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(54) **Pump condition monitoring and recording**

(57) A fluid pumping system includes a fluid pump, an actuator coupled to the fluid pump, and a controller operatively coupled to the actuator. The controller is configured to detect an irregular condition of at least one of the fluid pump, the actuator or the controller, and upon detecting the irregular condition, to modify at least one operating parameter of the actuator to prevent the irregular condition from transitioning to a fault condition.

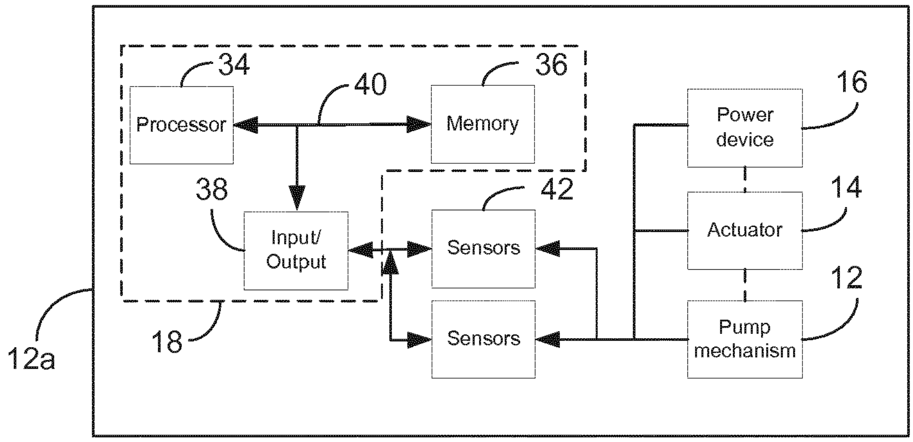

Fig. 2

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Description

[0001] The present invention relates to fluid pumps, and more particularly, to an apparatus, system and method for minimizing the occurrence of fault conditions that would otherwise shut down a fluid pump.

[0002] Control systems for controlling devices, such as electric motors, are well known in the art. Typically, a control system includes a main power component, e.g., a power module or the like that provides current and voltage to the motor, and a controller, e.g., a computer or other "smart" device that supervises system operation and provides control signals to the power module.

[0003] Part of the supervisory function of the controller includes the detection of fault conditions. A fault condition typically refers to any condition that is not within a predefined operating range of a component or group of components. For example, during normal operating conditions a motor may be expected to operate within a specific temperature range. Damage to the motor may result if the motor is operated when the motor temperature falls outside the temperature range. The controller typically shuts down the motor in response to such an "over- temperature" condition, preventing damage due to excessive heat.

[0004] A problem with conventional control systems that shut down on the occurrence of a fault is that they prevent use of the system, which can be problematic in certain situations. For example, if the fluid pump is a fuel pump for a vehicle, shutting down the fuel pump prevents operation of the vehicle.

[0005] The invention provides a system, apparatus and a method for controlling a device, such as a fluid pump or the like, in such a way that fault conditions that would otherwise prevent operation of the device are minimised or eliminated. For example, a fluid pumping system provides indicators regarding system functionality. In response to potential fault conditions, the system can take actions to maintain safe system operation so as to prevent the occurrence of a fault condition while also providing alerts to potential fault conditions. Examples of indicators include (a) a low voltage condition, which may be caused by a defective battery, a defective alternator, a cold start condition, (b) irregular pressure readings, which may indicate a higher than normal flow restriction, (c) pump starts with no load, which may indicate a dry running condition, and (d) high temperature conditions.

[0006] The system may take appropriate action when any of the above or other conditions are detected. For example, during a low voltage condition the system may command the pump to run at a reduced speed, thereby preventing a system shutdown and enabling system operation with limited power availability. Should a no load condition be detected, the system may increase pump speed to remove air from the system. If load does not increase within a prescribed time, then the system may be shut down. Regarding a high temperature condition, the system may run the pump at a reduced speed to protect mechanical and/or electronic components.

[0007] In addition, the system may save information regarding occurrences of irregular conditions such as over-current, under-voltage and over-temperature conditions. This information may be saved within a memory unit of the pump and accessed when servicing the pump, or when the pump is returned through the warranty process.

[0008] The invention therefore provides a fluid pumping system which includes a fluid pump, an actuator coupled to the fluid pump, and a controller operatively coupled to the actuator, the controller configured to detect an irregular condition of at least one of the fluid pump, the actuator or the controller, and upon detecting the irregular condition, modify at least one operating parameter of the actuator to prevent the irregular condition from transitioning to a fault condition.

[0009] Optionally, the fluid pump comprises at least one of a fuel pump, an oil pump, and a water pump.

[0010] Optionally, the actuator comprises an electric motor.

[0011] Optionally, the irregular condition comprises at least one of a low voltage condition, a fluid pressure condition, a no-load condition, or a high-temperature condition.

[0012] Optionally, the controller is configured to conclude the system is in a no-load start up condition when fluid pressure at the fluid pump is less than a predetermined pressure.

[0013] Optionally, the controller is configured to command the actuator to increase a speed of the fluid pump during the no-load startup condition.

[0014] Optionally, the controller is configured to stop the actuator when the pressure at the fluid pump does not exceed the predetermined pressure and a predetermined time period has elapsed.

[0015] Optionally, the system includes a variable flow device in fluid communication with the fluid pump, the controller being configured to command the actuator to decrease a speed of the fluid pump when fluid pressure at the fluid pump is greater than a predetermined pressure,.

[0016] Optionally, the controller is configured to provide an alert indicating the variable flow device requires maintenance when the fluid pressure at the fluid pump is greater than the predetermined pressure.

[0017] Optionally, the controller is configured to monitor an actual temperature of at least one of the fluid pump, a fluid in the system, the actuator, or the controller, and the controller is configured to command the actuator to reduce a speed of the fluid pump upon the actual temperature exceeding a corresponding predetermined temperature.

