction battery **104** is also electrically connected to electric machines **114** via the power electronics module **118**. The power electronics module **118** provides the ability to bi-directionally transfer electrical power between the traction battery **104** and the electric machines **114**. Further, in a regenerative mode, the power electronics module **118** converts AC electrical power from electric machine **114**, acting as a generator, to the DC electrical power form compatible with the traction battery **104**.

[0019] Similarly, the traction battery **104** may receive electrical power from FCS **102** via the power electronics module **118**. For instance, when FCS **102** provides electrical power for propelling FCEV **100**, any excess electrical power from the FCS **102** not used in propelling the FCEV **100** may be received by the traction battery **104** via the power electronics module **118**.

[0020] With the fuel tanks **116**, the FCEV **100** further includes a fuel delivery system **120** illustrated as dashed lines in FIG. **1**. The fuel delivery system **120** is configured to deliver fuel from a source (not shown) to the fuel tank **116**, and is further configured to deliver fuel from the fuel tanks **116** to the FCS **102**.

[0021] The FCS **102** and the traction battery **104** may have one or more associated controllers to control and monitor the operation thereof. In a non-limiting example, the FCEV **100** includes a control system **122** configured to control vehicle systems, such as but not limited to a FCS controller **124**. In one form, the FCS controller **124** is configured to control operation of the FCS **102** including operating one or more valves to control the flow of fluid/fuel from the fuel tanks **116** to the fuel cell stacks. The FCS controller **124** may be a microprocessor-based device with predefined software controls. As detailed herein, the FCS controller **122** includes a fuel valve diagnostic **126** for evaluating a state of one or more valves controlling flow of fuel from the tanks **116**.

[0022] The FCEV **100** also includes other components unrelated to the FCS **102** or general propulsion devices. In a non-limiting example, the FCEV **100** includes human machine interfaces (HMIs) **128** and a communication system (Comm. Sys.) **130**, which are in communication with the control system **122** via a vehicle communication network **132**.

[0023] In one form, the HMIs **128** includes devices that exchange information with a user of the FCEV **100**, and may include, but is not limited to: service indicators on a dashboard, touchscreen display, and/or an audio system including speakers and microphone. In one form, the control system **122** is configured to notify the user of an operation state of the FCEV **100** using one or more of the HMIs **128**. The HMIs **128** may also be used to receive inputs from the user, such as an acknowledgement of receiving a notification.

[0024] The communication system **130** is configured to exchange messages with external devices/systems, such as but not limited to, other vehicles, computing devices (e.g., smart phones), remote cloud-based servers, and/or roadside units. Accordingly, in one form, the communication system **130** may include, but is not limited to: a telematics control unit, BLUETOOTH communication device, and/or microprocessor configured to process messages to be sent or received using one or more communication protocols.

[0025] In one form, referring to FIG. **2**, the fuel delivery system **120** includes a fuel line **202** having an inlet **204**, a check valve **206**, a fill prevention valve **208**, and a fuel injector **210**. The fuel line **202** is adapted to provide a flow path for the hydrogen fuel from the inlet **204**, to the tanks **116**, and further to the injector **210** that provides the hydrogen fuel to the fuel cells of the FCS **102**. The fuel line **202** may be formed of one or more conduits connected together to provide the flow path. While one fuel injector **210** is illustrated, the fuel delivery system **120** may include one or more fuel injectors **210**.

[0026] In one form, the inlet **204**, which may also be referred to as a receptacle, is adapted to receive a fuel nozzle at a fuel station during a fill operation in which a selected fuel tank **116** is filled with fuel. The check valve **206** is arranged downstream of the inlet before the tanks **116** to inhibit fuel from traveling back to the fuel nozzle via the inlet **204**. The fill prevention valve **208** is operable to be inhibit fuel from flowing to/from the tanks **116** when closed, and during a fill operation, is operable in an open position to allow fuel to travel through the fuel line **202**. In some forms, the fuel delivery system **120** may not include the fill prevention valve **208**.

[0027] In the example of FIG. **2**, three fuel tanks **116**A, **116**B, and **116**C are connected to the fuel line **202**. Details regarding the connection of the fuel tanks **116** to the fuel line **202** is described with respect to the fuel tank **116**A and is also applicable to fuel tanks **116**B and **116**C. Accordingly, reference characters having "A" correlate with the fuel tank **116**A, "B" correlate with the fuel tank **116**B, and "C" correlate with fuel tank **116**C.

