A method for detecting a locked wheel on a locomotive is disclosed. The locomotive may have a plurality of wheels, a traction system configured to drive the plurality of wheels, and a controller in communication with the traction system. The traction system may have a traction motor coupled to each of the plurality of wheels, a speed sensor associated with each traction motor, an inverter connected to each traction motor, and at least one current sensor associated with each inverter. The method may include the controller detecting an initial locked wheel condition based on signals received from the speed sensors, and the controller determining if the initial locked wheel condition is true based on signals received from the current sensors.
FIG. 1
FIG. 2
FIG. 3
MONITOR SIGNALS FROM SPEED SENSORS

Is there an initial locked wheel condition?

MONITOR ELECTRICAL FEEDBACK FROM TRACTION SYSTEM

Has predetermined time period elapsed?

DISABLE FAULT ANNUNCIATION

ENABLE FAULT ANNUNCIATION

FIG. 4
AUTOMATIC DISABLING OF UNPOWERED LOCKED WHEEL FAULT DETECTION

FIELD OF THE DISCLOSURE

[0001] The present disclosure relates generally to locomotives and, more particularly, to locked wheel fault detection systems for locomotives.

BACKGROUND OF THE DISCLOSURE

[0002] Freight trains and passenger trains generally include a locomotive that provides the motive power for a train. Having no payload capacity of its own, the sole purpose of the locomotive is to move the train along the tracks. Typically, the locomotive may use an engine to drive a primary power source, such as, a main generator or an alternator. Converting mechanical energy into electrical energy, the primary power source provides power to traction motors in order to drive wheels of the locomotive. The traction motors propel the train along the tracks.

[0003] One or more wheels of the locomotive can become locked due to various reasons, such as gear train issues, inadvertent application of the parking brakes during operation, etc. In order to detect a locked wheel, speed probes may monitor a speed of each of the traction motors. However, in some instances, a speed probe may be at fault, which may result in false positive detection of a locked wheel. While a locked wheel may require the locomotive to be stopped, a faulty speed probe does not.

[0004] Thus, in conventional locked wheel fault detection systems, there is no way to ascertain whether the locked wheel fault is due to a truly locked wheel or a faulty speed probe. In both cases, conventional systems perform a fault annunciation of the locked wheel detection, thereby causing an operator of the locomotive to stop the train for inspection and get out of the locomotive to determine if the wheel is truly mechanically locked and not rotating. If the wheel is not actually locked, and the detection was due to a faulty speed probe, then the operator has to manually disable the locked wheel fault detection protection via the locomotive display. The locomotive can continue its mission and visit a maintenance facility at a later time to fix the faulty speed probe.

[0005] A system and a method for detecting a failure of a speed sensor on a locomotive propelled by an AC traction motor is disclosed in U.S. Pat. No. 6,456,908, entitled, “Traction Motor Speed Sensor Failure Detection for an AC Locomotive.” The ’908 patent describes evaluating speed sensors coupled to traction motors of the locomotive through various sensor tests. Following the evaluation of each of the speed sensors, a determination of a sensor health is completed by combining the results from the various sensor tests. In the ’908 patent, one of the sensor tests includes a Locked Axle Evaluation to determine if conditions similar to a locked axle are exhibited from the speed sensors. Under such conditions, the value for the sensor health may be adjusted. While effective for evaluating speed sensor health, the ’908 patent still does not verify whether an axle is truly locked. Improvements are desired to reduce unnecessary stopping of the locomotive due to false positive locked wheel fault detection.

SUMMARY OF THE DISCLOSURE

[0006] In accordance with one embodiment, a method for detecting a locked wheel on a locomotive is disclosed. The locomotive may have a plurality of wheels, a traction system configured to drive the plurality of wheels, and a controller in communication with the traction system. The traction system may have a traction motor coupled to each of the plurality of wheels, a speed sensor associated with each traction motor, an inverter connected to each traction motor, and at least one current sensor associated with each inverter. The method may include the controller detecting an initial locked wheel condition based on signals received from the speed sensors, and the controller determining if the initial locked wheel condition is true based on signals received from the current sensors.