[0018] Optionally, the controller is configured to provide an alert indicating the actual temperature has exceeded the predetermined threshold temperature.

[0019] The invention also provides a controller for controlling a fluid pump via an actuator coupled to the fluid pump, which includes a processor and memory, and logic stored in the memory and executable by the processor, the logic including logic configured to detect an irregular condition of at least one of the fluid pump, the actuator or the controller, and logic, upon detecting the irregular condition, configured to modify at least one operating parameter of the actuator to prevent the irregular condition from transitioning to a fault condition.

[0020] Optionally, the irregular condition comprises at least one of a low voltage condition, an irregular fluid pressure condition, a no-load condition, and a high-temperature condition.

[0021] Optionally, the controller is configured to store irregular conditions in non-volatile memory.

[0022] Optionally, the controller is configured to conclude the pump is in a no-load start up condition when fluid pressure at the fluid pump is less than a predetermined pressure.

[0023] Optionally, the controller is configured to command the actuator to increase a speed of the fluid pump during the no-load startup condition.

[0024] Optionally, the controller is configured to stop the actuator when the pressure at the fluid pump does not exceed the predetermined pressure and a predetermined time period has elapsed.

[0025] Optionally, the fluid pump is in fluid communication with a variable flow device, the controller is configured to command the actuator to decrease a speed of the fluid pump when fluid pressure at the fluid pump is greater than a predetermined pressure.

[0026] Optionally, the controller is configured to provide an alert indicating the variable flow device requires maintenance when the fluid pressure at the fluid pump is greater than the predetermined pressure.

[0027] Optionally, the controller is configured to monitor an actual temperature of at least one of the fluid pump, a fluid in the system, the actuator, or the controller, and the controller is configured to command the actuator to reduce a speed of the fluid pump upon the actual temperature exceeding a corresponding predetermined threshold.

[0028] Optionally, the controller is configured to provide an alert indicating the actual temperature has exceeded the predetermined threshold temperature.

[0029] The invention also provides a method of controlling a fluid pump via an actuator coupled to the fluid pump, which includes: detecting an irregular condition of at least one of the fluid pump or the actuator, and upon detecting the irregular condition, modifying at least one operating parameter of the actuator to prevent the irregular condition from transitioning to a fault condition.

[0030] The invention is described below by way of example with reference to the accompanying drawings, in which:

Fig. 1 is a schematic diagram showing a fluid pumping system.

Fig. 2 is a block diagram showing a fluid pumping system.

Fig. 3 is a flow chart steps for an auto-purge operation.

Fig. 4 is a flow chart showing a thermal de-rate operation.

Fig. 5 is a flow chart showing a fluid pump cooling operation.

Fig. 6 is a flow chart showing a voltage de-rate operation.

[0031] An apparatus, system and method for controlling a controlled element, such as a fluid pump (e.g., a fuel pump, water pump, oil pump, etc.) and the like, analyses actual system data to determine the presence of an irregular condition (e.g., a potential fault condition). In the event an irregular condition is detected, certain actions may be taken to prevent occurrence of a fault condition and thus prevent system shutdown, thereby maintaining a level of operation yet minimizing the likelihood of component damage.

[0032] As used herein, the term "fault condition" is defined as an event triggered due to an operating characteristic of the system and/or a component of the system exceeding a prescribed fault threshold level. Continued operation of the system above the fault threshold level may result in system damage.

[0033] As used herein, the term "irregular condition" is defined as an event triggered due to an operating characteristic of the system and/or a component of the system exceeding a prescribed safe threshold level. Such safe threshold level is preferably set such that operation of the system while at or exceeding the safe threshold level for short periods of time and beneath the fault threshold level does not result in system damage.

[0034] As used herein, the term "controlled element" refers to a device that is responsive to an input to produce a corresponding output.

[0035] Referring to the drawings, Fig. 1 shows an example of a fluid pumping system 10 which includes a controlled element in the form of a fluid pump 12 that is in fluid communication with a fluid source (e.g., a fuel tank), and an actuator 14 (e.g., an electric motor or other actuator) mechanically coupled to the pump 12 and operative to drive the pump 12. The pump 12 may be any conventional pump. A power device 16 is electrically coupled to the actuator 14 and is operative to provide electric power to the actuator 14. A controller 18 is communicatively coupled to the power device 16 and is operative to command the power device 16 to drive the actuator 14 at a desired speed, thereby producing an output from the fluid pump 12.

[0036] A variable flow device 20 is in fluid communication with an output of the pump 12. The variable flow device 20 may be any device in which a fluid flow through the device may change over time. One example of a variable flow device is a filter. When the filter is new, fluid flow through the filter is relatively unimpeded. Fluid flow through the filter becomes more restricted as the filter removes contaminants from the fluid.

[0037] A pressure sensor 22 is communicatively coupled to the controller 18 and is operative to measure head pressure at the pump 12. Additionally, a current sensor 24 is a communicatively coupled to the controller 18 and is operative to measure current provided to the actuator 14 (which can be used to infer pump head pressure). Temperature sensors 25a, 25b and 25c monitor the temperature of the fluid pump 12, actuator 14 and power device 16, respectively, and communicate such measured temperatures to the controller 18.

[0038] In one construction, the controller 18 is separate from the fluid pump 12, and in another embodiment the controller 18 is integral with the fluid pump 12. The controller 18 may include, for example, a processor memory (e.g., volatile and/or non-volatile memory). The memory may include code stored therein that is executable by the processor. The code may include any number of algorithms configured to carry out the methods in accordance with the present disclosure. Alternatively, the controller 18 may include dedicated logic, e.g., an application-specific integrated circuit (ASIC) configured to carry out the methods described herein.

[0039] Optionally, pump load may be monitored during a start-up condition to determine if the pump is experiencing a "no-load" condition. A start-up condition can be defined, for example, as the time period beginning when the pump 12 is commanded from an OFF state to an ON state and extending for a prescribed time period after the transition (e.g., 30 seconds). A no-load condition is defined as the controlled element (e.g., pump 12) experiencing a load that is less than a prescribed threshold load during a start-up condition.

