(54) Title: DRIVELINE FOR A FAN USING A CONTINUOUSLY VARIABLE TRANSMISSION

(57) Abstract: A device for driving a fan, such as a cooling fan of a stationary electrical generation unit is described herein. The device includes a driveline for transmitting power from a prime mover to the fan. The driveline includes a continuously variable transmission that is in a driving relationship with the fan. A protection device is provided in the driveline to protect the continuously variable transmission from torque spikes. The protection device has a driven member and a driving member and is capable to acquire a plurality of operative conditions, the plurality of operative conditions including a first operative condition and a second operative condition. During the second operative condition the driven member and the drive member manifesting a higher degree of slip than when the protection device is in the first operative condition.
Driveline for a fan using a continuously variable transmission.

The present invention generally relates to drivelines for fans. More specifically, the present invention is concerned with a driveline for a fan using a continuously variable transmission.

For simplicity, traditional stationary electrical generation units drive the cooling fan off an internal combustion engine used to drive the generator. The fan is often driven by a fixed ratio driveline that uses a simple driveshaft or a belt and a pulley arrangement. While this approach works well in terms of reliability it is not particularly effective from energy efficiency perspective. Indeed, since the cooling fan is always driven at the same speed, which is designed to provide a degree of airflow to satisfy the most demanding operational conditions, it follows that in all other operational conditions where the electrical load is less or the ambient temperature is relatively low, the provided airflow is unnecessarily high.

The amount of power that is necessary to drive the cooling fan creates a significant parasitic loss that increases the fuel consumption of the internal combustion engine. For that reason it is desired to provide a mechanism to regulate the speed of the fan according to the actual cooling needs and thus avoid overdriving the fan.

A continuously variable transmission (CVT) can be beneficial in many applications where a fan is driven by a prime mover, especially from
the perspective of energy efficiency. In a typical arrangement, a prime mover, such as an internal combustion engine, drives the CVT that drives in turn the fan. A control unit regulates the ratio of the CVT such that the fan is driven at the desired speed. By properly adjusting the ratio of the CVT according to the specific operational requirements, the speed of the fan can be finely tuned to push only the required airflow through the radiator that is needed to cool the engine and in turn achieve a higher degree of energy efficiency.

[0005] Generally, the fan that is driven by the CVT has a significantly high inertia, which may create torque spikes during start-up or shut down conditions, or more generally any condition during which the fan is subjected to an acceleration occurring at a rate sufficient to create a significant amount of torque in the driveline.

[0006] For CVTs in which power transmission is effected via rolling contact between disks or rollers, such as CVTs of the toroidal cavity type, torque spikes can be problematic since they can damage the CVT.

[0007] Therefore there is a need in the industry to provide improved methods, devices and operational techniques to manage torque spikes in a driveline containing a CVT that drives a fan having a high inertia.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[0008] In the appended drawings:

[0009] Figure 1 is a block diagram of a driveline of a stationary electrical generator unit that uses a CVT to drive a fan for cooling the internal combustion engine of the electrical generator unit;
Figure 2 is a block diagram of a driveline according to a non-limiting example of implementation that uses a torque protection device;

Figure 3 is a block diagram of a variant of the driveline shown in Figure 2;

Figure 4 is a block diagram of the driveline of the example of implementation depicted in Figure 2 also illustrating an electronic controller to manage the operation of various components of the driveline;

Figure 5 is a more detailed block diagram of the electronic controller shown in Figure 5;

Figure 6 is a flowchart illustrating the logic of the software executed by the electronic controller illustrated in Figure 5; and

Figure 7 is a variant of logic illustrated by the flowchart in Figure 6.

In the drawings, illustrative embodiments are shown by way of example. It is to be expressly understood that the description and drawings are only for purposes of illustration and as an aid to understanding, and are not intended to be a definition of the limits of the invention.