[0007] In accordance with another embodiment, a system for detecting a locked wheel on a locomotive is disclosed. The locomotive may have a plurality of wheels. Each of the plurality of wheels may have a traction motor coupled thereto, and each traction motor may have an inverter connected thereto. The system may include a speed sensor associated with each of the traction motors, each speed sensor configured to detect a speed of the associated traction motor; at least one current sensor associated with each of the inverters, each current sensor configured to detect a current of the associated inverter; and a controller in communication with each speed sensor and each current sensor. The controller may be configured to monitor signals indicative of a speed of each traction motor received from the speed sensors; monitor current feedback associated with each inverter received from the current sensors; compare the current feedback to the signals from the speed sensors; and verify if one of the plurality of wheels is locked.

[0008] In accordance with yet another embodiment, a method for preventing fault annunciation of a false positive locked wheel condition on a locomotive is disclosed. The locomotive may have a plurality of wheels, a traction system configured to drive the plurality of wheels, and a controller in communication with the traction system. The traction system may have a traction motor coupled to each of the plurality of wheels, an inverter connected to each traction motor, a speed sensor associated with each traction motor, and at least one current sensor associated with each inverter. The method may include the controller monitoring signals received from the speed sensors; the controller determining an initial locked wheel condition based on the signals from the speed sensors; the controller monitoring current feedback from the current sensors; the controller determining the initial locked wheel condition to be false based on the current feedback; and the controller disabling a fault annunciation of the initial locked wheel condition.

[0009] These and other aspects and features will become more readily apparent upon reading the following detailed description when taken in conjunction with the accompanying drawings. In addition, although various features are disclosed in relation to specific exemplary embodiments, it is understood that the various features may be combined with each other, or used alone, with any of the various exemplary embodiments without departing from the scope of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a diagrammatic view of a vehicle, in accordance with one embodiment of the present disclosure;

[0011] FIG. 2 is a diagrammatic view of part of a power system for the vehicle of FIG. 1;

[0012] FIG. 3 is a schematic representation of a system for detecting a locked wheel on a locomotive, in accordance with another embodiment of the present disclosure; and
[0013] FIG. 4 is a flowchart illustrating a process for detecting a locked wheel on a locomotive, in accordance with yet another embodiment. 

[0014] While the present disclosure is susceptible to various modifications and alternative constructions, certain illustrative embodiments thereof will be shown and described below in detail. The disclosure is not limited to the specific embodiments disclosed, but instead includes all modifications, alternative constructions, and equivalents thereof.

DETAILED DESCRIPTION

[0015] The present disclosure provides a system and method for detecting a locked wheel on a locomotive. The disclosed system and method verifies whether a wheel is truly locked by monitoring both speed sensor signals and electrical feedback from the traction motors. More specifically, the system and method verify an initial locked wheel condition from the speed sensor signals by additionally monitoring current feedback from the traction motors. By corroborating the initial locked wheel condition through current feedback, the system and method eliminate false positive locked wheel detection due to faulty speed probes. In addition, the disclosed system and method disable fault annunciations when the initial locked wheel condition is determined to be false. In so doing, a mission of the locomotive may be completed without unnecessarily stopping for inspection.

[0016] Reference will now be made in detail to specific embodiments or features, examples of which are illustrated in the accompanying drawings. Generally, corresponding reference numbers will be used throughout the drawings to refer to the same or corresponding parts.

[0017] FIG. 1 illustrates a vehicle 20 consistent with certain embodiments of the present disclosure. Although vehicle 20 is illustrated as a rail transport vehicle, the vehicle 20 may be any type of vehicle or machine used to perform a driven operation involving physical movement associated with a particular industry, such as, without limitation, transportation, mining, construction, landscaping, forestry, agriculture, etc.

[0018] Non-limiting examples of vehicles and machines, for both commercial and industrial purposes, include trains, diesel-electric locomotives, diesel mechanical locomotives, mining vehicles, on-highway vehicles, earth-moving vehicles, loaders, excavators, dozers, motor graders, tractors, trucks, backhoes, agricultural equipment, material handling equipment, marine vessels, and other types that operate in a work environment. It is to be understood that the vehicle 20 is shown primarily for illustrative purposes to assist in disclosing features of various embodiments, and that FIG. 1 does not depict all of the components of a vehicle.