[0040] Actual pump load can be determined, for example, by measuring actual current supplied to the actuator 14 driving the pump 12 via current sensor 24. Alternatively, pump load can be determined by measuring pressure at the pump head via pressure sensor 22. Regardless of how pump load is determined, the measured parameter (e.g., motor current, head pressure, etc.) then can be compared to a corresponding prescribed threshold value. If the measured parameter is less than the prescribed threshold value and the pump is in the start-up condition, then it can be concluded the pump is experiencing a "no-load" condition.

[0041] If a no-load condition is detected, then the controller 18 can command the power device 16 to increase motor speed (and thus pump speed) to quickly purge air out of the system. If the no-load condition continues after a prescribed time period, it can be concluded that fluid (e.g., fuel) is not being provided to the pump 12. The controller 18 can then command the power device 16 to stop the actuator 14 (and thus the pump 12).

[0042] Optionally, the condition of the variable flow device 20 may be monitored to determine if a flow restriction is present (e.g., due to the filter being dirty). Conventionally, filter replacement is required at intervals as specified by the manufacturer, regardless of actual filter condition. In accordance with the present disclosure, filter condition can be deduced based on pressure measurements and therefore changed on an "as needed" basis. This provides optimal maintenance of the filter medium and also can minimize costs, particularly in situation where the filter is not subjected to fluids have high levels of contaminants.

[0043] For example, in the case where the variable flow device 20 is a fluid filter the condition of the filter 20 can be determined based on a pressure measurement at the pump head and/or a pressure drop across the filter 20 itself (e.g., using a second pressure sensor at the output of the filter 20 and determining the pressure drop based on the pressure at the pump head and the pressure at the output of the filter 20). If pressure at the pump head exceeds a first prescribed pressure threshold and/or if a pressure drop across the filter 20 exceeds a second prescribed pressure threshold, it can be concluded the filter 20 is dirty and thus should be replaced. Alternatively, the condition of the filter 20 can be determined by monitoring load on the actuator 14. For example, it may be known that when the filter is new (clean) that a particular pump speed procures a correspond actuator current. Such expected parameters, which may be empirically determined, can be stored in memory of the fluid pump (e.g., in the form of a lookup table) and monitored over time. Should the actuator current for a particular speed exceed the stored value for a prescribed period of time, it can be concluded that the filter requires replacement.

[0044] The controller 18 can provide an alert informing the user that the filter 20 should be replaced in the event that a flow restriction be detected. Further, the controller 18 can command the power device 16 to reduce actuator speed (and thus pump speed). This will enable system operation at a reduced power level without incurring a possible fault condition due to a pump over-pressure or actuator over-current event. In other words, the pump 12 may still provide fuel to an engine to enable engine operation at a reduced power capacity. While the above example is in the context of a filter, the concept is applicable to any type of variable orifice/variable flow restrictor.

[0045] The controller 18 may protect itself, the fluid pump 12 and/or the power device 16 from damage due to high temperature conditions. Traditionally, high temperature faults shut off or permanently damage the pump/motor. If the pump 12 is a fuel pump, such shutdown results in complete shutdown of the engine to which the pump is supplying fuel, which may be undesirable. Optionally, temperature sensing devices can be operatively coupled to the pump 12, actuator 14, electronics of the controller 18 and/or power device 16. The measured temperatures can be compared by the controller 18 to one or more threshold temperatures. If the measured temperature of the pump 12, actuator 14, controller 18 and/or power device 16 exceeds a corresponding threshold temperature, the controller 18 can reduce the speed of the actuator 14 (and thus of the pump 12). The reduced speed not only reduces heat generated by the pump and actuator due to mechanical load, but also reduces the current drawn by the electronics (and thus the heat dissipated by the electronics) while still providing some minimum amount of pumping capacity to the system. In the case of a fuel pump, this enables the engine to be run at some minimum power level. Such feature can extend the longevity of the system and, if the user is alerted and action taken in time to address the conditions leading to the high temperature, the system is protected from catastrophic failure. Further, the system can continue running at a capacity that is reduced to sufficiently protect the system components while the end user addresses the reason for the high temperature condition.

[0046] An additional benefit of the system, apparatus and method provided by the invention is that events, such as over-current, under-voltage and over-temperature conditions, can be logged over time, which can be useful when analysing a warranty return for defects, and also when conducting field service of the component(s). For example, the events can be logged into non-volatile memory of the fluid pump 12. By logging data into memory of the pump 12, information can be recorded with very little added controller cost and no additional components. Moreover, when the pump 12 is serviced and/or upon pump failure, the data can be extracted from the pump memory and analysed to determine a possible cause of the failure. Such information can be used not only for correcting a possible problem within the overall system, but also for approving or denying warranty claims. More specifically, the information stored in the memory of the pump 12 may indicate whether or not the pump was operated outside OEM (original equipment manufacturer) specifications. If it can be determined that the pump was operated within OEM specifications and failed while within the warranty period, then the pump may be repaired and/or replaced under warranty. However, if it can be determined from the stored data that the pump 12 was operated outside the OEM specifications, warranty coverage may be denied.

[0047] Optionally, the pump or other system component can be arranged to be cooled automatically after system shutdown. For example, a temperature of the pump and/or fluid may be measured using a temperature sensor. A high pump and/or fluid temperature can be indicative of an undesirable condition that could eventually result in system reliability issues. For example, for an internal combustion engine the undesirable condition may be high cylinder head temperatures, which may cause the head to warp and lose sealing ability. For a turbocharger, the undesirable condition may be bearing over-temperature, which may result in shortened bearing life. In these and other situations, the cooling effect provided by continued fluid flow after engine shut down can minimize such conditions.