[0028] With respect to the fuel tank **116**A, a fuel tank valve **220**A and a tank check valve **222**A connect the fuel tank **116**A to the fuel line **202**. The fuel tank valve **220**A is operable in a closed state to inhibit fuel from the tank **116**A from traveling to the fuel line **202** and in an open state to have fuel from the tank **116**A flow through the fuel line **202** to the injector **210**. In a non-limiting example, the fuel tank valve **220**A is a solenoid valve operable by the FCS controller **124**, and in some variations, may be a normally closed valve such that to place the tank valve **220**A in a closed state, the FCS controller **124** does not provide power to the valve **220**A, and to place the tank valve **220**A in an open state, the FCS controller **124** applies power to the valve **220**A to open the valve **220**A (i.e., the FCS controller **124** drives the fuel tank valve **220**). In some variations, once opened, the fuel tank valve **220**A may remain open until the FCS controller **124** applies power to close the valve **220**A.

[0029] The tank check valve **222**A is provided to inhibit fuel from the tank **116**A from flowing through the fuel line **202**. However, during the fill operation, the fuel tank valve **220**A is maintained in the closed state and fuel from fuel line **202** enters the fuel tank **116**A via the check valve **222**A.

[0030] Similar to the fuel tank **116**A, fuel tanks **116**B and **116**C also include fuel tank valves **220**B and **220**C, and tank check valves **222**B and **222**C, respectively. The fuel tank valves **220**A, **220**B, and **220**C may collectively be referred to as fuel tank valves **220**, and the fuel check valves **222**A, **222**B, **222**C may collectively be referred to as fuel check valves **222**.

[0031] In one form, the fuel delivery system **120** further includes various sensors for measuring different characteristics related to the fuel provided in the system **120**, such as but not limited to, pressure and/or temperature. More particularly, in one form, the fuel delivery system **120** includes one or more pressures sensors, such as a tank line pressure (TLP) sensor **230** and one or more temperature sensors, such as a tank line temperature (TLT) sensor **232**A,**232**B, **232**C (collectively "TLT sensors **232**") and a tank end temperature (TET) sensor **234**A, **234**B, **234**C (i.e., collectively "TET sensors **234**") arranged opposite of the TLT sensors **232**. The sensors are configured to provide respective data to the FCS controller **124**, which in return controls operation of the fuel delivery system **120** and the FCS **102**.

[0032] The TLP sensor **230** is arranged between the tanks **116** and the inlet **204** to measure a pressure of fuel entering or exiting the tanks **116**. The TLT sensor **232** is configured to detect the temperature of the fuel entering and leaving the tank **116**, and the TET sensor **234** is configured to detect temperature of the fuel in the tank **116**.

[0033] In one form, the fuel delivery system **120** may include additional devices, such as but not limited to a pressure regulator **240** provided upstream of the fuel injector **210** to adjust the pressure of the fuel to a desired pressure level prior to the fuel being discharged by the injector **210**. In some applications, an output fuel pressure sensor **242** is provided between the pressure regulator **240** and the injector **210** to detect an output pressure value of the fuel, which may be provided to the FCS controller **124** to monitor fuel pressure and adjust the pressure via the pressure regulator **240** if needed (e.g., the output pressure value is below or higher than the desired pressure level).

[0034] As described herein, among other system checks conducted by the FCS controller **124**, the pressure values from the TLP sensor **230** and, in some instances, temperature values from at least the TLT sensor **232** are employed to detect whether the fuel tank valve **220** is a stuck closed state.

[0035] Specifically, at times, it is possible that the fuel tank valves **220** may not open when the valve **220** is operated to be in the open state, and instead is stuck in the closed stated (i.e., stuck closed state), which may occur for various reasons such as wear of the valve **220**. Using the fuel valve diagnostic **126**, the FCS controller **124** is configured to detect whether the fuel tank valves **220** are operating as intended. Specifically, the fuel valve diagnostic **126** is configured to selectively operate each fuel tank valve **220** in an open state while the other fuel tank valves **220** are operated in the closed state. Monitoring a fuel characteristic, the FCS controller **124** is able to detect if the fuel tank valve that is intended to be in the open state is actually open. With this selective operation of the fuel tank valve **220**, the fuel valve diagnostic **126** detects if one or more of the fuel tank valves **220** is in the stuck closed state and is further able to identify which of the fuel tank valves **220** is stuck closed.