DETAILED DESCRIPTION

In accordance with an illustrative embodiment, there is provided a driveline for transmitting power from a power output of a prime mover to a fan, the driveline comprising:
a continuously variable transmission having an input and an output; and

a protection device having a driven member and a driving member, the protection device being so configured as to acquire at least a first operative condition and a second operative condition, during the second operative condition the driven member and the driving member manifesting a higher degree of slip than when the protection device is in the first operative condition to protect the continuously variable transmission from torque spikes propagating in the driveline.

[0018] In accordance to another aspect, there is provided a driveline for transmitting power from a power output shaft of a prime mover to a fan, the driveline including:

a continuously variable transmission having a power input shaft and a power output shaft; and

a protection device so configured as to transmit torque when the prime mover generates power to drive the fan, and to allow the fan to remain in motion when the prime mover ceases generating power to drive the fan, thereby reducing the likelihood of a torque spike acting on the continuously variable transmission as a result of inertia of the fan.

[0019] The use of the word "a" or "an" when used in conjunction with the term "comprising" in the claims and/or the specification may mean "one", but it is also consistent with the meaning of "one or more", "at least one", and "one or more than one". Similarly, the word "another" may mean at least a second or more.

[0020] As used in this specification and claim(s), the words "comprising" (and any form of comprising, such as "comprise" and
"comprises"), "having" (and any form of having, such as "have" and "has"), "including" (and any form of including, such as "include" and "includes") or "containing" (and any form of containing, such as "contain" and "contains"), are inclusive or open-ended and do not exclude additional, unrecited elements or process steps.

[0021] The term "about" is used to indicate that a value includes an inherent variation of error for the device or the method being employed to determine the value.

[0022] It is to be noted that the expression "Transmission ratio" is to be construed herein and in the appended claims as the quotient of the value of the input speed divided by the value of the output speed. Accordingly, if the ratio increases and the output speed remains constant, the input speed increases.

[0023] Other objects, advantages and features will become more apparent upon reading of the following non-restrictive description of illustrative embodiments thereof, given by way of example only with reference to the accompanying drawings.

[0024] As embodied and broadly described herein, an illustrative embodiment provides a device for driving a cooling fan, which is part of a stationary electrical generation unit, for example. The device includes a driveline for transmitting power from a prime mover to the fan. The driveline has a continuously variable transmission, which is in a driving relationship with the fan. A protection device is provided in the driveline to protect the continuously variable transmission from torque spikes. The protection device has a driven member and a driving member and may be placed in at least two operative conditions, including a first operative condition and a second operative
condition. When the protection device is in the second operative condition the driven member and the drive member manifesting a higher degree of slip than when the protection device is in the first operative condition.

[0025] Figure 1 is a high-level block diagram of a driveline of a stationary, industrial capacity electrical generation unit that uses a CVT for driving a cooling fan. In this specific example, the stationary electrical generation unit uses a large internal combustion engine to drive an electrical generator (not shown). Since the generation unit is stationary, airflow is created through the radiator of the internal combustion engine by a fan. In order to produce a sufficient degree of cooling, the dimensions of the fan and its maximum speed of rotation are established according to the most demanding operational conditions that the electrical generation unit is likely to encounter in practice. In most cases this would be operation at high, continuous electrical loads when the ambient temperature is high, such as during the summer months.

[0026] In the example shown in Figure 1, the combination of the internal combustion engine 10, the CVT 12 and the fan 14 form a driveline 16 that conveys power from the internal combustion engine 10 to the fan 14. The CVT 12 provides a range of ratios allowing the variation of the speed of the fan such as to achieve an adequate airflow according to the current operational conditions. One example of a CVT that can be used for this application is described in the published US patent application 2009/0023545 filed on September 27th, 2005, the contents of which are hereby incorporated by reference. The CVT uses toroidal disks in rolling contact with rollers. The geometrical position of the rollers determines the ratio of the CVT. The position of the rollers, hence the ratio of the CVT can be changed by applying a control signal to an actuator that moves the rollers with relation to the toroidal disks accordingly. Although not shown in Figure 1 it will be understood that the CVT
is provided with some type of ratio control mechanism in order to adjust its ratio based on cooling needs. For example, the ratio control mechanism may be electronic and issue an electronic control signal to adjust the CVT ratio.