[0048] If the temperature exceeds a prescribed temperature threshold, but still within a safe operating temperature of the pump 12, the pump may be commanded to continue to operate even when the remainder of the system 10 is shut down (e.g., in the case of a fuel pump, the pump may continue to circulate fuel through fuel lines when the engine is shut down). This continued fluid flow acts to cool the pump 12 and/or other system component. Such continued fluid flow may continue for a prescribed time period or until the temperature of the pump and/or system component as measured by the sensor 25a drops below a prescribed temperature threshold.

[0049] In addition, other system conditions can be monitored, such as a dead battery, a malfunctioning alternator, a cold start condition due to low voltage, etc. Further, the system can respond to certain detected conditions so as to maintain system operation at a safe level. For example, the controller 18 can maintain constant pressure in a fuel delivery line to the engine by using a signal from pressure sensor linked to a PWM (pulse width modulated) control to vary BLDC (brushless direct current) motor speed. Additionally, the need for a pressure relief valve can be eliminated by reducing pump speed upon detecting an over-pressure condition. Also, the pump 12 can be protected from running dry by shutting the pump down when no load is detected.

[0050] Fig. 2 is a simple block diagram of a fluid pump assembly 12a where the controller 18, power device 16, actuator 14 and/or fluid pump 12 are formed as an integrated unit. More particularly, the fluid pump assembly 12a may be a smart fluid pump assembly 12a that includes a processor 34 or the like operatively coupled to memory 36 and an input/output (I/O) device 38 via a system buss 40. The processor 34 may be any conventional processor known in the art. The memory 36 preferably includes volatile memory and non-volatile memory, and in one embodiment stores instructions executable by the processor 34.

[0051] The I/O device 38 may be operatively coupled to one or more sensors 42, the sensors measuring one or more characteristics of the fluid pump 12 and associated components. For example, the one or more sensors 42 may include a temperature sensor, a pressure sensor and/or a speed sensor. In the construction shown in Fig. 2 the one or more sensors 42 are integral with the fluid pump assembly 12a. In another construction, the sensors are stand-alone sensors that may be mounted on or near the fluid pump 12.

[0052] During pump operation the processor 34, executing code stored in memory 36 can collect data from the sensors 42 and store the data in non-volatile memory 36. The data can be retrieved and processed as the pump assembly 12a is serviced. As noted above, this can be advantageous in processing warranty claims.

[0053] Fig. 3 is a flow chart showing steps for an auto-purge function. The auto-purge function is useful during initial pump startup as it can quickly purge air pockets from the system 10, thereby allowing system pressure to build rapidly. The steps shown in Fig. 3 can be implemented via the controller 18.

[0054] Beginning at block 100, power is applied to the fluid pumping system 10, which would typically occur during vehicle start, and at block 102 it is determined if communications can be established to the controller 18. In Fig. 3, the communications protocol is CAN bus, although other types of communication protocols may be implemented. If a CAN message is received by the controller 18, then at block 104 the controller commands the actuator 14 to run the pump 12 at a command speed, e.g., a speed commanded by some other subsystem or a preset speed. For example, a pump speed setpoint may be generated based on operating conditions of the system, e.g., cooling requirements, throttle position, engine speed, etc. Such speed setpoint may be generated within controller 18 or from some other controller.

[0055] Moving back to block 102, if a CAN message is not received at the controller 18, then this indicates a system startup is occurring or CANBus is not being used by the system. During system startup, a timer is initialized and started at block 106, and at block 108 the controller 18 commands the actuator 14 to run the pump 12 at a default speed. The default speed may be a preset speed stored, for example, in memory of the controller 18. Such default speed may be a minimum speed setting for the pump 12 or it may be some other speed setting as required by the application.

[0056] Next at block 110 it is determined if the pump 12 is under load. As noted herein, one way in which it may be determined if the pump 12 is under load is to monitor the current drawn by the actuator 14 that drives the pump 12. Such current may be obtained, for example, from current sensor 24. Alternatively, pressure at the pump head may be monitored via pressure sensor 22. If the monitored operating condition (current and/or pressure) is less than a corresponding prescribed threshold, then it can be concluded that the pump 12 is in a no-load condition. Conversely, if the operating condition is greater than the prescribed threshold, then if can be concluded that the pump 12 is under load.

[0057] At block 112, if the operating condition is greater than the threshold (i.e., the pump is loaded), then at block 114 the controller 18 commands the actuator 14 to run the pump 12 at a default speed (e.g., a preset speed or other speed as required by the application) and at block 116 the timer is stopped. In other words, the pump 12 is under load and thus auto-purge is not necessary. Therefore, the pump 12 is commanded to a speed required for normal operation. However, if at block 112 the operating condition is not greater than the threshold, then at block 118 auto purge is performed and the pump 12 is run at a higher speed, e.g., two times the default speed or some other speed suitable for auto-purge of the system. The higher pump speed draws fluid through the pump in a shorter time period than a normal (lower) pump speed. The goal is to minimize the time the pump 12 is in a no-load condition.

[0058] Next at block 120 the timer is compared to a prescribed time limit. Monitoring the time the pump 12 is not under load is particularly beneficial to the pump 12, as it prevents the pump 12 from a prolonged dry-run condition that can ultimately result in pump damage. In the present example the prescribed time limit is five minutes, although other time limits may be used as required by the application. If the timer value does not exceed the prescribed time limit, the method moves back to block 110 and steps 110 and 112 are repeated. However, if the timer exceeds the predetermined time limit, then at block 122 the controller 18 sets a fault bit and/or logs a fault into memory, and then at block 124 the controller 18 stops the actuator 14 (and thus the pump 12).

[0059] Accordingly, a method having the steps shown in the flow chart of Fig. 3 can be used to purge a fluid pump 12, and to provide an indication when such purge operation is unsuccessful.

[0060] Fig. 4 is a flow chart showing steps for implementing a thermal de-rating function. The thermal derating function can be implemented by the controller 18.

[0061] Beginning at block 130, a temperature from a component of the fluid pumping system 10 is measured. The temperature, which may be measured using a thermocouple, RTD or the like, may correspond to a temperature of the controller 18, the power device 16, the actuator 14 and/or the pump 12 itself.

