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Soliman

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(54) **CONNECTED ENERGY MANAGEMENT AND AUTONOMOUS DRIVING STRATEGY FOR ENGINE CYLINDER DEACTIVATION**

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F02D 17/02 (2006.01)

(52) **U.S. Cl.**
CPC ***F02D 41/0087*** (2013.01); *F02D 2200/602* (2013.01); *F02D 2200/702* (2013.01)

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USPC .... 701/102, 112–115; 123/198 F
See application file for complete search history.

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(57) **ABSTRACT**

The present invention is a connected energy management (CEM) strategy for controlling the activation of a plurality of engine cylinders in the engine of a vehicle. A powertrain controller is operable for controlling the operation of the engine, and a second controller is in electrical communication with the powertrain controller. The second controller may be a telematics controller, or an autonomous driving vehicle controller. The second controller communicates at least one parameter to the powertrain controller, and the parameter is used to determine which of the plurality of cylinders are to be activated or deactivated. The powertrain controller then activates or deactivates one or more of the plurality of cylinders using the powertrain controller based on the parameter, which may include various road data, such as road curve shape or road grade. The parameter may also be based on a desired autonomous driving path.

15 Claims, 5 Drawing Sheets

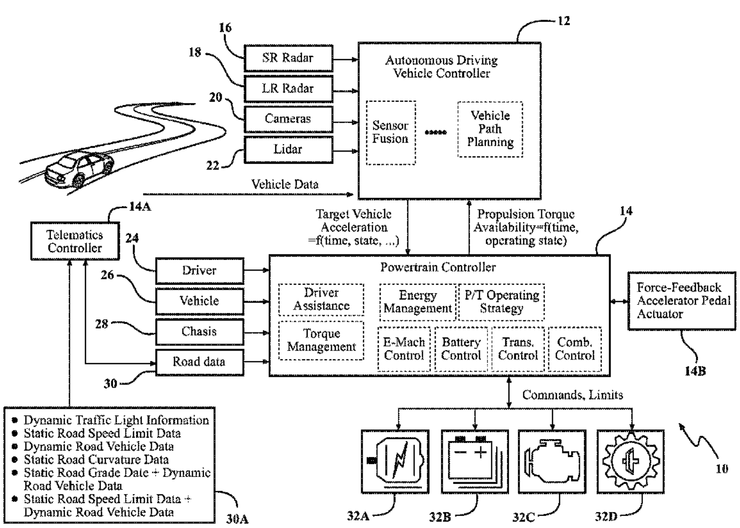

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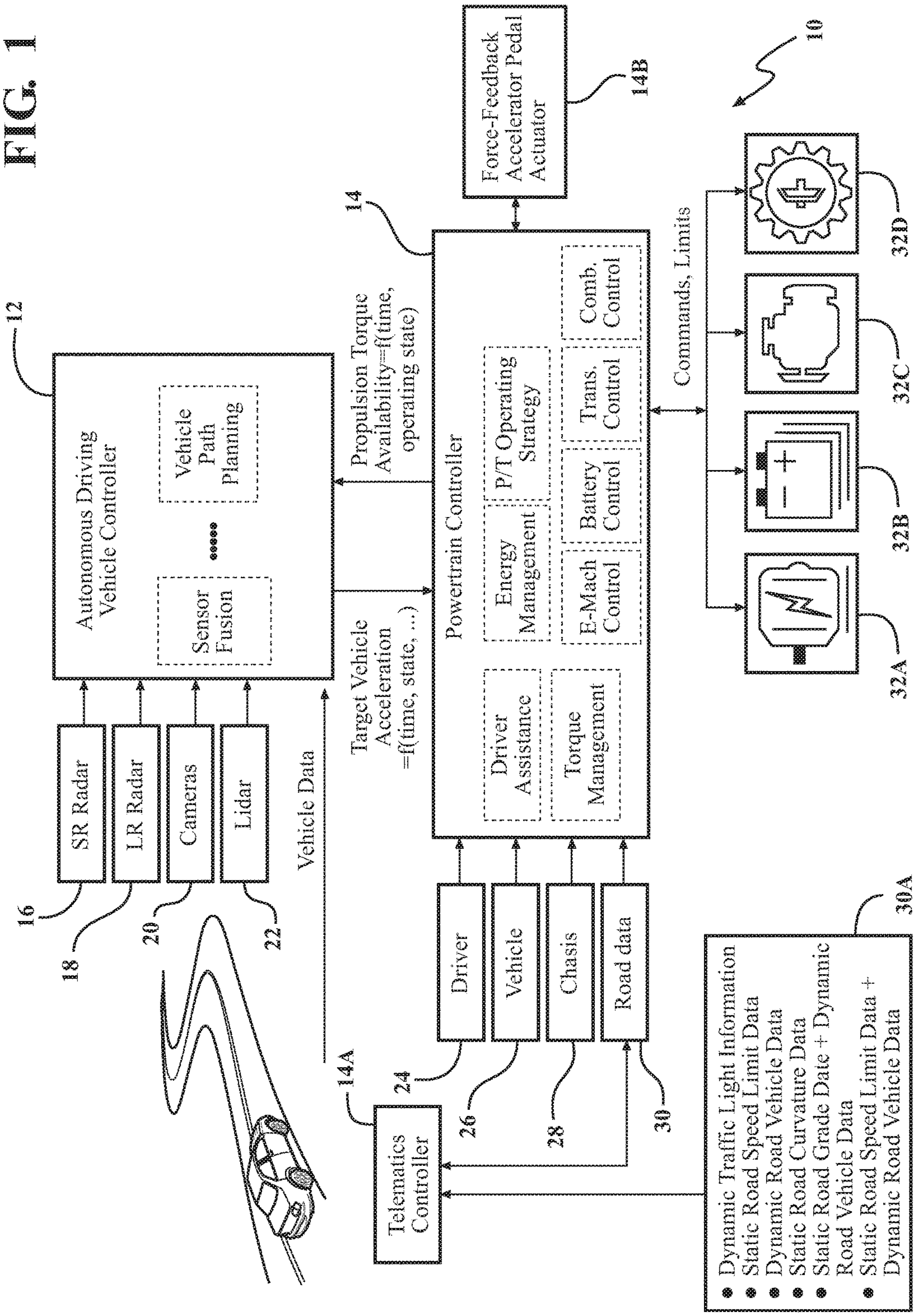
FIG. 1


Autonomous Driving Vehicle Controller
Sensor Fusion
Vehicle Path Planning
12
SR Radar
LR Radar
Cameras
Lidar
16
18
20
22
Vehicle Data
14A
Target Vehicle Acceleration =f(time, state, ...)
Propulsion Torque Availability=f(time, operating state)
14
Powertrain Controller
Driver Assistance
Torque Management
Energy Management
P/T Operating Strategy
E-Mach Control
Battery Control
Trans. Control
Comb. Control
Force-Feedback Accelerator Pedal Actuator
14B
Commands, Limits
10
32A
32B
32C
32D
Driver
Vehicle
Chasis
Road data
24
26
28
30
Telematics Controller
30A
Dynamic Traffic Light Information
Static Road Speed Limit Data
Dynamic Road Vehicle Data
Static Road Curvature Data
Static Road Grade Date + Dynamic Road Vehicle Data
Static Road Speed Limit Data + Dynamic Road Vehicle Data