[0019] The vehicle 20 may include a locomotive 22 coupled to at least one railcar 24. The vehicle 20 may travel along a route 26, such as, one or more rails of a track. Railcars 24 may be passenger cars or freight cars for carrying passengers, goods, or other loads. The locomotive 22 may include an engine 28, or other power source, and a power system 30. The engine 28 may be electric, diesel, steam, hydrogen, gas turbine powered, hybrid, or of any other type for generating energy to propel the vehicle 20. Power system 30 may be configured to distribute electrical power to propulsion and non-propulsion electric loads.

[0020] Referring now to FIG. 2, with continued reference to FIG. 1, a diagrammatic view of part of the power system 30 is shown, in accordance with an embodiment of the present disclosure. It is to be understood that only part of the power system 30 is shown primarily for illustrative purposes to assist in disclosing features of various embodiments, and that FIG. 2 does not depict all of the components of a power system. The power system 30 may include an alternator 32 operatively coupled to the engine 28. The alternator 32 may convert mechanical energy generated by the engine 28 into electrical energy in the form of alternating current (AC). However, other types of generators than alternator 32 may be used. At the output of the alternator 32, rectifiers 34 may convert AC to direct current (DC) that is conveyed on DC links 36.

[0021] The power system 30 may further include a traction system 38. The traction system 38 may be configured to move the locomotive 22 and propel the vehicle 20 along the route 26. For example, DC link 36 may convey DC to the traction system 38. The traction system 38 may include inverters 40 to convert DC into AC for traction motors 42 configured to drive wheels 44 (FIG. 1) of the locomotive 22. Although, in FIG. 2, the traction system 38 includes six inverters 40 and six traction motors 42, one inverter 40 per individual traction motor 42, and one traction motor 42 per wheel 44 (FIG. 1), it is to be understood that other configurations are certainly possible. For example, the traction system 38 may include multiple traction motors 42 in parallel, powered from a single inverter 40.

[0022] Referring now to FIG. 3, with continued reference to FIGS. 1 and 2, a diagrammatic view of a system 50 for detecting a locked wheel on the locomotive 22 is shown, according to an embodiment of the present disclosure. The system 50 may be implemented using one or more of a processor, a microprocessor, a microcontroller, a digital signal processor (DSP), a field-programmable gate array (FPGA), an electronic control module (ECM), an electronic control unit (ECU), and a processor-based device that may include or be associated with a non-transitory computer readable storage medium having stored thereon computer-executable instructions, or any other suitable means for electronically controlling functionality of the locomotive 22. Other hardware, software, firmware, or combinations thereof may be included in the system 50. In addition, the system 50 may be configured to operate according to predetermined algorithms or sets of instructions programmed or incorporated into memory that is associated with or at least accessible to the system 50.

[0023] For example, the system 50 may comprise a controller 52, such as, a locomotive control computer (LCC), in communication with an operator interface 54 and inverter controllers 56. In one embodiment, the controller 52 may comprise an Electro-Motive EM2000 device, although other devices for the controller 52 may be used. The operator interface 54 may be configured to receive input from and output data to an operator of the locomotive 22. For example, the operator interface 54 may include a Functionality Integrated Railroad Electronics (FIRE) display 58. However other operator controls may be included in the operator interface 54, such as, without limitation, one or more pedals, joysticks, buttons, switches, dials, levers, steering wheels, keyboards, touchscreens, displays, monitors, screens, lights, speakers, horns, sirens, buzzers, alarm bells 60, voice recognition software, microphones, control panels, instrument panels, gauges, etc.

[0024] In communication with the controller 52, inverter controllers 56 may perform control and protection functions related to inverters 40. Each of the inverters 40 may be in
communication with a single inverter controller. In addition, each of the inverter controllers 56 may be configured to read sensor inputs from the inverters 40, receive and send signals to and from the controller 52. For example, each of the inverter controllers 56 may comprise an A4PI device or an A5PI device, although other devices may be used. It is to be understood that although controller 52 and inverter controllers 56 are shown as separate controllers, other configurations may be used as well.