[0062] Next at block 132 the measured temperature is compared to a temperature threshold corresponding to the specific system component. For example, each of the pump 12, the actuator 14, the power device 16 and the controller 18 may have a corresponding temperature threshold, and these thresholds may be different from one another. The measured temperature for the pump 12 is compared to a temperature threshold corresponding to the pump, the measured temperature for the actuator 14 is compared to a temperature threshold corresponding to the actuator, and so on.

[0063] Next at block 134 it is determined if any of the measured temperatures exceed the corresponding temperature threshold. If none of the measured temperatures exceed the corresponding threshold, then at block 136 the controller 18 commands the actuator 14 to drive the pump 12 at a commanded/default speed. However, if any of the measured temperatures exceed the corresponding temperature threshold, then at block 138 the controller 18 commands the actuator to run at a reduced speed.

[0064] For example, the controller 18 may be configured to reduce the speed to a predetermine percentage of the commanded or default speed. The reduced speed enables the system to provide uninterrupted operation (at reduced performance levels) without incurring damage to system components. Finally, at block 140 the controller 18 sets a fault bit corresponding to a thermal derate of the system, and logs the fault into memory. The fault bit can be used to flag an operator that system maintenance is required.

[0065] Fig. 5 is a flow chart showing steps for implementing a thermal cooling function. The thermal cooling function seeks to use fluid flow through the fluid pump 12 to provide a cooling effect to the pump 12 and/or any system components, particularly after the remainder of the system 10 has been shut down. A benefit of such cooling function is that it can prevent or minimize heat-soak of the pump and/or system components. The thermal cooling function can be implemented by the controller 18.

[0066] Beginning at block 150, the current system ON/OFF status is determined. For example, the controller 18 may generate a run status bit corresponding to a run command for the actuator 14, and this run status bit can be used to determine if the fluid system 10 is in an ON state or an OFF state. As will be appreciated, other methods may be employed to determine an ON/OFF state of the fluid system 10. If at block 152 the system 10 is in an ON state, then at block 154 the actuator 14 (and thus the pump 12) is commanded to the ON state and the method moves back to block 150.

[0067] Moving back to block 152, if the system 10 is in an OFF state, then the method moves to block 156 to determine if there has been an ON-OFF transition of the fluid system 10. More particularly, the thermal cooling function of Fig. 5 is preferably executed only when the system 10 transitions from a running (ON) state to a not running (OFF) state. If an ON-OFF transition has not occurred, then the method moves to block 160 and the actuator 14 (and thus the pump 12) remain/are placed in the OFF state. However, if at block 156 an ON-OFF transition has occurred, then the method moves to block 162 where a temperature of the fluid pump 12 (or other system component) is measured. Such temperature measurement may be made by a temperature sensor integrated within the pump 12 or other component, or by a separate temperature sensor (e.g., a contactless temperature sensor).

[0068] Next at block 164 it is determined whether the measured temperature exceeds a prescribed threshold temperature. Such threshold temperature may be a preset temperature that is set, for example, during initial system setup. If the measured temperature does not exceed the prescribed temperature, then pump or system cooling is not required and thus the method moves to block 160 where the actuator 14 (and thus the pump) is turned off and the method moves back to block 150.

[0069] Moving back to block 164, if the measured temperature of the pump 12 is greater than the temperature threshold, this indicates that fluid flow through the pump 12 should continue after the system 10 is shutdown in order to bring the temperature down to a desired temperature. In this regard, the method moves to block 166 where a timer is initialized and started. Next the method loops at block 168 until the timer exceeds a prescribed timer threshold (which may be application specific). During this looping period the pump is in the ON state and therefore pumping fluid. Once the timer exceeds the timer threshold, the method moves to block 160 and the actuator 14 (and thus the pump 12) is commanded to the OFF state. In this manner, fluid is circulated through the fluid pump 12 while the system is otherwise in an OFF state, thereby providing a cooling effect.

[0070] In another embodiment, instead of using a timer at block 168 to determine when to disable the actuator/pump, the measured temperature can be used to determine when the actuator/fluid pump should be placed in the OFF state. For example, the method could simply loop at block 168 until the measured temperature is no longer greater than the temperature threshold.

[0071] Fig. 6 is a flow chart showing steps for implementing a voltage de-rating function based on system voltage. The voltage de-rating function also can be implemented by the controller 18.

[0072] Beginning at block 200, system voltage is measured, for example, using a voltage sensor. The voltage at issue is the voltage supplied to the system, e.g., the power provided from a battery, alternator, generator, or other source that provides the primary power to the system 10.

[0073] Next at block 202 the measured voltage is compared to a prescribed voltage threshold for the system. Preferably, the prescribed voltage threshold is set during system setup and stored in memory of the controller 18. Next at block 204 it is determined if the measured voltage greater than the prescribed voltage threshold. If the measured voltage is greater than the prescribed voltage threshold, then a low voltage condition does not exist and at block 206 the controller 18 commands the actuator 14 to drive the pump 12 at a commanded/default speed. However, if the measured voltage is not greater than the prescribed voltage threshold, then at block 208 the controller 18 commands the actuator 14 to drive the pump 12 at a reduced speed.

[0074] For example, the controller 18 may be configured to reduce the speed to a predetermine percentage of the commanded or default speed. The reduced speed enables the system to provide uninterrupted operation (at reduced performance levels) without incurring damage to system components. Finally, at block 210 the controller 18 sets a fault bit corresponding to a voltage derate of the system, and logs the fault into memory. The fault bit can be used to flag an operator that system maintenance is required.

Claims

1. A fluid pumping system (10), comprising:

a fluid pump (12),
an actuator (14) coupled to the fluid pump, and
a controller (18) operatively coupled to the actuator, the controller being configured:

to detect an irregular condition of at least one of the fluid pump, the actuator or the controller, and
upon detecting the irregular condition, to modify at least one operating parameter of

the actuator to prevent the irregular condition from transitioning to a fault condition.