Driving Situation	cEM Function	Connected Data Utilized	Cylinder Deactivation Strategy
Approaching Traffic Light (about to turn red in X secs)	Intelligent Traffic Light Assist	dynamic traffic light information	Engine cylinder deactivation extended (& triggered earlier) by using future traffic light status & timing
Vehicle Deceleration due to decreasing speed limits	Intelligent Deceleration Assist	static road speed limit data	Engine cylinder deactivation triggered earlier to maximize energy recuperation by reducing pumping losses (xHEV application)
Vehicle Deceleration due to increasing traffic congestion	Intelligent Deceleration Assist	dynamic road vehicle data (traffic congestion)	Engine cylinder deactivation triggered earlier to maximize energy recuperation by reducing pumping losses (xHEV application)
Vehicle Approaching Road Curvature	Intelligent Curve Assist	static road curvature data (future)	Engine cylinder deactivation extended (& triggered earlier) by using upcoming road curvature knowledge. May be combined with dynamic traffic light information
Vehicle Approaching Downhill Road Grade with vehicle traffic	Intelligent Road Slope Assist	static road grade data + dynamic road vehicle data	Engine cylinder deactivation extended due to reduced road load (with downhill grade) in addition to future vehicle traffic
Vehicle Deceleration due to Approaching Downhill Road Grade	Intelligent Deceleration+Slope Assist	static road grade data + dynamic road vehicle data	Engine cylinder deactivation switched to fuel cutoff (pumping losses maximized) only for maximized engine breaking for hill descent control
Vehicle Creeping During Low Speed Zone (or with traffic)	Intelligent Deceleration+Traffic Light Assist	static road speed limit data + dynamic road vehicle data (traffic congestion)	Engine cylinder deactivation extended using dynamic traffic data information. Expected longer period of low engine load operation

FIG. 2

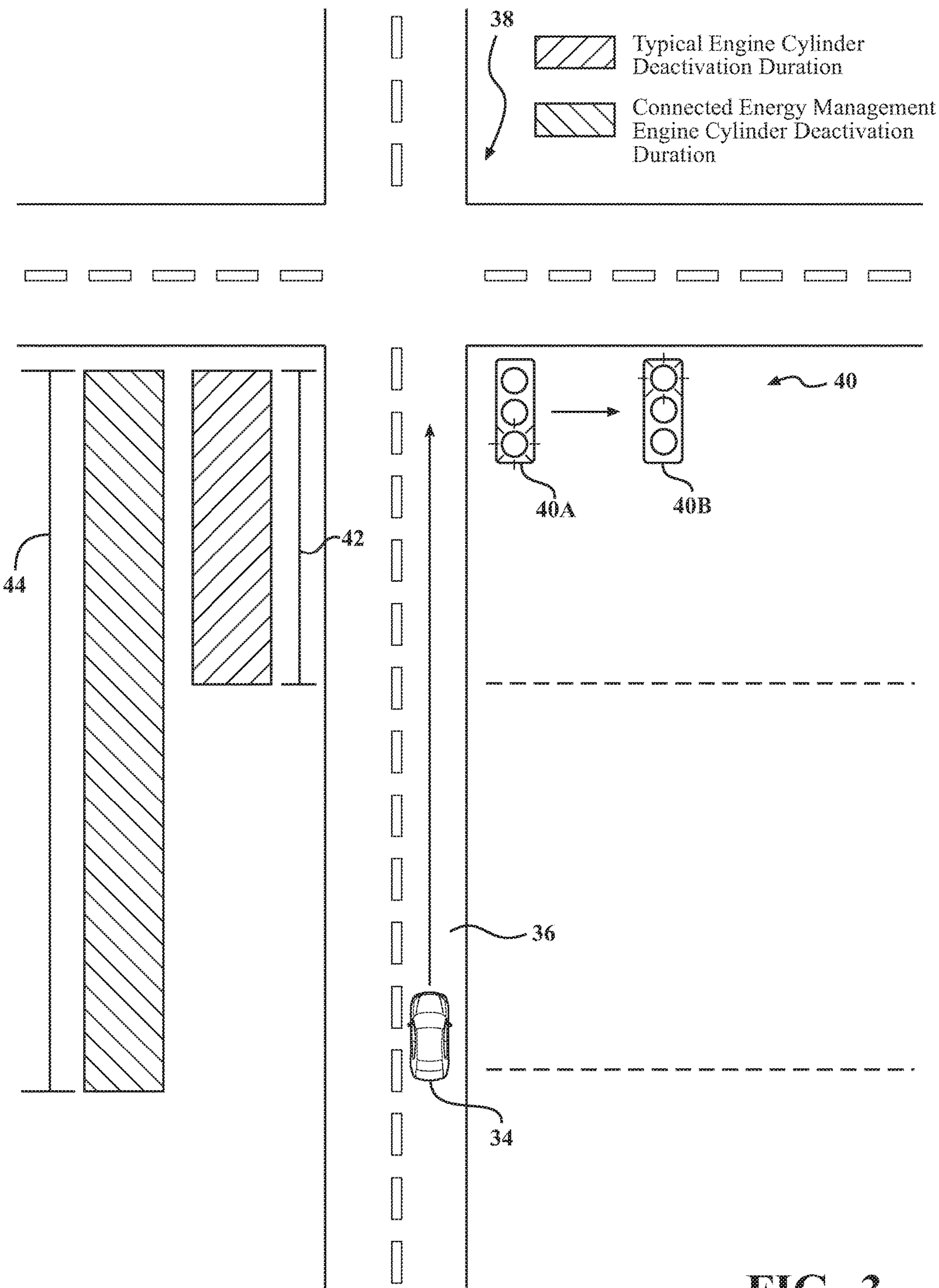

38
Typical Engine Cylinder Deactivation Duration
Connected Energy Management Engine Cylinder Deactivation Duration
40
40A
40B
42
44
36
34