[0036] Details regarding the fuel valve diagnostic **126** is now described with reference to FIG. **3**, which provides a fuel valve diagnostic routine **300** executed by the FCS controller **124**. In one form, the FCS controller **124** is configured to perform the fuel valve diagnostic routine **300** when the FCEV **100** is turned on at which the fuel tank valves **220** are all in the closed state. At operation **302**, the FCS controller **124** is configured to select one of the fuel tank valves **220** to run the diagnostic test on to assess if the fuel tank valve **220** is in a stuck closed state, and operates the selected fuel tank valve (FTV) **220** in the open state. For example, starting with fuel tank valve **220**A, the FCS controller **124** applies power to the selected FTV **220**A to place the valve **220**A in the open state. In one form, the fuel tank valves **220**B and **220**C are operated in the closed state by not providing power to the valves **220**B and **220**C.

[0037] At operation **304**, the FCS controller **124** is configured to operate the injector **210** to release fuel to the fuel cell stack, and to obtain one or more fuel characteristics of the fuel in the fuel line **202**. By releasing fuel, the pressure of fuel within the fuel line **202**, which is detected by the TLP sensor **230**, would change (i.e., decrease) if the selected FTV **220**A is in the stuck closed state since fuel is not being provided in the fuel line **202**. In one form, the fuel characteristics may include pressure, density, and/or mass. As indicated above, the pressure may be detected by the TLP sensor **230**, and if the pressure begins to decrease, the FCS controller **124** determines that the selected FTV **220** is stuck closed.

[0038] In addition to or in lieu of monitoring only pressure, the FCS controller **124** is configured to obtain a density and/or mass of the fuel. Density may be a more accurate characteristic to monitor than pressure since density accounts for the effect temperature has on the fuel in the fuel line **202**. Density is a function of pressure and temperature, and mass is a function of density and volume, which is a constant.

[0039] In one form, to obtain the density, the FCS controller **124** is configured to obtain the pressure measurements from TLP sensor **230** and temperature measurements from the TLT sensor **232** associated with the fuel tank **116** having the selected FTV **220**. The FCS controller **124** is further configured to employ a fuel characteristic correlation that associates temperature values and pressure values with density values. In some variations, the fuel characteristic correlation is configured to adjust the temperature measurement to estimate a temperature of fuel at or closer to the TLP sensor **230** to improve accuracy of the density estimation. In one form, the fuel characteristic correlation is provided as a model, a series of algorithms, and/or a look-up table, where the temperature measurement and the pressure measurements are inputs, and a density value is an output.

[0040] In some variations, the fuel characteristic is provided as mass, and the FCS controller **124** employs another fuel characteristic correlation that is configured to correlate pressure measurements and temperature measurements with mass values. Alternatively, the FCS controller **124** is configured to use fuel characteristic correlation employed for determining density, and then multiples the density with the volume of the fuel line, which is a constant and predetermined.

[0041] At operation **306**, the FCS controller **124** is configured to determine whether the selected FTV **220** is open. Specifically, with the fuel characteristic being pressure, density, and/or mass, the FCS controller **124** is configured to detect the selected FTV **220** as being stuck closed and not open in response to the fuel characteristics decreasing. Accordingly, if stuck closed, the FCS controller **124** is configured issue a corrective action at operation **308**. The corrective action may include, but is not limited to: notifying a user of the FCEV **100** to request further evaluation of the selected FTV **220** (e.g., illuminating a service indicator on a dashboard, presenting a message on display, providing an audio message); notifying a vehicle service platform, which includes a remote cloud-based server configured to monitor and assist FCEVs, by transmitting a message to the vehicle service platform indicating the FCEV **100** has a stuck valve; and/or issuing and storing a diagnostic trouble code associated with a stuck closed FTV **220**; and/or reducing remaining travel distance of the FCEV **100** to account for unavailability of fuel from the tank **116** having the stuck closed FTV **220**, and the remaining travel distance may be displayed to the user on the dashboard.

[0042] If the selected FTV **220** is open as detected by the fuel characteristic not decreasing, the FCS controller **124** closes the selected FTV **220**, at operation **310**, and determines if all of the FTVs **220** are tested at **312**. If all FTVs **220** were tested, the fuel valve diagnostic ends. If one or more FTVs **220** still need to be tested, the FTC controller selects the next FTV **220** at operation **314** and proceeds to operation **302**.

[0043] The fuel valve diagnostic **126** may be configured in various suitable ways in accordance with the present disclosure and should not be limited to the example of routine **300**. In a non-limiting example, the fuel valve diagnostic **126** is configured to test only one FTV **220** each time the FCEV **100** is turned on. Thus, prior to operating all of the FTVs **220** in the open state as is generally done when the FCEV **100** is turned on, one of the FTVs **220** will undergo the diagnostic test. Accordingly, not all of the FTVs **220** are tested after the FCEV **100** is turned on. In addition, the selected FTV **220** may be closed prior to determining if the selected FTV is open (i.e., operations **310** may come before operation **306**).