[0025] The system 50 may further comprise a speed sensor 62 and at least one current sensor 64 associated with each traction motor 42. The speed sensors 62 may be configured to detect a speed of the associated traction motors 42 and send corresponding signals to the controller 52. For example, the speed sensor 62 may detect a rotational speed of the motor shaft. However, other sensors detecting the gear train, axle, wheel speed, or other parts of the motor may also be used.

[0026] The current sensors 64 may be configured to detect a current of the associated inverters 40 and send corresponding signals to the inverter controller 56. The controller 52 may receive corresponding signals from the inverter controller 56 indicating the same. For example, the current sensor 64 may measure AC from the inverter 40 to the traction motor 42. However, other sensors detecting electrical feedback, such as voltage, flux, or other currents associated with the inverter and traction motor may also be used. For instance, current sensors 66 may measure DC input into the inverter 40.

Industrial Applicability

[0027] In general, the foregoing disclosure finds utility in various industrial applications, such as, in transportation, mining, earthmoving, construction, industrial, agricultural, and forestry vehicles and machines. In particular, the disclosed load management system may be applied to locomotives, trains, mining vehicles, on-highway vehicles, earthmoving vehicles, loaders, excavators, dozers, motor graders, tractors, trucks, backhoes, agricultural equipment, material handling equipment, marine vessels, and the like.

[0028] Turning now to FIG. 4, with continued reference to FIGS. 1-3, a flowchart illustrating an example process 70 for detecting a locked wheel on the locomotive 22 is shown, according to another embodiment of the present disclosure. The process 70 may be programmed into the memory associated with the controller 52 of the locomotive 22. At block 72, the controller 52 may monitor signals from the speed sensors 62. The controller 52 may determine if there is an initial locked wheel condition, at block 74, based on the signals received from the speed sensors 62.

[0029] For example, the controller 52 may compare the speeds of all the traction motors 42 to each other. If one of the speed sensors is detecting a different speed than a speed of the other speed sensors, then there may be an initial locked wheel condition. The initial locked wheel condition may indicate that either the locomotive 22 has a locked wheel or one of the speed sensors 62 is at fault.

[0030] In one example, there may be an initial locked wheel condition if one of the six speed sensors is detecting zero (0) rpm, while the other five speed sensors are each detecting non-zero speeds. The one speed sensor detecting the zero speed may initially indicate that the associated traction motor may not be rotating while the other traction motors are rotating. Thus, the wheel associated with the one speed sensor and traction motor may be locked, or alternatively, the one speed sensor may be faulty. However, other circumstances may also trigger detection of an initial locked wheel condition.

[0031] At block 74, if there is an initial locked wheel condition is determined, the controller 52 may corroborate the initial detection, at block 76. In order to verify whether the initial locked wheel condition is true and the locomotive 22 actually has a locked wheel, as opposed to a faulty speed sensor, the controller 52 may monitor electrical feedback from the traction system 38, at block 76. More specifically, the controller 52 may monitor current feedback based on signals from the current sensors 64, 66. At block 78, the controller 52 may determine if the initial locked wheel condition is true or false.

[0032] For example, the controller 52 may compare current feedback of all the inverters 40 to each other. If current feedback associated with the one traction motor having a speed sensor detecting a zero speed is different from current feedback associated with the other traction motors, then the initial locked wheel condition may be true. For instance, for the one traction motor detecting a zero speed, a spike in current feedback from the inverter 40 may indicate a stalled traction motor. This may then indicate a locked axle, which may verify that the associated wheel is mechanically locked.

[0033] If current feedback associated with the one traction motor having a speed sensor detecting a zero speed is similar to current feedback associated with the other traction motors, then the initial locked wheel condition may be false. If all of the current feedback is the same between all the inverters 40, this indicates that the one fraction motor having a speed sensor detecting a zero speed is actually rotating. Thus, with the one traction motor rotating, the axle and associated wheel is probably not locked, which may indicate a faulty speed sensor.