2. The fluid pumping system according to claim 1, in which the irregular condition comprises at least one of a low voltage condition, a fluid pressure condition, a no-load condition, or a high-temperature condition.

3. The fluid pumping system according to claim 1 or claim 2, in which the controller is configured to conclude the system is in a no-load start up condition when fluid pressure at the fluid pump is less than a predetermined pressure.

4. The fluid pumping system according to claim 3, in which the controller is configured to command the actuator to increase a speed of the fluid pump during the no-load startup condition.

5. The fluid flow system according to claim 3 or claim 4, in which the controller is configured to stop the actuator when the pressure at the fluid pump does not exceed the predetermined pressure and a predetermined time period has elapsed.

6. The fluid pumping system according to any one of claims 1 to 7, which includes a variable flow device in fluid communication with the fluid pump, and in which the controller is configured to command the actuator to decrease a speed of the fluid pump when fluid pressure at the fluid pump is greater than a predetermined pressure.

7. The fluid pumping system according to claim 6, in which the controller is configured to provide an alert indicating the variable flow device requires maintenance when the fluid pressure at the fluid pump is greater than the predetermined pressure.

8. The fluid pumping system according to any one of claims 1 to 7, in which the controller is configured to monitor an actual temperature of at least one of the fluid pump, a fluid within the system, the actuator, or the controller, and the controller is configured to command the actuator to reduce a speed of the fluid pump upon the actual temperature exceeding a corresponding predetermined temperature.

9. A controller (18) for controlling a fluid pump (120 via an actuator (18) coupled to the fluid pump, the controller comprising a processor (34) and memory (36), and logic stored in the memory and executable by the processor, the logic including:

logic which is configured to detect an irregular condition of at least one of the fluid pump, the actuator or the controller, and
logic which is configured upon detecting the irregular condition to modify at least one operating parameter of the actuator to prevent the irregular condition from transitioning to a fault condition.

10. The controller according to claim 9, in which the irregular condition comprises at least one of a low voltage condition, an irregular fluid pressure condition, a no-load condition, or a high-temperature condition.

11. The controller according to claim 9 or claim 10, in which when fluid pressure at the fluid pump is less than a predetermined pressure, the controller is configured to conclude the pump is in a no-load start up condition.

12. The controller according to claim 11, in which during the no-load startup condition the controller is configured to command the actuator to increase a speed of the fluid pump.

13. The controller according to claim 11 or claim 12, in which the controller is configured to stop the actuator when the pressure at the fluid pump does not exceed the predetermined pressure and a predetermined time period has elapsed.

14. The controller according to any one of claims 9 to 13, in which the fluid pump is in fluid communication with a variable flow device, in which when fluid pressure at the fluid pump is greater than a predetermined pressure the controller is configured to command the actuator to decrease a speed of the fluid pump.

15. The controller according to any one of claims 9 to 14, in which the controller is configured to monitor an actual temperature of at least one of the fluid pump, a fluid in the system, the actuator, or the controller, and the controller is configured to command the actuator to reduce a speed of the fluid pump upon the actual temperature exceeding a corresponding predetermined threshold.

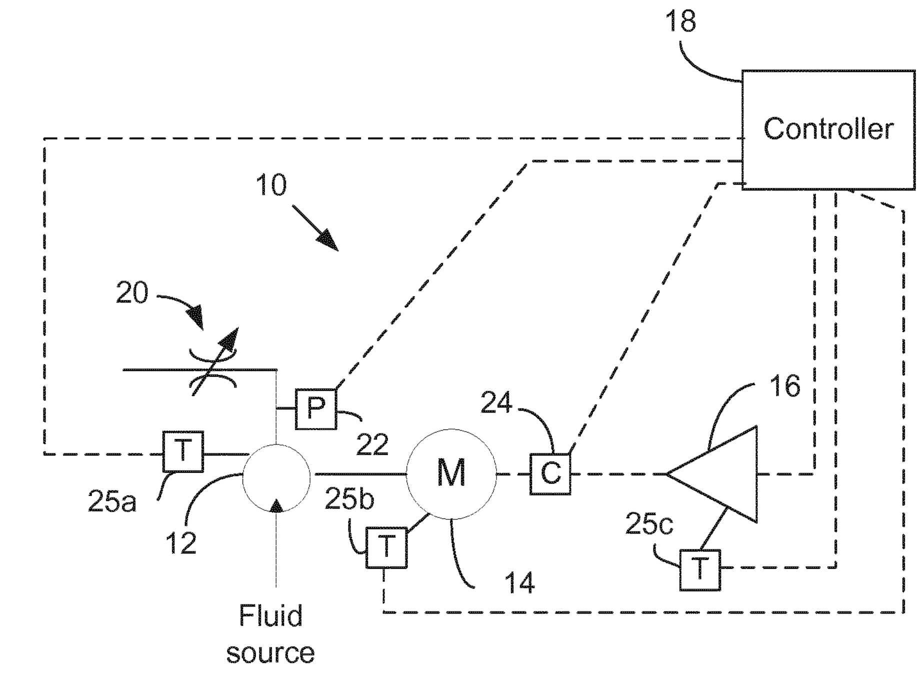
18
Controller
10
20
16
P
24
22
M
C
T
25a
25b
12
T
25c
T
14
Fluid source