[0044] In a non-limiting example, FIG. **4** illustrates a fuel density graph **400** depicting density of the fuel line **202** based on the operation of the selected FTV **220** over time. At **402**, the selected FTV **220**A is operated to be in the open state and at **404**, fuel is released from the injector **210**. If the selected FTV **220**A is open, the density in the fuel line should remain relatively constant (e.g., around 20 grams/liter (g/l)), as illustrated by line **406**. However, if the selected FTV **220**A is in a stuck closed state with the other FTVs **220**B and **220**C being in the closed state, the density begins to drop, as generally indicated by line **408**. Each FTV **220** is operated in a similar manner. For example, at **410**, the selected FTV **220**A is closed, and at **412**, as the selected FTV, the FTV **220**B is operated to be in the open state. Lines **414** and **416** provide density trend for when the FTV **220**B is open or is stuck closed, respectively. At **418**, the FTV **220**B is closed, and at **420**, as the selected FTV **220**C, is operated to be in the open state. Lines **422** and **424** provide density trends for when the FTV **220**C is open or is stuck closed, respectively.

[0045] While exemplary embodiments are described above, it is not intended that these embodiments describe all possible forms of the invention. Rather, the words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the invention. Additionally, the features of various implementing embodiments may be combined to form further embodiments of the invention.

[0046] In this application, the term "controller" and/or "module" may refer to, be part of, or include: an Application Specific Integrated Circuit (ASIC); a digital, analog, or mixed analog/digital discrete circuit; a digital, analog, or mixed analog/digital integrated circuit; a combinational logic circuit; a field programmable gate array (FPGA); a processor circuit (shared, dedicated, or group) that executes code; a memory circuit (shared, dedicated, or group) that stores code executed by the processor circuit; other suitable hardware components that provide the described functionality; or a combination of some or all of the above, such as in a system-on-chip.

[0047] The term memory is a subset of the term computer-readable medium. The term computer-readable medium, as used herein, does not encompass transitory electrical or electromagnetic signals propagating through a medium (such as on a carrier wave); the term computer-readable medium may therefore be considered tangible and non-transitory. Non-limiting examples of a non- transitory, tangible computer-readable medium are nonvolatile memory circuits (such as a flash memory circuit, an erasable programmable read-only memory circuit, or a mask read only circuit), volatile memory circuits (such as a static random access memory circuit or a dynamic random access memory circuit), magnetic storage media (such as an analog or digital magnetic tape or a hard disk drive), and optical storage media (such as a CD, a DVD, or a Blu-ray Disc).

[0048] The apparatuses and methods described in this application may be partially or fully implemented by a special purpose computer created by configuring a general-purpose computer to execute one or more particular functions embodied in computer programs. The functional blocks, flowchart components, and other elements described above serve as software specifications, which can be translated into the computer programs by the routine work of a skilled technician or programmer.

[0049] As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A OR B OR C), using a non-exclusive logical OR, and should not be construed to mean "at least one of A, at least one of B, and at least one of C."

[0050] The description of the disclosure is merely exemplary in nature and, thus, variations that do not depart from the substance of the disclosure are intended to be within the scope of the disclosure. Such variations are not to be regarded as a departure from the spirit and scope of the disclosure.

What is claimed is:

1. A control system for a fuel cell electric vehicle (FCEV), comprising:
a controller configured to:
control a fuel delivery system to release fuel via an injector with a selected fuel tank valve among a plurality of fuel tank valves controlled to be in an open state and with the other fuel tank valves controlled to be in a closed state; and
cause a corrective action in response to a fuel characteristic indicating the selected fuel tank valve is stuck closed.

2. The control system of claim 1, wherein the fuel characteristic is a pressure of fuel in a fuel line connected to a plurality of fuel tanks associated with the plurality of fuel tank valves, and the controller is configured to detect the selected fuel tank valve as being stuck closed in response to the pressure decreasing.

3. The control system of claim 1, wherein the fuel characteristic is density, and the controller is configured to detect the selected fuel tank valve as being stuck closed in response to the density decreasing.

4. The control system of claim 3, wherein the controller is configured to detect the density based on a temperature, a pressure, and a fuel characteristic correlation that associates temperature values and pressure values with density values.

5. The control system of claim 1, wherein:
the fuel characteristic is fuel mass, and
the controller is configured to detect the fuel mass based on a temperature, a pressure, and a fuel characteristic correlation that associates temperature values and pressure values with fuel mass values, and to detect the selected fuel tank valve as being stuck closed in response to the fuel mass decreasing.