[0027] A characteristic of the driveline 10 is that the fan may have a significant level of inertia, which depends on the size of the fan, its mass and its speed of rotation. As such, the fan tends to resist motion changes that are induced by or in the driveline. Motion changes would typically occur during start-up of the fan, shut down or more generally any changes in the rotational speed of the fan (increase or decrease). When motion changes occur, the fan inertia will have a tendency to create torque spikes in the driveline. The magnitude of the torque spikes depends largely on the degree of speed change imposed on the fan; the larger the speed change the larger the torque spike will be. The torque spikes are undesirable because they can damage the CVT, in particular when the CVT is of the toroidal type cavity as indicated earlier.

[0028] Figure 2 is a block diagram of a driveline 17, which includes a torque protection device to protect the driveline and the CVT in particular from torque spikes. The driveline 17 is similar to the driveline 16 discussed in connection with Figure 1, with the exception of the torque protection device 24.

[0029] More specifically, the driveline 17 includes an internal combustion engine 18, driving a CVT 20, which, in turn, drives a fan 22 via a torque protection device 24. The purpose of the torque protection device 24 is to protect the CVT against torque spikes propagating in the driveline 17 as will be discussed hereinbelow.

[0030] In one illustrative example of implementation, the torque protection device 24 has at least two different modes of operation. The modes of operation are distinguished from one another on the basis of the capability of
the torque protection device 24 to transmit rotary motion. In one mode of operation the torque protection device 24 is in a torque-transmission mode during which there can be little or no slippage between a driving member provided on the internal combustion engine side of the driveline 17 and a driven member provided on the fan side of the driveline 17. In another mode of operation, the torque protection device 24 is in a torque-limiting mode in which a greater degree of slippage between the driving member and the driven member is allowed to limit the degree of torque that is being transmitted through the driveline 17.

[0031] Note that the torque-limiting mode of operation may be an operating condition during which no torque is being transmitted at all, or an operating condition in which still some torque is being transmitted through the driveline but it is limited to some value. For instance when the driven member and the drive member of the torque protection device 24 are completely disengaged, no rotary motion is transmitted; hence no torque is also transmitted through the driveline 17. However, when the driven member and the drive member are in some degree of engagement that allows slippage between them, rotary motion is still being transmitted but the amount of torque is limited.

[0032] The torque protection device 24 can change its operating mode, for instance it can switch from the torque-transmission mode to the torque-limiting mode, in different ways. In one example of implementation, the switch can occur without any external control or influence. In this example the relationship between the driven member and the driving member and their arrangement is such that when a certain level of torque is reached they will start slipping thus entering the torque-limiting mode. When the torque that is being transmitted through the driveline 17 falls below the value that induces
slippage, the torque protection device 24 resumes the torque-transmission mode.

[0033] In another example of implementation, the switch between the torque-transmission mode and the torque-limiting mode can be made under external control or influence such as by applying a control signal to the torque protection device 24. The torque protection device 24 is responsive to the control signal and acquires the desired mode of operation. The control signal can be electric, hydraulic, mechanical, pneumatic any other signal that can communicate a command to the torque protection device 24. Note that the signal can convey information or can also carry the energy necessary to change the relationship between the driven member and the drive member such as to acquire the desired mode. When the signal is hydraulic, pneumatic or mechanical, it will typically use pressure or mechanical force to change the relationship between the driven member and the drive member. When the signal is purely electronic it will typically be intended for processing by the torque protection device 24, which in turn implements the command conveyed by the logic signal.