Fig. 1

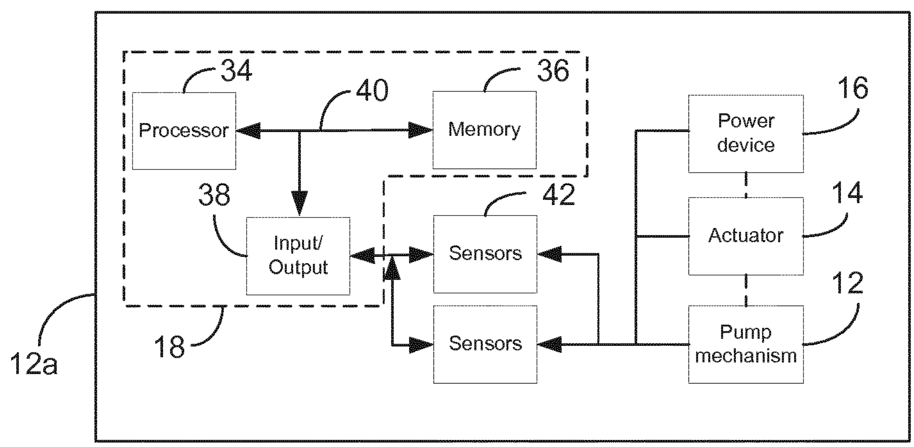
34
40
36
16
Processor
Memory
Power device
38
42
14
Input/ Output
Sensors
Actuator
12
12a
18
Sensors
Pump mechanism

Fig. 2

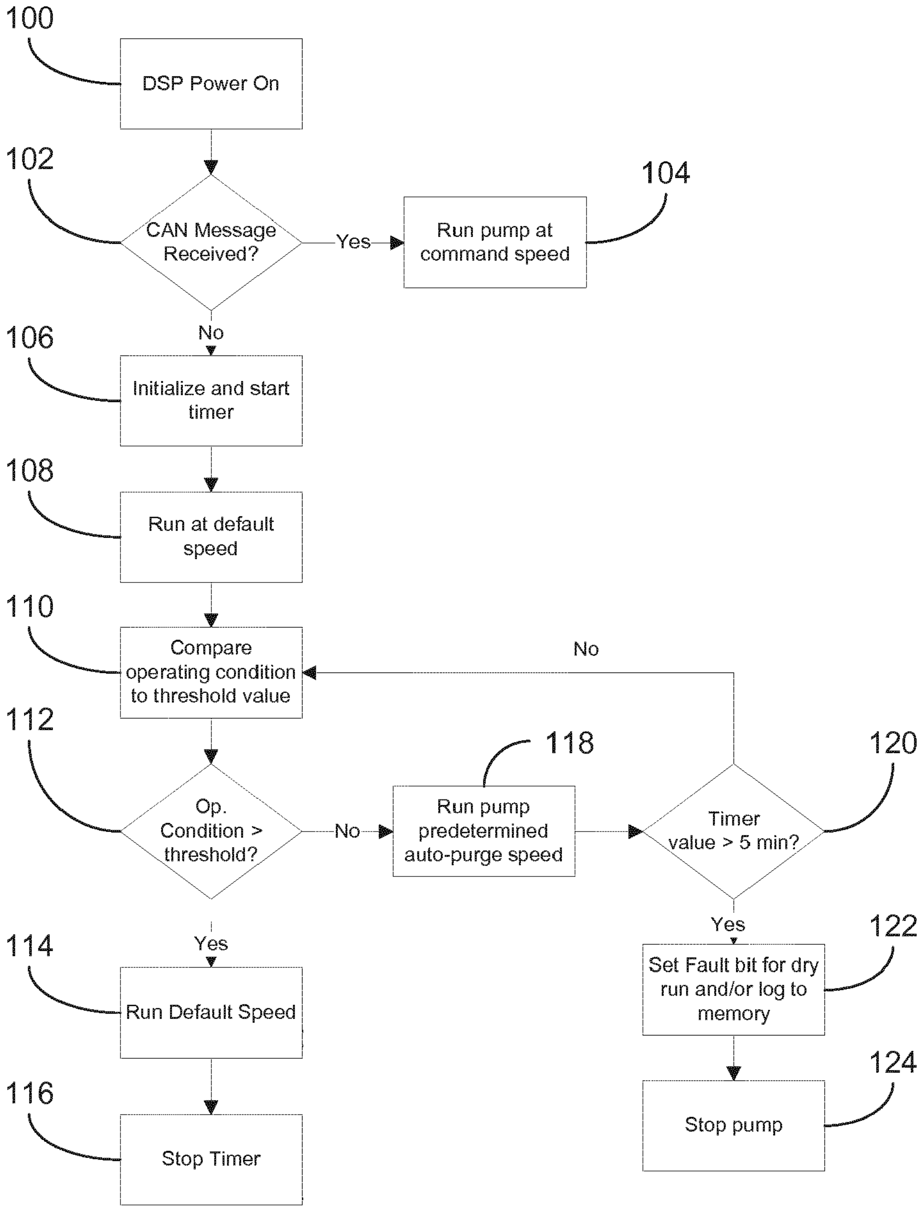
100
DSP Power On
102
CAN Message Received?
Yes
Run pump at command speed
104
No
106
Initialize and start timer
108
Run at default speed
110
Compare operating condition to threshold value
No
112
Op. Condition > threshold?
No
118
Run pump predetermined auto-purge speed
120
Timer value > 5 min?
Yes
114
Run Default Speed
116
Stop Timer
Yes
122
Set Fault bit for dry run and/or log to memory
124
Stop pump

Fig. 3

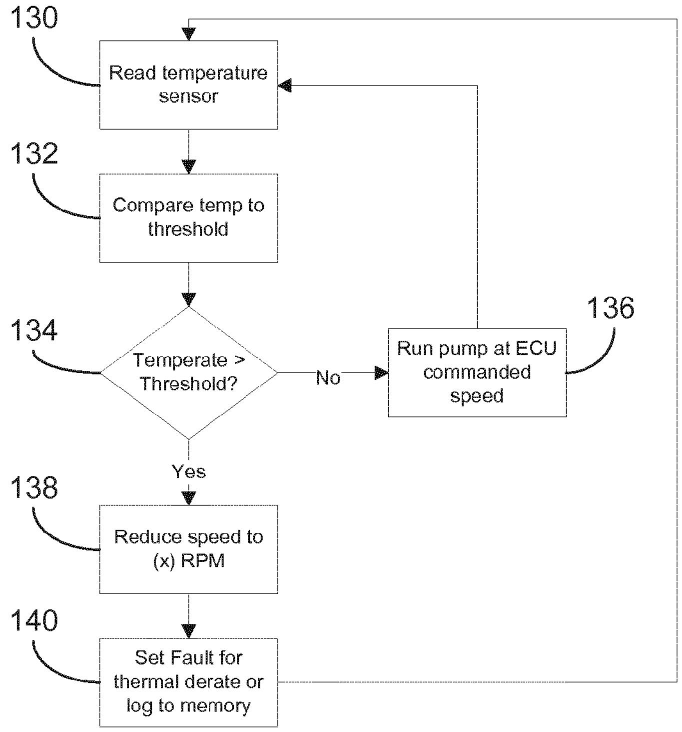
130
Read temperature sensor
132
Compare temp to threshold
134
Temperate > Threshold?
No
136
Run pump at ECU commanded speed
Yes
138
Reduce speed to (x) RPM
140
Set Fault for thermal derate or log to memory