FIG. 3

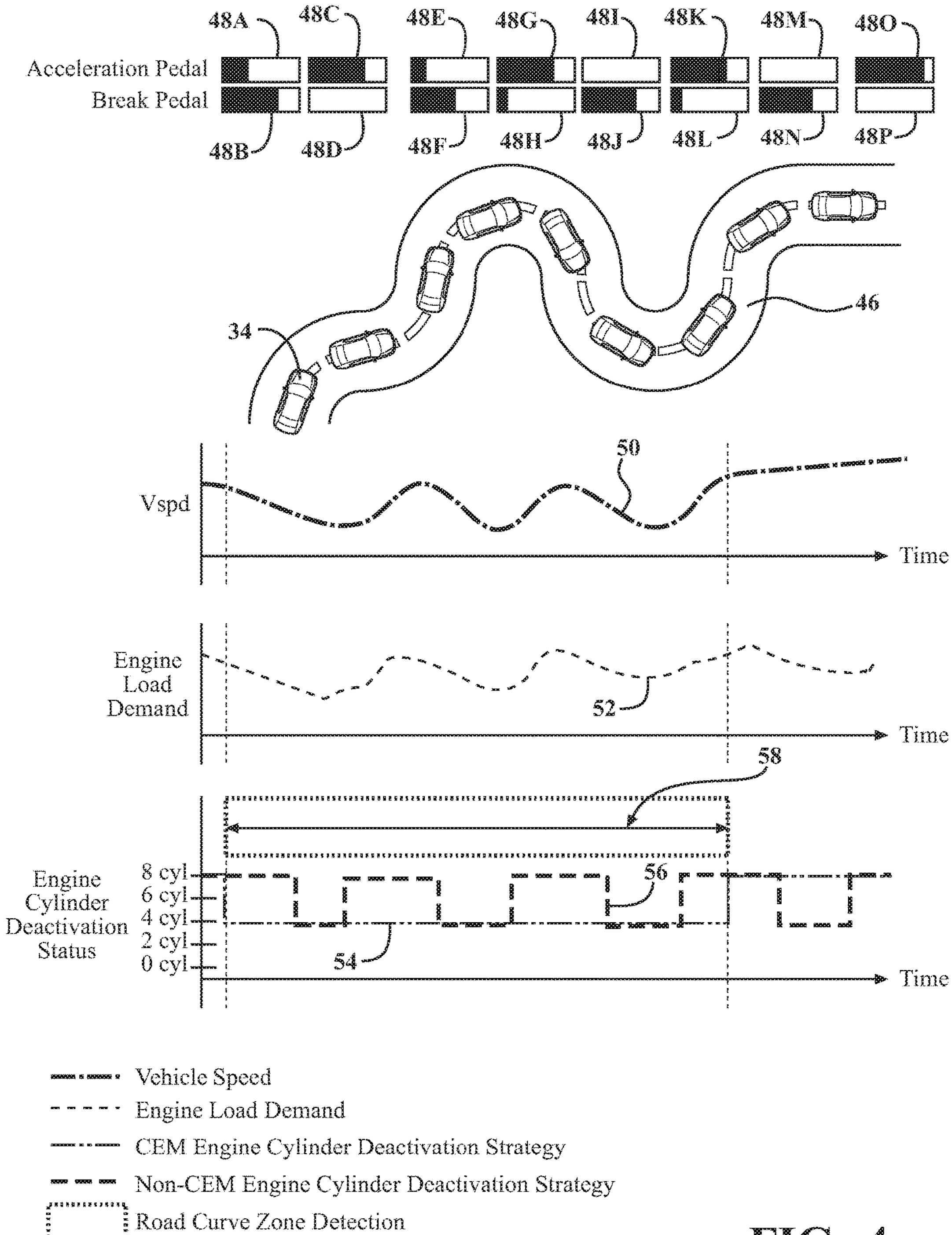

48A
48C
48E
48G
48I
48K
48M
48O
Acceleration Pedal
Break Pedal
48B
48D
48F
48H
48J
48L
48N
48P
34
46
50
Vspd
Time
Engine
Load
Demand
52
Time
58
Engine
Cylinder
Deactivation
Status
8 cyl
6 cyl
4 cyl
2 cyl
0 cyl
56
54
Time
Vehicle Speed
Engine Load Demand
CEM Engine Cylinder Deactivation Strategy
Non-CEM Engine Cylinder Deactivation Strategy
Road Curve Zone Detection

FIG. 4

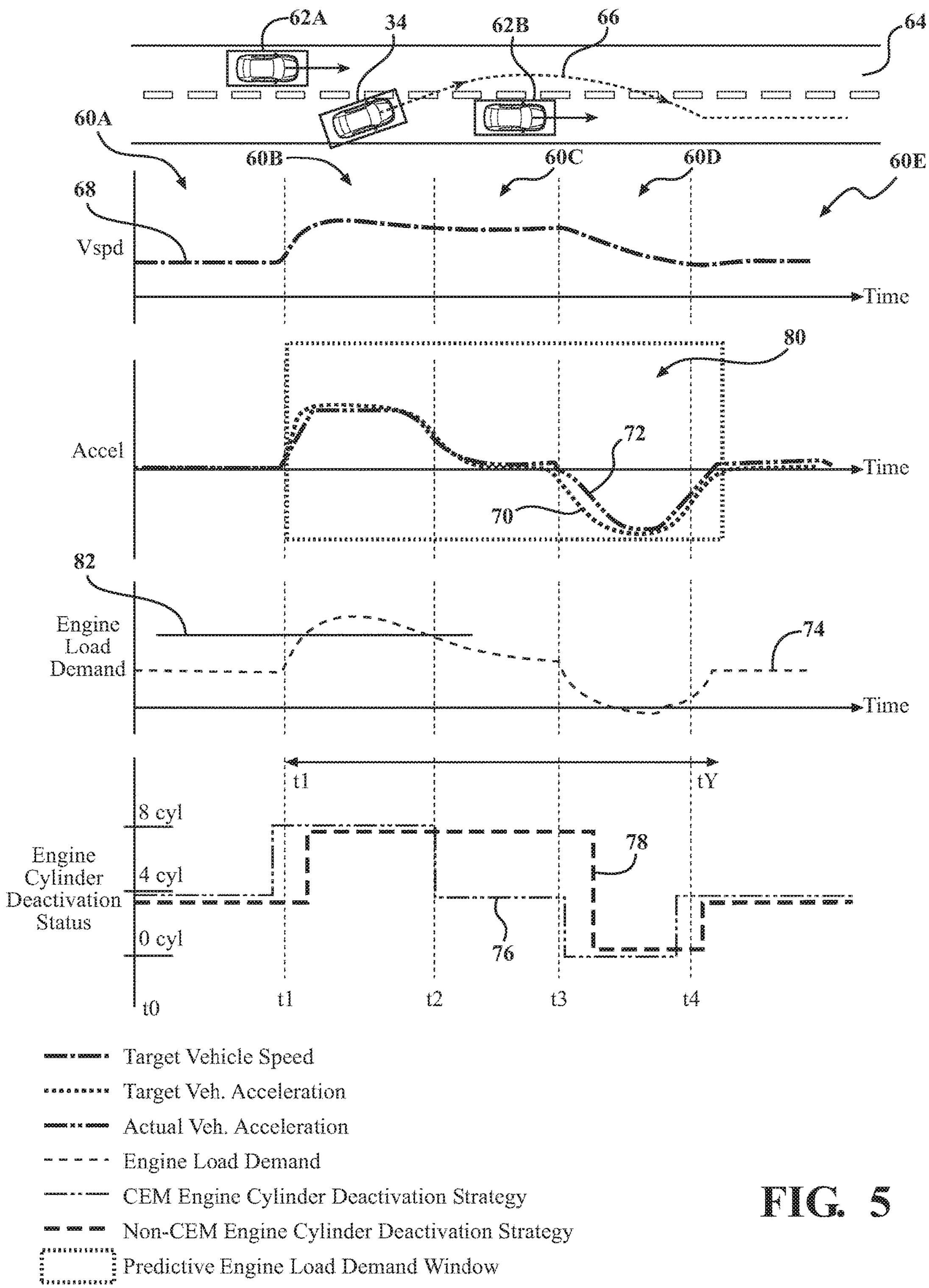

62A
34
62B
66
64
60A
60B
60C
60D
60E
68
Vspd
Time
80
Accel
72
70
Time
82
Engine
Load
Demand
74
Time
t1
tY
8 cyl
4 cyl
0 cyl
Engine
Cylinder
Deactivation
Status
78
76
t0
t1
t2
t3
t4
Target Vehicle Speed
Target Veh. Acceleration
Actual Veh. Acceleration
Engine Load Demand
CEM Engine Cylinder Deactivation Strategy
Non-CEM Engine Cylinder Deactivation Strategy
Predictive Engine Load Demand Window

FIG. 5

CONNECTED ENERGY MANAGEMENT AND AUTONOMOUS DRIVING STRATEGY FOR ENGINE CYLINDER DEACTIVATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 62/462,408 filed Feb. 23, 2017. The disclosure of the above application is incorporated herein by reference.