[0034] Specific examples of implementation of the torque protection device 24 will be described which require no external influence to switch between the torque-transmission and the torque-limiting modes include:

[0035] · Slip clutch - a slip clutch has a driven member and a drive member that have friction surfaces pressed against one another. The degree of force with which the surfaces engage each other determines the torque limit, namely the torque value at which the clutch will start slipping, hence enter the torque-limiting mode. The slip clutch can be wet or dry. A wet clutch is immersed in lubricating and cooling liquid while a dry clutch is not bathed in fluid.
Magnetic coupling - in this example, magnets on the driven member and/or the drive member create attraction and can transmit rotational motion. The relative strength and the number of the magnets as well as their geometry determine the degree of mutual attraction and the ability of the coupling to transmit torque before slippage occurs.

Belt and pulley arrangement - in this example, the torque protection device 24 includes a pair of pulleys connected by a belt. In a normal (torque-transmission mode) there is little or no slippage between the pulleys and the belt. However, when the torque limit is reached, slippage occurs between one of the pulleys and the belt and the torque protection device 24 enters the torque-limiting mode. The belt and pulley system is designed such that the slippage occurs at the degree of torque, which is safe to handle by the components of the driveline 18, especially the CVT 20.

Fluid coupling - a hydrodynamic transmission that uses a fluid to convey rotary motion. A fluid coupling may be useful in protecting the CVT 20 especially at start-up conditions when the fan 22 is stationary and the internal combustion engine is started. Initially, the torque protection device 24 would inherently acquire the torque-limiting mode and as speed is build up it will switch to the torque-transmission mode where it can transmit rotary movement with a lesser degree of slip between the drive member and the driven member. Note that the nature of the fluid coupling is such that in almost all conditions, a degree of slip always exists between the driven member and the drive member. As such the difference between the torque-transmission mode and the torque-limiting mode resides in the degree of slippage.

Locking fluid coupling - this is a special type of fluid coupling that includes a clutch that can lock the fluid coupling is such a way that the torque is no longer transmitted via the fluid but by a direct mechanical
link and the locked clutch. When the clutch is open the coupling acts as a normal fluid coupling but when it is closed there is no more inherent slippage in the coupling.

[0040] Centrifugal clutch - a centrifugal clutch uses a drive member and a driven member that engage each other with a force determined by the degree of centrifugal force, which in turn is determined by the speed of rotation of the driven member. The level of force determines the torque limit. At start-up, when the driven member starts rotating, the clutch is inherently in the torque-limiting mode since the friction surfaces are not yet engaged. As the speed of rotation increases, the friction surfaces engage one another with a progressively increasing force and reducing slippage. At that point the centrifugal clutch enters the torque-transmission mode. The centrifugal clutch can be particularly useful for applications where it is necessary to protect the driveline against torque spikes at start-up and at shut down. In these conditions, the centrifugal clutch is inherently in the torque-limiting mode and progressively brings the fan up to speed or to a stop with little or no torque spikes.

[0041] One-way drive - a drive connection that transmits rotation only in one direction. This example of implementation is particularly useful in instances where protection is desired at shut down, when the internal combustion engine 18 suddenly stops. As the stop occurs, the one-way drive allows the fan to continue free running without creating any torque spikes on the driveline 18. Accordingly, the one-way drive enters the torque-limiting mode as soon as the fan starts to free run.

[0042] Specific illustrative examples of implementation of the torque protection device 24 will be described which require an external influence to switch between the torque-transmission and the torque-limiting modes:
[0043] · Slip clutch responsive to an electronic control signal. In this case an electronic control signal is produced to convey the desired state of the clutch, namely engaged (torque-transmission mode) or semi-engaged or fully disengaged (torque-limiting mode). The signal is produced according to the operational conditions. For instance, when a torque spike is detected or is considered likely to occur, the signal may be generated to cause the clutch to acquire the torque-limiting mode. The clutch has a mechanism that is responsive to the electronic control signal to implement the command.

[0044] · Electromagnetic clutch - clutch that requires the application of an electric field to establish a driving connection between the drive member and the driven member. The application of the electric field determines the operational condition of the clutch, namely torque-transmission mode, torque-limiting mode or freewheeling mode. Alternatively, the electric field level could be so chosen that the normal torque would be transferred while any torque spikes would cause slippage.