[0034] If, at block 78, the initial locked wheel condition is true, then the process 70 proceeds to block 80. At block 80, the controller 52 enables a fault annunciation of the locked wheel fault detection. The fault annunciation may comprise alerting an operator of the locomotive 22 or other personnel that the system 50 detected a locked wheel fault. For example, a message may be displayed on the FIRE display 58, an alarm bell 60 may ring, and/or the locked wheel fault detection may be recorded in a fault log. Other various annunciations may be performed as well.

[0035] In addition, the controller 52 may be configured to send the fault annunciation to an off-board location. For instance, the system 50 may further include a communication system 68 (FIG. 3), which connects to off-board components, such as through cellular, Wi-Fi, and other wired or wireless communication devices. In an example, the communication system 68 may send the fault annunciation to a back office where railroad personnel can view data and operating conditions at the time of the locked wheel fault detection.

[0036] If, at block 78, the initial locked wheel condition is false, then the process 70 proceeds to block 82. At block 82, the controller 52 may disable the fault annunciation. For example, the controller 52 may disable a message on the FIRE display 58 and may disable ringing of the alarm bell 60 so that the locomotive operator does not stop the train, but instead continues on the mission. The initial locked wheel condition may still be recorded in the fault log and communicated to an off-board location to inform, for instance, railroad personnel that the speed sensor should be fixed.

[0037] Furthermore, at block 84, the controller 52 may disable the fault annunciation for a predetermined period of
time. In so doing, the system 50 allows the locomotive 22 to complete its mission and reach a maintenance facility before executing the fault annunciation. The predetermined period of time may be determined based on a pre-mapped location of maintenance facilities or a global positioning system (GPS). In another example, the predetermined period of time may be a set amount of time programmed into the memory of the controller 52. For instance, the predetermined period of time may be twenty-four hours, forty-eight hours, or any other amount of time. The controller 52 may have an associated timer configured to measure an amount of time that has passed and send a signal to the controller 52 indicating the time period has elapsed.

If, at block 84, the predetermined time period has not elapsed, the process 70 may return to block 76 in order to continue monitoring current feedback from the current sensors after disabling of the fault annunciation at block 82. More specifically, if while the fault annunciation is disabled a wheel of the locomotive actually locks up during the predetermined time period, the system 50 will still be able to determine the initial locked wheel condition to be true and enable the fault annunciation upon verification. Thus, an actual mechanically locked wheel condition can still be detected, verified, and annunciated even if the associated speed sensor is faulty.

At block 84, if the predetermined time period has elapsed, the process 70 may return to block 72 and go through the rest of the process. Therefore, if the initial locked wheel condition is still false after the predetermined time period has elapsed, the controller 52 may re-disable the fault annunciation for the predetermined time period again. After blocks 74, 80 and 84, the process 70 may start over in order to continue locked wheel fault detection on the wheels 44 of the locomotive.

It is to be understood that the flowchart in FIG. 4 is shown and described as an example only to assist in disclosing the features of the disclosed system, and that more or less steps than that shown may be included in the method corresponding to the various features described above for the disclosed system without departing from the scope of the disclosure.

By applying the disclosed system and method to a locomotive, false positive locked wheel detection due to faulty speed probes is eliminated. In particular, the system and method verify an initial locked wheel condition from the speed sensor signals by additionally monitoring current feedback from the traction motors. By corroborating the initial locked wheel condition through current feedback, fault annunciations may be disabled when the initial locked wheel conditions are determined to be false, thereby allowing the locomotive to complete its mission without wasting time for unnecessary inspection. Furthermore, the disclosed system and method provide the advantage of diagnosing two faults, a faulty speed probe and a locked wheel, through a single process, thus significantly reducing the time and cost of repair for the locomotive.

While the foregoing detailed description has been given and provided with respect to certain specific embodiments, it is to be understood that the scope of the disclosure should not be limited to such embodiments, but that the same are provided simply for enabling and best mode purposes. The breadth and spirit of the present disclosure is greater than the embodiments specifically disclosed and encompassed within the claims appended hereto. Moreover, while some features are described in conjunction with certain specific embodiments, these features are not limited to use with only the embodiment with which they are described, but instead may be used together with or separate from, other features disclosed in conjunction with alternate embodiments.