FIELD OF THE INVENTION

The invention relates generally to a cylinder deactivation strategy based on telematics and connectivity or in combination with parameters associated with autonomous driving.

BACKGROUND OF THE INVENTION

Current internal combustion engine cylinder deactivation strategies are primarily based on the requested propulsion torque at the current vehicle operating conditions, and are used to improve fuel economy. Internal combustion engines have an order in which each piston located in each cylinder is scheduled for firing. In using a cylinder deactivation strategy, cylinders are either scheduled for combustion or deactivation, depending on the engine torque demand, NVH (noise, vibration and harshness), and vehicle/engine constraints. This approach applies to conventional fixed-mode cylinder deactivation systems (e.g., changing between eight active cylinders and four active cylinders, or changing between four active cylinders and two active cylinders), or multi-mode cylinder deactivation systems, in which any number of cylinders in a given engine cycle can be deactivated or fired to meet the engine load demand. In all of these systems, future knowledge of the vehicle operating conditions or vehicle environment is not accounted for or included when scheduling cylinder deactivation (or individual cylinder firings). This typically leads to a suboptimal powertrain fuel efficiency improvement. This is particularly true if frequent changes in the required engine load demand and changes in the upcoming vehicle driving conditions lead to unnecessary cylinder deactivations or potentially poor system response when attempting to reactivate (i.e., fire) some or all of the engine cylinders. A vehicle utilizing engine cylinder deactivation for fuel efficiency gains may encounter these drawbacks in various situations, including, but not limited to: heavy traffic driving, traffic light approaches, road curvatures, road grades, and general vehicle deceleration.

One example of these drawbacks may occur where a vehicle is driven on a road with one or more curvatures. In this instance, a typical engine cylinder deactivation strategy frequently deactivates and reactivates the cylinders as the driver tips in and out (i.e., applies and releases) the accelerator and brake pedals while negotiating a curve. This is to be expected in a conventional cylinder deactivation strategy as current engine load demand changes. This irregular engine cylinder deactivation, or "hunting," may have a negative effect on drivability and fuel efficiency/emissions. One reason these negative effects occur is that as cylinders are fired for reactivation, in particular for a fixed-mode cylinder deactivation system (e.g., changing from eight cylinders to four cylinders, and vice versa), ignition retard is typically used to prevent engine torque surges during the cylinder reactivation. In some engine cylinder deactivation

strategies, deactivation hunting is prevented by means of an engine deactivation inhibit hysteresis logic, which prevents further deactivations when the time since the last deactivation was too short. This may lead to fuel efficiency gains that are not realized, since the cylinder deactivation becomes inhibited while preventing hunting.

Accordingly, there exists a need for an optimized engine cylinder deactivation strategy which improves fuel efficiency based on either or both of a combination of vehicle telematics and autonomous driving strategies.

SUMMARY OF THE INVENTION

In one embodiment, the present invention is an optimized engine cylinder deactivation strategy using connected energy management with advanced telematics including both static and dynamic data. In another embodiment, the present invention is an optimized engine cylinder deactivation strategy using connected energy management with autonomous driving strategies. In yet another embodiment, the present invention is an optimized engine cylinder deactivation strategy using connected energy management with advanced telematics including both static and dynamic data in combination with autonomous driving strategies.

If the engine controller (or powertrain controller) receives the current requested vehicle propulsion demand (torque or acceleration) and future vehicle propulsion demand, engine cylinder deactivation may be scheduled for ideal engine fuel efficiency. This allows the energy management strategy to maximize and extend the duration of engine cylinder deactivation operation, including vehicle cruising, passing, freeway entering/exiting maneuvers, etc. By having knowledge of the future vehicle acceleration/deceleration demand, the future engine load demand may be predicted and used to extend the duration of engine cylinder deactivation operation or alternatively modify the degree or level of engine cylinder deactivation (e.g. four-cylinder to six-cylinder operation on an eight-cylinder application) in order to meet the target vehicle trajectory set by the autonomous driving controller.

In an embodiment, the present invention is a connected energy management (CEM) system, which includes a strategy for controlling the activation of a plurality of engine cylinders in the engine of a vehicle. The CEM strategy is used with an engine having a plurality of cylinders, where a powertrain controller is operable for controlling the operation of the engine. A second controller is in electrical communication with the powertrain controller. In one embodiment, the second controller is a telematics controller, and in another embodiment, the second controller is an autonomous driving vehicle controller.

The second controller communicates at least one parameter to the powertrain controller, and the parameter is used to determine which of the plurality of cylinders are to be activated or deactivated. The powertrain controller then activates or deactivates one or more of the plurality of cylinders using the powertrain controller based on the parameter.

In the embodiment where a telematics controller is used, the parameter may be several parameters that include road data, such as both dynamic and static data. The static and dynamic data may include several different types of data, including, but not limited to, road curve shape, road grade, road surface, speed limits, traffic light data, vehicle traffic data, and vehicle accidents.

The vehicle includes an accelerator pedal and a brake pedal used for accelerating and decelerating the vehicle. The accelerator pedal is in electrical communication with the powertrain controller, and the desired load of the engine is controlled using the accelerator pedal, such that the load on the engine is changed based on the position of the accelerator pedal as detected by the powertrain controller. When incorporating the CEM strategy according to an embodiment of the present invention, one or more of the cylinders is activated or deactivated based on the at least one parameter, which may occur while propulsion torque is being requested (i.e., the driver is still applying force to the accelerator pedal). More specifically, when the driver of the vehicle has applied force to either the brake pedal or the accelerator pedal, the powertrain controller may activate or deactivate one or more of the cylinders to optimize efficiency of the engine.

In one embodiment, the CEM strategy may include a feedback mechanism which is used to communicate to the driver of the vehicle that the powertrain controller has activated or deactivated one or more of the plurality of cylinders, which may occur while the driver is still applying force to the accelerator pedal. In one embodiment, the feedback mechanism is a force-feedback accelerator pedal actuator, which works in opposition to the force applied to an accelerator pedal by the driver of the vehicle. In another embodiment, the feedback mechanism is an alert, which informs the driver of the vehicle that the powertrain controller has activated or deactivated one or more of the plurality of cylinders.

In the embodiment where the second controller is an autonomous driving vehicle controller, the parameter may be multiple parameters, including, but not limited to a current requested vehicle propulsion torque, and a future requested vehicle propulsion torque based on a target vehicle trajectory, such as a desired autonomous driving path. The powertrain controller activates or deactivates one or more of the plurality of cylinders based on the current requested vehicle propulsion torque and the future requested vehicle propulsion torque. More specifically, the autonomous driving vehicle controller communicates a plurality of data points to the powertrain controller. The plurality of data points represents the magnitude of the at least one parameter at a current time, and at least one future time. The powertrain controller activates or deactivates one or more of the cylinders using the data points at both the current time and the at least one future time to optimize efficiency such that the vehicle achieves the target vehicle trajectory (i.e., navigates the desired autonomous driving path).