[0045] · Hydraulically, pneumatically or mechanically operated slip clutch - hydraulic fluid, compressed air or mechanical motion is used to control the clutch and its operational condition.

[0046] Note that the torque protection device 24 is not limited to any single one of the above illustrative examples, and can very well include a combination of different modules where each module provides protection against torque spikes that can arise at different operational conditions of the driveline 18. For instance one module may protect the driveline during start-up while another module protects the driveline during shut-down.

[0047] A variant of the driveline is shown in Figure 3. This variant shows that the torque protection device 24 can be located at different positions
in the driveline and does not necessarily need to reside between the CVT and the fan. In Figure 3, the torque protection device is located between the internal combustion engine and the CVT.

[0048] Figure 4 is a block diagram of the driveline described in connection with Figure 2, provided with an illustrative example of an electronic controller 26 that is used to control the operation of the torque protection device 24 when the torque protection device 24 uses an external influence to switch between operational modes.

[0049] The driveline 16 includes an electronic controller 26 that receives inputs from the fan 22, the torque protection device 24, the CVT 20 and the internal combustion engine 18 and is also capable of sending commands to the internal combustion engine 18, the CVT 20 and the torque protection device 24.

[0050] A more detailed block diagram of the controller 26 is shown in Figure 5. The controller 26 is software based and uses a computer platform comprising a processor 28 and a memory 30. The processor 28 and the memory 30 communicate via a data bus 32. The controller 26 can communicate with external devices, such as the components of the driveline 16 via an interface 34, which also connects with the data bus 32.

[0051] Figure 5 shows the various inputs and outputs arriving at the interface 34, namely:

[0052] · Rotational speed communication link 36 connected to a speed sensor (not shown) to generate a signal indicative of the speed at which the fan 22 rotates.
· Torque protection communication link 38, which conveys an electronic signal carrying a command to direct the torque protection device 24 to acquire a specific operational condition (such as torque-transmission mode or torque-limiting mode, for example). Note that the communication link 38 is bi-directional, which is denoted by the double arrow. This implies that the communication link 38 may also be optionally used by the controller 26 to read the operational state of the torque protection device 24 such that it can confirm that a desired operational condition has in fact been implemented.

· CVT communication link 40. This is also a bi-directional communication link that is used for sending commands to the CVT 20, such as to establish a desired ratio in order to control the speed of rotation of the fan 22, and also to optionally receive data indicative of the actual ratio at which the CVT 20 is.

· Internal combustion engine communication link 42. This is also a bi-directional communication link used for sending commands to the internal combustion engine 18 such as, start-up, shut-down or to increase/decrease power. In terms of data gathered from the internal combustion engine 18, the communication link 42 can convey information such as engine speed, engine temperature and amount of power being produced, among others.

· Operator commands communication link 41 that convey information such as commands to start-up the internal combustion engine 18, commands to shut-down the internal combustion engine 18 or others.

The function of the electronic controller 26 is determined by software, which is stored in the memory 30. In operation, the instructions of the
software are executed by the processor 28 which, therefore, implements the control logic built into the software.

[0058] As will easily be understood by one skilled in the art, the above-described electronic controller 26 is an illustrative example only and could be replaced by a simpler controller. For example, a controller (not shown) that would be so designed as to acquire the state of the internal combustion engine (starting, running or stopping) and to control the torque protection device 24 accordingly. Of course, other hardware or software based controllers could be used.

[0059] The flowchart in Figure 6 illustrates, in broad terms, the software logic for controlling the torque protection device 24. Note that the torque protection device logic can be one of many other software components, which are executed by the electronic controller 26. In other words, the electronic controller 26 may have other functions in the overall operation of the devices (not shown) integrating the driveline 17.