What is claimed is:

1. A method for detecting a locked wheel on a locomotive having a plurality of wheels, a traction system configured to drive the plurality of wheels, and a controller in communication with the traction system, the traction system having a traction motor coupled to each of the plurality of wheels, a speed sensor associated with each traction motor, an inverter connected to each traction motor, and at least one current sensor associated with each inverter, the method comprising:

   the controller detecting an initial locked wheel condition based on signals received from the speed sensors; and
   the controller determining if the initial locked wheel condition is true based on signals received from the current sensors.

2. The method of claim 1, further comprising the controller disabling a fault annunciation if the initial locked wheel condition is determined to be false.

3. The method of claim 2, further comprising the controller disabling the fault annunciation for a predetermined time period upon determination of the initial locked wheel condition to be false.

4. The method of claim 3, further comprising the controller monitoring current feedback from the current sensors after disabling the fault annunciation.

5. The method of claim 4, further comprising the controller determining the initial locked wheel condition to be true during the predetermined time period when the fault annunciation is disabled, and the controller enabling the fault annunciation upon determination of the initial locked wheel condition to be true.

6. The method of claim 4, further comprising the controller determining the initial locked wheel condition to be false when the predetermined time period elapses, and the controller re-disabling the fault annunciation for a subsequent predetermined time period.

7. The method of claim 1, further comprising the controller determining the initial locked wheel condition to be true when signals received from the current sensors indicate a stalled traction motor.

8. The method of claim 7, further comprising the controller enabling a fault annunciation upon determination of the initial locked wheel condition to be true.

9. The method of claim 8, further comprising the controller sending the fault annunciation to an off-board location via a communication system.

10. The method of claim 1, further comprising the controller determining the initial locked wheel condition to be false when signals received from the current sensors indicate similar feedback between each of the traction motors.

11. A system for detecting a locked wheel on a locomotive having a plurality of wheels, each of the plurality of wheels having a traction motor coupled thereto, each traction motor having an inverter connected thereto, the system comprising:

   a speed sensor associated with each of the traction motors,
   each speed sensor configured to detect a speed of the associated traction motor;

   at least one current sensor associated with each of the inverters, each current sensor configured to detect a current of the associated inverter; and
a controller in communication with each speed sensor and each current sensor, the controller configured to:

monitor signals indicative of a speed of each traction motor received from the speed sensors;

monitor current feedback associated with each inverter received from the current sensors;

compare the current feedback to the signals from the speed sensors; and

verify if one of the plurality of wheels is locked.

12. The system of claim 11, wherein the current detected by each current sensor is an alternating current (AC) from the inverter to the traction motor.

13. The system of claim 11, wherein the current detected by each current sensor is a direct current (DC) input into the inverter.

14. The system of claim 11, wherein the controller is further configured to determine an initial locked wheel condition when a speed of one traction motor is zero while a speed of the other traction motors is nonzero.

15. The system of claim 14, wherein the controller is further configured to determine the initial locked wheel condition is true when current feedback associated with the one traction motor is different from current feedback associated with the other traction motors.

16. The system of claim 15, wherein the controller is further configured to determine the initial locked wheel condition is false when current feedback associated with the one traction motor is similar to current feedback associated with the other traction motors.

17. The system of claim 16, wherein the controller is further configured to disable a fault annunciation when the initial locked wheel condition is determined to be false.

18. The system of claim 17, wherein the controller is further configured to disable the fault annunciation for a predetermined period of time.

19. The system of claim 18, wherein the controller is further configured to continue monitoring current feedback after the fault annunciation is disabled.

20. A method for preventing fault annunciation of a false positive locked wheel condition on a locomotive, the locomotive having a plurality of wheels, a traction system configured to drive the plurality of wheels, and a controller in communication with the traction system, the traction system having a traction motor coupled to each of the plurality of wheels, an inverter connected to each traction motor, a speed sensor associated with each traction motor, and at least one current sensor associated with each inverter, the method comprising:

the controller monitoring signals received from the speed sensors;

the controller determining an initial locked wheel condition based on the signals from the speed sensors;

the controller monitoring current feedback from the current sensors;

the controller determining the initial locked wheel condition to be false based on the current feedback, and

the controller disabling a fault annunciation of the initial locked wheel condition.