The target vehicle trajectory may be used to predict the load demand on the engine based on the current requested vehicle propulsion torque and the future requested vehicle propulsion torque.

Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIG. **1** is a diagram of an autonomous driving system which incorporates a cylinder deactivation strategy, according to embodiments of the present invention;

FIG. **2** is a table of several non-limiting examples of how an optimized engine cylinder deactivation strategy is implemented in a vehicle with advanced telematics, according to embodiments of the present invention;

FIG. **3** is a diagram of an example of how an optimized engine cylinder deactivation strategy is used with dynamic traffic light data, according to embodiments of the present invention;

FIG. **4** is a diagram of an example of how an optimized engine cylinder deactivation strategy is used with road curve data, according to embodiments of the present invention; and

FIG. **5** is a diagram of an example of how an optimized engine cylinder deactivation strategy is used with autonomous driving data to perform a passing maneuver, according to embodiments of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following description of the preferred embodiment(s) is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

The present invention is an optimized engine cylinder deactivation strategy using connected energy management and autonomous driving strategies. Referring to FIG. **1**, an autonomous driving system for a vehicle having a connected energy management (CEM) strategy is shown generally at **10**. The system **10** includes an autonomous driving vehicle controller **12** in electrical communication with a powertrain controller **14**. The autonomous driving vehicle controller **12** receives many different types of parameters based on input from various devices, such as short range (SR) Radar **16**, long range (LR) Radar **18**, cameras **20**, and lidar **22**, such that various autonomous driving maneuvers may be performed by the vehicle. The data received by the autonomous driving vehicle controller **12** from each of these devices is used to develop a plan for energy management, such as cylinder deactivation, where one or more cylinders are deactivated at various points in time as various autonomous driving maneuvers are performed such that the vehicle travels an autonomous driving path. In different embodiments, the powertrain controller **14** receives different parameters based on input from the vehicle driver **24**, different types of vehicle input **26** (such as, but not limited to, vehicle speed, temperature, barometric pressure, and any other type of desired input from the vehicle), chassis **28**, and various road data **30**, and uses this information for energy management and to provide an operating strategy of the various powertrain components **32**A-**32**D, such as at least one actuator, which in this embodiment is a traction drive motor **32**A, a battery **32**B, an engine **32**C, and a driveline component **32**D. The driveline component **32**D may be any component in the driveline of the vehicle, such as a gear box or power split device.

The autonomous driving system **10** having the CEM strategy of the present invention expands the interface between the powertrain system of the vehicle and the autonomous driving controller **12**, such that data received by both the autonomous driving vehicle controller **12** and the powertrain controller **14** may be used to provide for a more accurate CEM strategy for the vehicle, and potentially changes the operating state of one or more of the cylinders of the engine **32**C at both a current operating time, in addition to multiple points in time in the future, to optimize the CEM strategy.

In one embodiment, the autonomous driving system **10** using a CEM strategy for cylinder deactivation applies to a vehicle with advanced telematics using the road data **30**, including both static and dynamic data around the vehicle including, but not limited to: road map database data (curves, grades, surface, speed limits, etc), and dynamic road events (traffic light real-time data, vehicle traffic data per lane, vehicle accidents, etc.). The road data **30** may be obtained using some type of device, such as a telematics controller **14**A, which is in communication with the powertrain controller **14**, with examples of road data **30** obtained by the telematics controller **14**A shown in at **30**A in FIG. **1**. A summary table with non-limiting examples of various driving situations from which road data **30** is generated is shown in FIG. **2**. In this embodiment, the vehicle does not include the autonomous driving vehicle controller **12**, and does not have autonomous driving capability. However, it is within the scope of the invention that the autonomous driving vehicle controller **12** may be included in this embodiment, such that the vehicle has autonomous driving capability, and the use of the telematics controller **14**A and the autonomous driving vehicle controller **12** may be combined to further optimize the CEM strategy according to the present invention. In this embodiment, and all of the embodiments described in this application, the vehicle may also be an HEV (hybrid electric) vehicle, or the vehicle may be internal combustion only.

An example of an approach using a CEM strategy for engine cylinder deactivation using parameters which include road data **30**, such as dynamic traffic light data information, according to the first embodiment of the present invention is shown in FIG. **3**. In the example shown in FIG. **3**, a vehicle **34** is shown which incorporates the CEM strategy according to the present invention, but only includes the powertrain controller **12** and the telematics controller **14**A, and does not have the autonomous driving vehicle controller **12**, and therefore does not have autonomous driving capability. The vehicle **34** is travelling on a road **36** towards an intersection, shown generally at **38**, having a traffic light signal, shown generally at **40**. The CEM strategy of the present invention in this example includes deactivating one or more of the engine cylinders of the vehicle **34**, as the vehicle **34** approaches the traffic light signal **40**.

Typically, with regard to a conventional engine cylinder deactivation, the deactivation is not scheduled until vehicle deceleration begins as the driver begins to release the accelerator pedal (i.e., "tips out"), and ultimately brakes, as the traffic light signal **40** is approached. The distance the vehicle has travelled while one or more of the engine cylinders has been deactivated (using a conventional cylinder deactivation strategy) is shown at **42**.

The CEM strategy of the present invention involves triggering engine cylinder deactivation over a larger distance **44** by utilizing dynamic traffic light data **30**A obtained by the telematics controller **14**A. The traffic light signal **40** is shown with the green light illuminated shown at **40**A, and the red light illuminated at **40**B. The amount of time between the green light being illuminated and the red light being illuminated is communicated to the vehicle **34**. In the example shown in FIG. **3**, the cylinder deactivation occurs at an earlier point in time, as compared to conventional cylinder deactivation, leading to the cylinder deactivation occurring over the greater distance **44**. This earlier cylinder deactivation in this example is triggered with the driver still requesting propulsion torque (i.e., the foot of the driver is still on the accelerator pedal). The vehicle **34** also includes some type of feedback mechanism, which is used to inform the driver of the vehicle **34** of the cylinder deactivation while propulsion torque is still being requested. In one embodiment, the feedback mechanism is provided through an alert, such as a telltale in the instrument cluster of the vehicle. Essentially, the driving situation shown in FIG. **3** is recognized by the powertrain controller **14**, and a prediction of future engine load reduction triggers earlier engine cylinder deactivation. The example shown in FIG. **3** is only an illustrative non-limiting example, and similar strategies are applied in other driving situations (e.g. road curvatures, road grade changes, etc.) in the table shown in FIG. **2**.

In an alternate embodiment, another type of feedback mechanism, such as a force-feedback accelerator pedal actuator **14**B is included and controlled by the powertrain controller **14**. The force-feedback accelerator pedal actuator **14**B works in opposition to the force applied to the accelerator pedal by the driver of the vehicle **34**. Earlier cylinder deactivation is initiated by the powertrain controller **14** through the use of the force-feedback accelerator pedal actuator **14**B to communicate to the driver to stop application of the accelerator pedal. This is possible since vehicle deceleration up to the intersection **38** is predicted by the powertrain controller **14** by using the road data **30** and dynamic traffic light data **30**A.

In another alternate embodiment, it is within the scope of the invention that in the example shown in FIG. **3**, the autonomous driving vehicle controller **12** may be included in this embodiment, such that the vehicle **34** has autonomous driving capability, and the use of the telematics controller **14**A and the autonomous driving vehicle controller **12** may be combined to further optimize the CEM strategy according to the present invention, when approaching the traffic signal **40**.