[0060] The logic process flow starts at 44. At step 45 the electronic controller 26 reads the various parameters conveyed via the communication links 36, 38, 40 and 42. At step 46, which is a conditional step, the various parameters are interpreted to determine if a torque spike is imminent. Illustrative examples of conditions that would indicate imminent torque spikes are discussed below. It should be explicitly noted that those are examples only and other conditions can be taken into account to determine that a torque spike is likely to occur in the driveline 17.

[0061] · The internal combustion engine 18 is being shut down, is stalling or for any other reason it is ceasing to operate. This condition can be sensed, for example, by reading the engine rotation speed. When the speed
drops below a certain threshold, which can represent an engine speed that cannot be sustained, say 400 RPM for example, the logic concludes that the internal combustion engine will stop imminently which is likely to produce a torque spike in the driveline if the torque protection device 24 does not switch to the torque-limiting mode. Note that in case of voluntary engine shut down procedures, if the shut down command is channeled through the electronic controller 26, the logic will have prior knowledge of the potential torque spike before any change in engine speed is observed. In that case, the information of the shut down command is sufficient to conclude that a torque spike is imminent.

[0062] · The internal combustion engine is starting-up. A start-up condition, which indicates an impending torque spike since the fan is stationary and is being put in motion, can be detected in a number of possible ways. One is to read the engine speed and when the engine speed exceeds a certain value, indicative of a cranking cycle, the logic concludes that the engine is in a start-up mode. For example, when the engine speed data indicates that an engine speed in excess of 50 RPM or any other low RPM value that can be reliably read, the logic concludes that the engine is cranked and that it will start up imminently. As in the previous example, the engine start-up command may be channeled via the electronic controller 26 such that the electronic controller has prior knowledge of the event and can react accordingly before any RPM change has been noted.

[0063] · High rate of RPM change, which indicates a condition in which the fan will be subject to acceleration. A high RPM, change can indicate an engine shut down condition, an engine start-up condition or simply a sharp variation in the speed of the internal combustion engine. The rate of RPM change is computed by measuring the internal combustion engine 18 speed at different points in time and then performing a computation of the rate of RPM
change. If the computed rate is above a threshold, the logic concludes the fan will be subject to acceleration and a torque spike will be occurring.

[0064] Returning to the description of the process flow in Figure 6, if an impending torque spike is detected at step 46, the process moves to step 48 at which a control signal is issued over communication link 38 to cause the torque protection device 24 to acquire the torque-limiting mode. In a specific example of implementation this signal is a logic signal that conveys a command. The signal is received by the torque protection device 24 and the command is executed. Note that the signal propagation path from the electronic controller 26 to the torque protection device 24 may include devices to convert the signal in a form that is more suitable for the torque protection device 24, such as hydraulic, pneumatic or mechanical.

[0065] When the decision step 46 is answered in the negative, to the effect that no torque spike is impending, the process returns to step 45.

[0066] Figure 7 is a variant of the process described in connection with Figure 6. The variant is best suited for applications where the torque spike may result from operator commands, such as start-up, shut down or commands that produce a variation of the RPM of the internal combustion engine. The process in Figure 7 has two additional steps. One is the conditional step 50 at which an assessment is made by the electronic controller 26 as to whether or not the torque protection device 24 has acquired the torque-limiting mode. The confirmation is received over the communication link 38. In the affirmative, the process continues at step 52 at which the operator command is implemented. However, in the negative, when no confirmation has been received, the electronic controller 26 assumes that the torque protection device 24 has not yet acquired the torque-limiting mode and defers implementation of the command. For instance, if the command is to shut down the internal
combustion engine 18 then the engine is maintained in operation until a confirmation about the correct status of the torque protection device 24 is received. When the command is to start-up the engine, then the engine will not crank up until the confirmation is received. Similarly, when the command is to vary the RPM, the RPM is maintained at its current value until a confirmation is received.

[0067] From a process perspective the deferral of the command implementation is illustrated in the flowchart with the arrow 53, which shows that the execution returns back to step 48. This loop repeats until the confirmation is received.