6. The control system of claim 1, wherein the corrective action includes at least one of:
outputting a notification indicating the selected fuel tank valve may be stuck closed and request further evaluation of the selected fuel tank valve, or illuminating a service indicator on a dashboard of the FCEV.

7. The control system of claim 1, wherein the controller is configured to:
operate a selected subsequent fuel tank valve from among the plurality of fuel tank valves to have the selected subsequent fuel tank valve in the open state while the other fuel tank valves of the plurality of fuel tank valves are operated in the closed state;
control the fuel delivery system to release fuel via the injector; and
cause the corrective action in response to the fuel characteristic indicating the selected subsequent fuel tank valve is stuck closed.

8. The control system of claim 7, wherein the selected subsequent fuel tank valve is operated in the closed state at a subsequent time that the FCEV is turned on.

9. The control system of claim 7, wherein the selected subsequent fuel tank valve is operated in the closed state after the selected fuel tank valve and before the FCEV is turned off.

10. The control system of claim 1, wherein the controller is configured to identify the selected fuel tank valve as being stuck closed in response to the fuel characteristic decreasing.

11. A method comprising:
controlling a fuel delivery system of a fuel cell electric vehicle (FCEV) to release fuel via an injector with a selected fuel tank valve among a plurality of fuel tank valves controlled to be in an open state and with the other fuel tank valves controlled to be in a closed state; and
causing a corrective action in response to the selected tank valve being stuck closed as indicated by a fuel characteristic that is decreasing as fuel is being released.

12. The method of claim 11, wherein the fuel characteristic is a pressure of fuel in a fuel line connected to a plurality of fuel tanks associated with the plurality of fuel tank valves, and the selected fuel tank valve is detected as being stuck closed in response to the pressure decreasing.

13. The method of claim 11, further comprising:
detecting a plurality of density values, as the fuel characteristic, based on one or more temperature values, one or more pressure values, and a fuel characteristic correlation that associates temperature values and pressure values with density values; and
detecting the selected fuel tank valve as being stuck closed in response to the density values decreasing.

14. The method of claim 11, the method further comprising, as the corrective action, at least one of:
outputting a notification indicating the selected fuel tank valve may be stuck closed and requesting further evaluation of the selected fuel tank valve; or illuminating, as the corrective action, a service indicator on a dashboard of the FCEV.

15. The method of claim 11, further comprising:
operating a selected subsequent fuel tank valve from among the plurality of fuel tank valves to have the selected subsequent fuel tank valve in the open state while the other fuel tank valves of the plurality of fuel tank valves are operated in the closed state;
controlling the fuel delivery system to release fuel via the injector; and
causing the corrective action in response to the fuel characteristic indicating the selected subsequent fuel tank valve is stuck closed.

16. The method of claim 15, wherein the selected subsequent fuel tank valve is operated in the closed state at a subsequent time that the FCEV is turned on.

17. The method of claim 15, wherein the selected subsequent fuel tank valve is operated in the closed state after the selected fuel tank valve and before the FCEV is turned off.

18. A fuel cell electric vehicle (FCEV), comprising:
a plurality of fuel tanks;
a plurality of fuel tank valves;
a fuel delivery system fluidly coupled to the plurality of fuel tanks via the plurality of fuel tank valves, the fuel delivery system including a fuel line connecting the plurality of fuel tanks to an injector; and
a control system including a controller that is configured to execute a fuel valve diagnostic during which the controller is configured to, for each fuel tank valve:
control the fuel delivery system to release fuel via the injector with a selected fuel tank valve controlled to be in an open state and with the other fuel tank valves controlled to be in a closed state; and
cause a corrective action in response to the selected tank valve being stuck closed as indicated by a fuel characteristic that is decreasing as fuel is being released.

19. The FCEV of claim **18**, further comprising:

a plurality of temperature sensors downstream of the plurality of fuel tanks measuring a temperature of fuel from the plurality of fuel tanks; and

a pressure sensor downstream of the plurality of fuel tank valves measuring a pressure of the fuel,

wherein the controller is configured to detect a density, as the fuel characteristic, based on a temperature associated with the selected fuel tank valve, the pressure, and a fuel characteristic correlation that associates temperature values and pressure values with density values.

20. The FCEV of claim **18**, wherein the corrective action includes at least one of:

outputting a notification indicating the selected fuel tank valve may be stuck closed and request further evaluation of the selected fuel tank valve, or

illuminating a service indicator on a dashboard of the FCEV.

* * * * *