The vehicle **34** incorporating another example of the CEM strategy according to the first embodiment of the present invention is shown in FIG. **4**, where in this example, the vehicle **34** is being controlled by the driver to navigate a road **46** having several curves. In the example shown in FIG. **4**, the vehicle **34** is shown using the CEM strategy according to the present invention, but only includes the powertrain controller **12** and the telematics controller **14**A, and does not have the autonomous driving vehicle controller **12**, and therefore does not have autonomous driving capability.

FIG. **4** also includes several pairs of graphic representations **48**A-**48**P of the level of actuation of the brake pedal and accelerator pedal by the driver, with the accelerator pedal being represented by the graphics **48**A,**48**C,**48**E,**48**G, **48**I,**48**K,**48**M,**48**O and the brake pedal being represented by the graphics **48**B,**48**D,**48**F,**48**H,**48**J,**48**L,**48**N,**48**P. FIG. **4** also includes a chart which includes several operating parameters, such as vehicle speed **50**, engine load demand **52**, as well as two different indications of cylinder activation/deactivation. There is an indication of cylinder activation/deactivation **54** which incorporates the CEM strategy of the present invention, and an indication of cylinder activation/deactivation **56** which is for conventional cylinder deactivation (for comparison purposes). Also generally shown is a zone **58** where the curvature of the road **46** is detected between time t**1** and time t**2**.

Because the vehicle **34** includes the autonomous driving system **10** which uses the CEM strategy of the present invention, one of the parameters detected is the upcoming curves of the road **46**, represented by the road curve zone **58** (which the vehicle **34** travels between time t**1** and time t**2**), and various cylinders of the engine **32**C are activated and deactivated as the vehicle **34** travels the road **46** without frequent hunting. The engine **32**C has eight cylinders, and in the example shown in FIG. **4**, the powertrain controller **14** changes the mode of operation of the engine **32**C, where during a first mode of operation, four cylinders are active, and during a second mode of operation, eight cylinders are active, to optimize the operation of the engine **32**C. The curvature of the road **46** is detected and anticipated, such that the road curve zone **58** is part of the road data **30**, and starting at time t**1** in FIG. **4**, the engine **32**C is operating in the first mode of operation, where only four cylinders are active, and the engine **32**C remains in the first mode of operation until at least time t**2**, represented by **54** in FIG. **4**.

In comparison, the cylinder activation/deactivation **56** of a vehicle which does not incorporate the CEM strategy of the present invention is shown in FIG. **4**, where all eight cylinders are activated at various times between t**1** and t**2**, as the brake pedal and accelerator pedal are depressed and released, as shown by **48**A-**48**P, which increases fuel consumption, and reducing efficiency.

One of the advantages of implementing the CEM strategy of the present invention is that the average engine load demand is anticipated throughout the various curves of the road **46** (i.e., the road curve zone **58**) such that cylinder deactivation is optimized without frequent hunting. This leads to overall fuel efficiency gains as the curves of the road **46** are navigated. Unnecessary cylinder deactivations/reactivations and corresponding torque surges are reduced or eliminated. This CEM strategy according to the present invention, which anticipates the road curvature or crossing detection, is not limited to a fixed-mode cylinder deactivation system, but also applies to any multi-mode cylinder deactivation system in which one or more cylinders may be fired or reactivated in any given engine cycle.

In another embodiment, it is within the scope of the invention that in the example shown in FIG. **4**, the autonomous driving vehicle controller **12** may be included in this embodiment, such that the vehicle **34** has autonomous driving capability, and the use of the telematics controller **14**A and the autonomous driving vehicle controller **12** may be combined to further optimize the CEM strategy according to the present invention, when navigating the curves of the road **46**.

A second embodiment of the present invention is shown in FIG. **5**, which includes a CEM strategy for cylinder deactivation which applies to a semi-automated or fully autonomous driving vehicle in which the current requested vehicle propulsion torque (or acceleration/deceleration), as well as future requested vehicle propulsion torque (or acceleration/deceleration), required for a target vehicle trajectory plan are known. In the example shown in FIG. **5**, the vehicle **34** shown incorporates the CEM strategy according to the present invention, but includes the powertrain controller **12** and the autonomous driving vehicle controller **12**, and does not include the telematics controller **14**A. Engine cylinder deactivation scheduling may be predicatively scheduled (or engine cylinder deactivation inhibited) during various autonomous driving conditions. FIG. **5** illustrates an example where the vehicle **34** is in an autonomous driving mode, and is performing an autonomous driving maneuver, which in this example is a passing maneuver, while incorporating the CEM strategy for cylinder deactivation according to a second embodiment of the present invention.

The graphs in FIG. **5** are broken up into five phases, where the first phase **60**A occurs between times t**0** and t**1**, the second phase **60**B occurs between times t**1** and t**2**, the third phase **60**C takes place between times t**2** and t**3**, the fourth phase **60**D takes place between times t**3** and t**4**, and the fifth phase **60**E takes place after time t**4**. Also shown in FIG. **5** is the vehicle **34** performing a passing maneuver while two other vehicles **62**A,**62**B are also driving down the road **64**. The autonomous driving vehicle controller **12** interprets the environment around the vehicle **34**, and the position of each of the other vehicles **62**A,**62**B relative to the vehicle **34**, which is continuously changing as the vehicle **34** navigates the road **64**. Based on the environment around the vehicle **34**, and the position of the vehicles **62**A,**62**B relative to the vehicle **34**, the autonomous driving vehicle controller **12** uses these parameters to determine an autonomous driving path **66**, which the vehicle **34** follows to perform the passing maneuver. The graphs in FIG. **5** depict other parameters, such as the target vehicle speed **68** and corresponding target vehicle acceleration **70**, the actual measured vehicle acceleration **72**, engine load demand **74**, as well as a comparison of the activated cylinders, where one indication of active cylinders **76** occurs when the CEM strategy of the present invention is implemented for use with the vehicle **34**. For comparison, another indication of active cylinders **78** is shown where a vehicle that does not use the CEM strategy of the present invention. Also shown in FIG. **5** is a threshold level **82**, which represents the level at which the engine load demand **74** has increased to which all eight cylinders of the engine **32**C are required to be active to meet the engine load demand **74**.

As the vehicle **34** is moving on the road **64**, the autonomous driving vehicle controller **12** determines the autonomous driving path **66** necessary for the passing maneuver to be performed. During the first phase **60**A, the vehicle **34** is travelling at a substantially constant speed, and both the target vehicle acceleration **70** and actual measured vehicle acceleration **72** are substantially zero. The engine load demand **74** is also substantially constant, and the vehicle **34** is operating in the first mode of operation, where four cylinders are active. The autonomous driving vehicle controller **12** predicts and calculates the target acceleration **70** within a predictive engine load demand window **80**, where the window **80** includes the target vehicle acceleration **70** needed to perform the entire passing maneuver, based on both the current requested vehicle propulsion torque, which occurs at the current time t**1**, and future requested propulsion torque, which occurs at a future time, such that the vehicle **34** achieves the target vehicle acceleration **70**. The future time may occur at any point in time between t**1** and tY in the predictive engine load demand window **80**. The window **80** is broken up incrementally into a plurality of data points representing the various parameters, such that any number of data points may be used between times t**1** and tY as the future time.