[0068] The command is implemented at step 52 only if the conditional step 50 is answered in the affirmative.

[0069] One skilled in the art will understand that the controller 26 can be so configured as to control the transmission ratio of the CVT 20 in response to the speed changes of the ICE 18 so as to limit the torque spike potential. Indeed, if the CVT ratio is so controlled as to be increased when the speed of the ICE increases and to be decreased when the speed of the ICE decreases, the speed of the fan in less likely to be dangerously affected by speed changes of the ICE.

[0070] Accordingly, and within limits, the rate of change of the speed of the fan 22 can be adjusted to prevent torque spikes by a rapid and careful control of the CVT ratio.
It is to be noted that the inventive concepts described herein should not be limited to the specific application of an electrical generation unit, rather they may also be useful in other applications as well.

It is to be understood that the invention is not limited in its application to the details of construction and parts illustrated in the accompanying drawings and described hereinabove. The invention is capable of other embodiments and of being practiced in various ways. It is also to be understood that the phraseology or terminology used herein is for the purpose of description and not limitation. Hence, although the present invention has been described hereinabove by way of illustrative embodiments thereof, it can be modified, without departing from the spirit, scope and nature of the subject invention as defined in the appended claims.
WHAT IS CLAIMED IS:

1. A driveline for transmitting power from a power output of a prime mover to a fan, the driveline comprising:
   - a continuously variable transmission (CVT) having an input and an output;
   - a protection device having a driven member and a driving member, the protection device being so configured as to acquire at least a first operative condition and a second operative condition, during the second operative condition the driven member and the driving member manifesting a higher degree of slip than when the protection device is in the first operative condition to protect the continuously variable transmission from torque spikes propagating in the driveline.

2. A driveline as recited in claim 1, wherein:
   - the input of the CVT is associated with the power output of the prime mover;
   - the output of the CVT is associated with the driving member of the protection device; and
   - the driven member of the protection device is associated with the fan.

3. A driveline as recited in claim 1, wherein:
   - the driving member of the protection device is associated with the power output of the prime mover;
   - the input of the CVT is associated with the driven member of the protection device; and
the output of the CVT is associated with the fan.

4. A driveline as recited in claim 1, further comprising a control device for selectively altering the operative condition of the protection device.

5. A driveline as recited in claim 1, wherein the CVT includes a pair of toroidal disks and at least one roller in rolling contact with the toroidal disks to transmit power from one toroidal disk to the other toroidal disk.

6. A driveline as recited in claim 1, wherein when the protection device acquires the second operative condition, the driven member and the drive member are fully disengaged.

7. A driveline as recited in claim 1, wherein the protection device is selected from the group consisting of slip clutch, magnetic coupling, electromagnetic clutch, fluid coupling, centrifugal clutch and one way coupling.

8. A driveline as recited in claim 1, further comprising an electronic controller a) so connected to the prime mover as to receive speed data therefrom; b) so connected to the CVT as to control a transmission ratio between the CVT input and the CVT output; c) so connected to the protection device as to selectively change the operating condition of the protection device.

9. A driveline as recited in claim 8, wherein the electronic controller is further configured as to receive operator commands.

10. A driveline as recited in claim 8, wherein the electronic controller is so configured as to control the transmission ratio of the CVT in response to the speed data received from the prime mover to thereby control a
rate of change of the speed of the fan to thereby limit the likelihood of a torque spike.

11. A driveline for transmitting power from a power output shaft of a prime mover to a fan, the driveline including:

   a continuously variable transmission (CVT) having a power input shaft and a power output shaft; and

   a protection device so configured as to transmit torque when the prime mover generates power to drive the fan, and to allow the fan to remain in motion when the prime mover ceases generating power to drive the fan, thereby reducing the likelihood of a torque spike acting on the CVT as a result of inertia of the fan.