Fig. 4

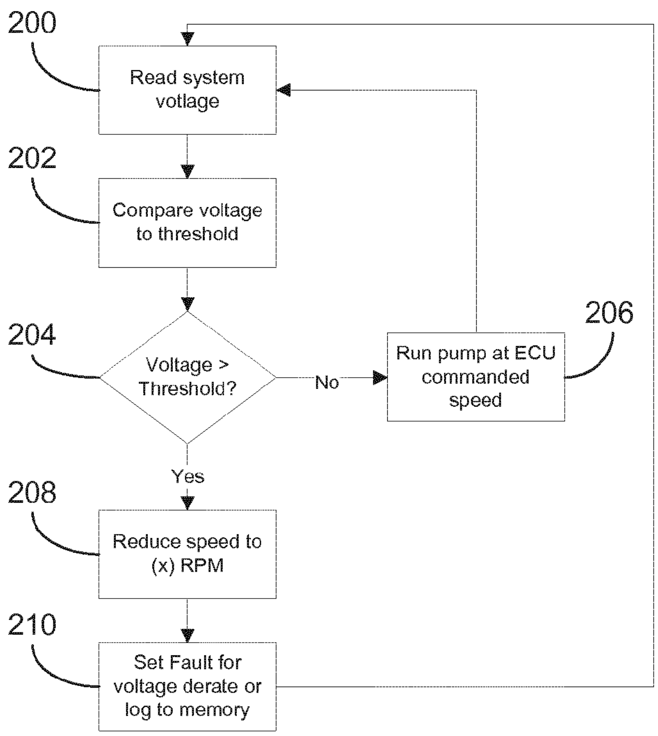
200
Read system votlage
202
Compare voltage to threshold
204
Voltage > Threshold?
No
206
Run pump at ECU commanded speed
Yes
208
Reduce speed to (x) RPM
210
Set Fault for voltage derate or log to memory

Fig. 6

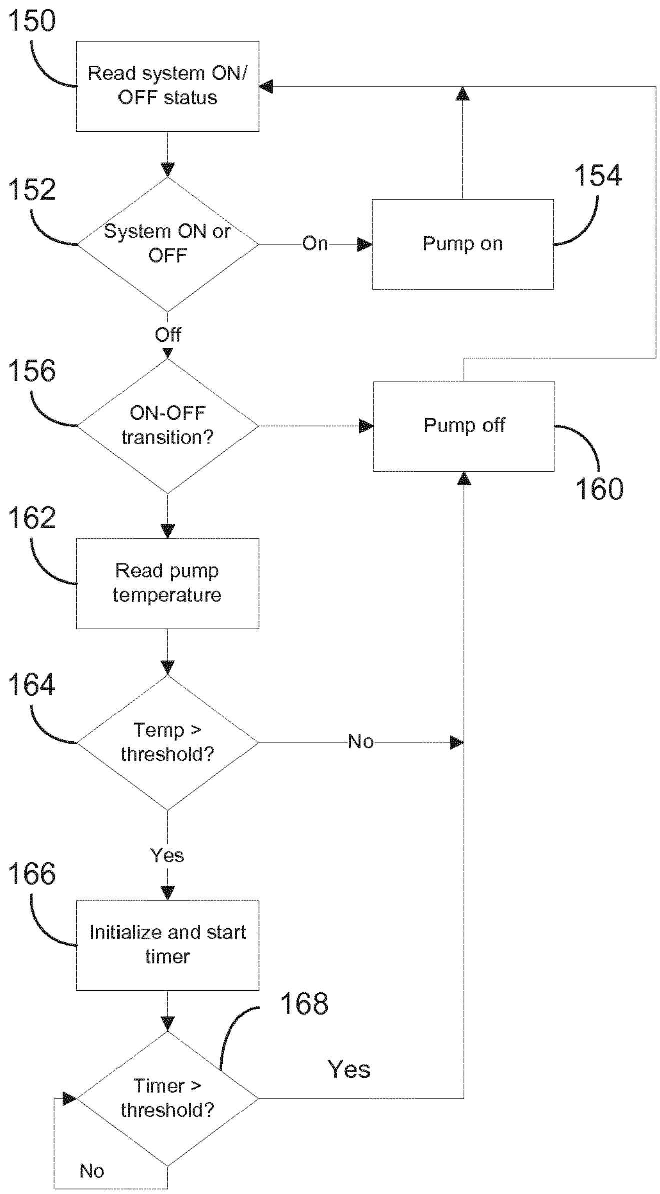
150
Read system ON/ OFF status
152
System ON or OFF
On
Pump on
154
Off
156
ON-OFF transition?
Pump off
160
162
Read pump temperature
164
Temp > threshold?
No
Yes
166
Initialize and start timer
168
Yes
Timer > threshold?
No

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 14 19 5831

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Y	US 6 187 177 B1 (OGBURN SCOTT E [US]) 13 February 2001 (2001-02-13) * figures 1A, 7 * * column 11, line 19 - column 12, line 65 * -----	7	
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	17 April 2015	Ricci, Saverio

CATEGORY OF CITED DOCUMENTS

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