As mentioned above, the graphs in FIG. **5** are broken up into five phases **60**A-**60**E. Although times t**1**, t**2**, t**3**, and t**4** are shown, and are included as part of the plurality of data points, the data points used between t**1** and tY may be such that an infinite number of data points are used. The predictive engine load demand window **80** may also be expanded to include a greater or lesser number of data points beyond both t**1** and tY, where any number of the data points is used to represent the various parameters mentioned above.

The vehicle **34** begins to perform the passing maneuver beginning in the second phase **60**B, where the engine load demand **74** increases, as the vehicle **34** accelerates and increases speed. It is shown in FIG. **5** that in the second phase **60**B, the target vehicle speed **68** increases, and so does both the target vehicle acceleration **70** and measured vehicle acceleration **72**. It is also shown in FIG. **5** that the engine load demand **74** passes the threshold level **82** (where all eight cylinders are needed to achieve the target vehicle acceleration **70**) during the second phase **60**B. The powertrain controller **14** is able to then switch the engine **32**C to the second mode of operation, where all eight cylinders are active, prior to the second phase **60**B, such that the engine **32**C is generating the required torque necessary for the vehicle **34** to achieve the target vehicle acceleration **70**. Because the autonomous driving vehicle controller **12** has determined the autonomous driving path **66**, and the necessary corresponding torque, target vehicle acceleration **70**, and target vehicle speed **68** needed throughout the entire predictive engine load demand window **80**, the switch to the second mode of operation is performed prior to performing the passing maneuver, such that the target vehicle acceleration **70** is achieved in a more responsive and efficient manner.

Once the vehicle **34** has been accelerated to the target vehicle speed **68** to pass the second vehicle **62**B, the vehicle **34** then remains at a substantially constant speed in the third phase **60**C, such that the engine **32**C is switched back to the first mode of operation, where only four cylinders are active.

After the vehicle **34** has passed the second vehicle **62**B, the vehicle **34** is then decelerated during the fourth phase **60**D. During the fourth phase **60**D, since the vehicle **34** is being decelerated, the engine load demand **74** decreases during the fourth phase **60**D, and is negative for a period of time. Because the engine load demand **74** is so low during the fourth phase **60**D, the powertrain controller **14** changes the engine **32**C to a third mode of operation, where none of the cylinders are active, the intake valves and exhaust valves are closed, and there is no fueling, reducing fuel consumption. During most of the fourth phase **60**D, the engine **34** is operating in the third mode of operation, where no cylinders are active. In an alternate embodiment, during the fourth phase **60**D, engine braking may be maximized by changing the engine **32**C to the second mode of operation, where all eight cylinders are active, there is no fueling, and the intake valves and exhaust valves are open. This is typical deceleration fuel cut-off, and such that engine braking is used to gently decelerate the vehicle **34**.

During the end of the fourth phase **60**D, and knowing that a constant vehicle speed is then to be maintained after completion of the passing maneuver (in the fifth phase **60**E), the CEM strategy of the present invention includes changing the engine **32**C back to the first mode of operation, where only four cylinders are active because in the fifth phase **60**E the target vehicle acceleration **70** in the future requested from the autonomous driving vehicle controller **12** is zero (i.e, zero acceleration). Once the vehicle **34** has completed the passing maneuver, and has completed deceleration, the vehicle **34** returns to travelling at a constant speed in the fifth phase **60**E. The powertrain controller **14** maintains the operation of the engine **32**C in the first mode of operation, where four cylinders are active.

In further regard to the CEM strategy according to the present invention, at time t**0**, the current and future engine load demand **74** (between times t**1** and tY) is calculated based on the desired autonomous driving path **66** (and corresponding parameters including vehicle acceleration/deceleration or propulsion torque requests, as well as both the target vehicle speed **68** and target vehicle acceleration **70**) provided by the autonomous driving vehicle controller **12**. The CEM engine cylinder deactivation strategy of the present invention schedules the engine **32**C to operate in the second mode of operation (all eight cylinders active) toward the end of the first phase **60**A and during the second phase **60**B in preparation to meet the required torque demand and target vehicle acceleration **70** needed for the vehicle **34** to perform the passing maneuver. At the beginning of the third phase **60**C, vehicle longitudinal acceleration is no longer requested as the vehicle **34** is then passing at a constant speed, and ultimately the engine load demand **74** decreases, where the engine **32**C is changed back to the first mode of operation, such that four cylinders are active. Unlike the non-CEM (conventional) cylinder deactivation approach, knowing the data points for each of the parameters, including the propulsion torque demand for the entire predictive engine load demand window **80**, allows for a more optimized cylinder deactivation operating strategy.

As shown in FIG. **5**, when comparing the two indications of active cylinders **76**,**78**, it is seen that when using the CEM strategy of the present invention, the powertrain controller **14** changes the engine **32**C from the first mode of operation, where four cylinders are active, to the second mode of operation, were eight cylinders are active, prior to the second phase **60**B. The engine **32**C then remains in the second mode of operation through the second phase **60**B, and is then changed back to the first mode of operation in the third phase **60**C.

This is in contrast to when the CEM strategy of the present invention is not used, where as shown by the indication of active cylinders **78**, the powertrain controller **14** does not change the engine **32**C from the first mode of operation to the second mode of operation until after t**1** in the second phase **60**B, and switches to the third mode of operation after time t**3** in the fourth phase **60**D. The engine **32**C does not revert back to the first mode of operation until during the fifth phase **60**E (after time t**4**).

In FIG. **5**, an engine cylinder deactivation strategy which does not use the CEM strategy of the present invention operates primarily based on the current engine load demand at the current operating conditions (engine, vehicle, etc.), and does not take into account any future engine load demand or operating conditions. In the example shown in FIG. **5**, the engine **32**C is initially operating in the first mode of operation, where four cylinders are active, at the initial engine load demand **74** before the requested engine load demand **74** increases at time t**1** (due to the vehicle **34** performing the passing maneuver as commanded by the autonomous driving vehicle controller **12**), which is the earliest point that the typical cylinder deactivation strategy changes the engine **32**C to the second mode of operation, where all eight cylinders are active as shown by the indication of active cylinders **78**. Shortly after time t**1**, all eight cylinders are active, while the vehicle **34** accelerates to perform the passing maneuver during the second phase **60**B and the third phase **60**C. Once the autonomous driving vehicle controller **12** reduces the vehicle acceleration request starting in the fourth phase **60**D, the powertrain controller **14** ultimately schedules all eight cylinders to be deactivated (between times t**3** and t**4**) as shown by the indication of active cylinders **78**, when the vehicle **34** is decelerating during the fourth phase **60**D, and engine load demand **70** is minimal, or slightly negative. Starting in the fifth phase **60**E when the autonomous driving vehicle controller **12** requests the target vehicle acceleration **70** to be zero to maintain the current speed of the vehicle **34**, the cylinder deactivation strategy (which does not use the CEM strategy of the present invention) schedules the first mode of operation (i.e., four cylinders active) based on the required engine load demand **74** for the current speed of the vehicle **34**.