12. A driveline as recited in claim 11, wherein the protection device has a driven member and a driving member, the protection device being so configured as to acquire at least a first operative condition and a second operative condition, during the second operative condition the driven member and the driving member manifesting a higher degree of slip than when the protection device is in the first operative condition to protect the CVT from torque spikes propagating in the driveline.

13. A driveline as recited in claim 12, wherein:

   the power input shaft of the CVT is associated with the power output shaft of the prime mover;

   the power output shaft of the CVT is associated with the driving member of the protection device; and

   the driven member of the protection device is associated with the fan.
14. A driveline as recited in claim 12, wherein:
   the driving member of the protection device is associated with the power output shaft of the prime mover;
   the power input shaft of the CVT is associated with the driven member of the protection device; and
   the power output shaft of the CVT is associated with the fan.

15. A driveline as recited in claim 12, further comprising a control device for selectively altering the operative condition of the protection device.

16. A driveline as recited in claim 11, wherein the CVT includes a pair of toroidal disks and at least one roller in rolling contact with the toroidal disks to transmit power from one toroidal disk to the other toroidal disk.

17. A driveline as recited in claim 12, wherein when the protection device acquires the second operative condition, the driven member and the drive member are fully disengaged.

18. A driveline as recited in claim 11, wherein the protection device is selected from the group consisting of slip clutch, magnetic coupling, electro-magnetic clutch, fluid coupling, centrifugal clutch and one way coupling.

19. A driveline as recited in claim 12, further comprising an electronic controller a) so connected to the prime mover as to receive speed data therefrom; b) so connected to the CVT as to control a transmission ratio of the CVT between the power input shaft and the power output shaft; and c) so
connected to the protection device as to selectively change the operating condition of the protection device.

20. A driveline as recited in claim 19, wherein the electronic controller is further configured as to receive operator commands.

21. A driveline as recited in claim 19, wherein the electronic controller is so configured as to control the transmission ratio of the CVT in response to the speed data received from the prime mover to thereby control a rate of change of the speed of the fan to thereby limit the likelihood of a torque spike.
Fig. 1

Internal combustion engine → CVT → Fan

Fig. 2

Internal combustion engine → CVT → Torque protection → Fan

Fig. 3

Internal combustion engine → Torque protection → CVT → Fan
Start

Read parameters

Impending torque spike?

Yes

Issue control signal to torque protection device

No
Start

Read parameters

Impending torque spike?

Yes

Issue control signal to torque protection device

No

Torque limiting mode acquired?

Yes

Implement command

No
INTERNATIONAL SEARCH REPORT

International application No. PCT/CA201 1/000228

A. CLASSIFICATION OF SUBJECT MATTER

IPC: F16H 35/10 (2006.01), B60K 25/00 (2006.01), F01P 5/04 (2006.01), F01P 7/04 (2006.01), F02B 67/04 (2006.01), F04D 25/08 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F16H 35/10 (2006.01), B60K 25/00 (2006.01), F01P 5/04 (2006.01), F01P 7/04 (2006.01), F02B 67/04 (2006.01), F04D 25/08 (2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)

Canadian Patents Database, EPOQUE (Epodoc)
- Search terms used: electrical, power, drive, variable transmission, cooling fan, torque, slip clutch and similar terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>WO 2008/002457 A2 (POHL., B. et al.) 3 January 2008 (03-01-2008) * Abstract; Fig. 1A *</td>
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<td>CA 2,302,238 A1 (LFNK, L. R.) 4 March 1999 (04-03-1999) * Abstract; Fig. 2 *</td>
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[X] See patent family annex.

[ ] Further documents are listed in the continuation of Box C.

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Date of the actual completion of the international search
8 June 2011 (08-06-2011)

Date of mailing of the international search report
16 June 2011 (16-06-2011)

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Canadian Intellectual Property Office
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Facsimile No.: 001-819-953-2476

Authorized officer
Catherine Soucy (819) 997-8808
## INTERNATIONAL SEARCH REPORT
### Information on patent family members

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