Furthermore, when comparing the indication of active cylinders **78** (which does not use the CEM strategy of the present invention) to the indication of active cylinders **76** (which incorporates the CEM strategy of the present invention), it is shown by that there is a lag when changing from the first mode of operation to the second mode of operation near time t**1**. The indication of active cylinders **78** also shows the change from the second mode of operation directly to the third mode of operation after time t**3** in the fourth phase **60**D, which is different from the indication of active cylinders **76**, which transitions to back to the first mode of operation during the third phase **60**C, instead of remaining in the second mode of operation during the third phase **60**C. The indication of active cylinders **78** indicates the engine **32**C remains in the second mode of operation for a longer period of time, increasing fuel consumption, and reducing efficiency. There is another lag when changing from the third mode of operation back to the first mode of operation around time t**4**. Furthermore, when the CEM strategy of the present invention is not used, the vehicle **34** may not perform the passing maneuver as desired, or reach the target vehicle acceleration **70**, because of the lag which occurs when changing between the first mode of operation (four cylinder active) and the second mode of operation (eight cylinders active). Using the CEM strategy of the present invention provides a more optimized use of available engine torque.

While the example shown in FIG. **5** illustrates a CEM strategy of the present invention for a cylinder deactivation system having three modes of operation (i.e., four cylinders active, eight cylinders active, and zero cylinders active), the concept of the present invention applies to any fixed X-mode or multi-mode cylinder deactivation system in which one or more cylinders may be deactivated during a given engine cycle.

In another embodiment, it is within the scope of the invention that in the example shown in FIG. **5**, the telematics controller **14**A may be included in this embodiment, such that the vehicle **34** has connective capability, and the use of the telematics controller **14**A and the autonomous driving vehicle controller **12** may be combined to further optimize the CEM strategy according to the present invention, when performing an autonomous driving maneuver, such as the passing maneuver shown in FIG. **5**.

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

What is claimed is:

1. A connected energy management cylinder deactivation system, comprising:

an engine having a plurality of cylinders;

a powertrain controller operable for controlling operation of the engine;

an autonomous driving vehicle controller in electrical communication with the powertrain controller;

at least one parameter received by the autonomous driving vehicle controller, the at least one parameter used to determine which of the plurality of cylinders are to be activated and deactivated, the at least one parameter being communicated to the powertrain controller from the autonomous driving controller;

a plurality of data points representing the at least one parameter;

a current time, at least one of the plurality of data points representing a magnitude of the at least one parameter at the current time; and

at least one future time, another of the plurality of data points representing a magnitude of the at least one parameter at the at least one future time;

wherein the powertrain controller activates or deactivates one or more of the plurality of cylinders based on the plurality of data points at both the current time and the at least one future time.

2. The connected energy management cylinder deactivation system of claim **1**, the at least one parameter further comprising:

a current requested vehicle propulsion torque;

a future requested vehicle propulsion torque based on a target vehicle trajectory;

wherein the powertrain controller activates or deactivates one or more of the plurality of cylinders based on the current requested vehicle propulsion torque and the future requested vehicle propulsion torque.

3. The connected energy management cylinder deactivation system of claim **2**, wherein load demand on the engine is predicted based on the current requested vehicle propulsion torque and the future requested vehicle propulsion torque to achieve the target vehicle trajectory.

4. An connected energy management cylinder deactivation system, comprising:

an engine having a plurality of cylinders;

a powertrain controller operable for controlling operation of the engine;

an autonomous driving vehicle controller in electrical communication with the powertrain controller;

a telematics controller in electrical communication with the powertrain controller;

a plurality of parameters received by the autonomous driving vehicle controller, the plurality of parameters used to determine which of the plurality of cylinders are to be activated and deactivated, a portion of the plurality of parameters being communicated to the powertrain controller from the autonomous driving vehicle controller, and a portion of the parameters being communicated to the powertrain controller from the telematics controller;

a plurality of data points representing the at least one parameter;

a current time, at least one of the plurality of data points representing a magnitude of the at least one parameter at the current time; and

at least one future time, another of the plurality of data points representing a magnitude of the at least one parameter at the at least one future time;

wherein the powertrain controller activates or deactivates one or more of the plurality of cylinders based on the plurality of data points at both the current time and the at least one future time.

5. The connected energy management cylinder deactivation system of claim **4**, wherein the powertrain controller activates or deactivates one or more of the plurality of cylinders while propulsion torque is being requested.

6. The connected energy management cylinder deactivation system of claim **4**, the plurality of parameters further comprising:

dynamic data;

static data;

a current requested vehicle propulsion torque; and

a future requested vehicle propulsion torque based on a target vehicle trajectory;

wherein the powertrain controller activates or deactivates one or more of the plurality of cylinders based on the static data, dynamic data, the current requested vehicle propulsion torque and the future requested vehicle propulsion torque.

7. The connected energy management cylinder deactivation system of claim **6**, wherein load demand on the engine is predicted based on the current requested vehicle propulsion torque and the future requested vehicle propulsion torque to achieve the target vehicle trajectory.

8. The connected energy management cylinder deactivation system of claim **4**, further comprising a feedback mechanism, wherein the feedback mechanism communicates to a driver of the vehicle that the powertrain controller has activated or deactivated one or more of the plurality of cylinders.

9. A method for controlling activation of a plurality of engine cylinders, comprising the steps of:

providing an engine having a plurality of cylinders;

providing a powertrain controller operable for controlling operation of the engine;

providing an autonomous driving vehicle controller in electrical communication with the powertrain controller;

providing a plurality of parameters received by the autonomous driving vehicle controller;

providing a plurality of data points representing the plurality of parameters;

providing a current time; and

providing at least one future time;

communicating the plurality of parameters from the second controller to the powertrain controller;

using the plurality of parameters to determine which of the plurality of cylinders are to be activated or deactivated;

representing a magnitude of each of the plurality of parameters at the current time using the at least one of the plurality of data points;

representing a magnitude of the plurality of parameters at the at least one future time using another of the plurality of data points;

activating or deactivating one or more of the plurality of cylinders using the powertrain controller based on the plurality of data points at both the current time and the at least one future time.

10. The method of claim **9**, further comprising the steps of activating or deactivating one or more of the plurality of cylinders while propulsion torque is being requested.

11. The method of claim **9**, further comprising the steps of:

providing a feedback mechanism;

using the feedback mechanism to communicate to a driver of the vehicle that the powertrain controller has activated or deactivated one or more of the plurality of cylinders.

12. The method of claim **11**, further comprising the steps of:

providing the feedback mechanism to be a force-feedback accelerator pedal actuator;

opposing a force applied to an accelerator pedal by the driver of the vehicle with the force-feedback accelerator pedal actuator when the powertrain controller has activated or deactivated one or more of the plurality of cylinders based on the plurality of parameters.

13. The method of claim **11**, further comprising the steps of:

providing the feedback mechanism to be an alert;

using the alert to inform the driver of the vehicle that the powertrain controller has activated or deactivated one or more of the plurality of cylinders.

14. The method of claim **9**, further comprising the steps of providing the plurality of parameters to further comprise:

a current requested vehicle propulsion torque;

a future requested vehicle propulsion torque based on a target vehicle trajectory;

activating or deactivating one or more of the plurality of cylinders based on the current requested vehicle propulsion torque and the future requested vehicle propulsion torque.

15. The method of claim **14**, further comprising the steps of predicting load demand on the engine based on the current requested vehicle propulsion torque and the future requested vehicle propulsion torque to achieve the target vehicle trajectory.

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