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### Specification

#### Title of the Invention:

Method and apparatus for predicting recovery time and hard disk drive

. Detailed Description of the Invention:

The present invention relates to a method and an apparatus for predicting a recovery time of a power supply from a waiting state of a hard disk drive in a system provided with the hard disk drive, as well as a hard disk drive.

[0002]

[Background art].

Usually, in a system provided with a hard disk drive, the priority of each read/write task in the hard disk drive is high and accordingly, the task is required of fast responses. However, once the hard disk drive stops its spindle motor and unloads the actuator so as to save the power thereof, the hard disk drive takes a long time to restore the spindle motor and the actuator up to a usable state respectively.

[0003]

That is, if a host system transmits a power save command to such a hard disk drive, the hard disk drive enters a stand-by mode or a sleep mode according to the received command. In the stand-by mode, only the interface circuit of the host system is active, so that the host system can receive commands. However, other components of the host system are all in a power-off state. In the sleep mode, all the operations of the host system enter the power-off state. To be restored from this mode, the host system receives only a hard reset command or a soft reset command. A time required until the host system exits the stand-by or sleep mode so as to enter an idle mode or a time required until the host system executes a read/write operation is assumed as a power supply recovery time, mainly consisting of a time until the spindle motor reaches a predetermined rotation speed (also referred to as a time required for restarting the spindle motor) and a time required until the actuator released from an unloaded position so as to calibrate the servo, then moved to a predetermined cylinder (also referred to as a time required for moving the actuator to

a predetermined cylinder). This recovery time of the power supply has been long so far.

[0004]

[Problems to be solved by the invention]

In a system provided with a conventional hard disk drive, the host system had to wait without executing any task until the hard disk drive is restored to a usable state during a period of time between when the hard disk drive was restored from a stand-by state for power saving in which, for example, the spindle motor was stopped and the actuator was unloaded and when the hard disk drive was restored to a usable state. Consequently, the time required until such a restoration from a stand-by state was wasteful. Especially, it took several seconds until the spindle motor was restarted in some cases. This has been a serious problem for hard disk drives for which fast responses are expected.

[0005]

Under such the circumstances, it is an object of the present invention to provide a method and an apparatus for predicting a recovery time, to be employed in a system provided with a hard disk drive that can solve the above conventional problems and speed up the processing in the whole system provided with such a hard disk drive with efficient use of a recovery time of the power supply that has been long to restore from a stand-by state, as well as a hard disk drive that uses the method.

[0006]

[Summary of the invention]

According to the method of the present invention for predicting a recovery time, at first, a power supply recover time required until a hard disk drive is restored to a usable state from a

stand-by state is predicted when a host system requests the hard disk drive to exit the stand-by state. Next, the predicted recovery time of the power supply is reported to the host system.

[0007]

According to the present invention, the host system can know a time required until the power supply is recovered. Consequently, the host system can schedule a task to be ended within this period of time to be executed before the hard disk drive is restarted, so that scheduling of all the tasks to be executed in the whole system can be optimized. Consequently, it is possible to speed up the processing in the whole system provided with a hard disk drive significantly. In addition, the host system can notify the user of a time required until the response is returned, although it depends on the type of the host system.

[0008]

In a concrete preferred example according to the present invention, the hard disk drive predicts a power supply recovery time by itself with reference to the current state and the past operation history thereof. In addition, the hard disk drive calculates such a power supply recovery time as follows if it is assumed that a time required until the spindle motor thereof is restarted is  $t_s$ , a time required until the actuator thereof is moved to a predetermined cylinder is  $t_v$ , and a power supply recovery time is  $t_R$ .

$$t_R = t_s + t_v$$

Furthermore, the hard disk drive calculates a time  $t_s$  required until the spindle motor thereof is restarted as follows;

$$t_s = f(Rc) \text{ or}$$

$$t_s = k \cdot f(Rc),$$

where  $R_c$  is the current rotation speed,  $f(R_c)$  is a time required until the spindle motor is restarted at  $R_c$  and at a reference temperature,  $k$  is a temperature correction coefficient ( $k = g(T)$ ), and  $T$  is the current temperature value.

Then, the hard disk drive corrects the power supply recovery time calculated as described above according to the current temperature. In any cases, the power supply recovery time can be predicted more accurately so as to be assumed a preferred one.

[0009]

Furthermore, the apparatus of the present invention for predicting such a recovery time includes a device for receiving a predetermined signal from outside, a device for predicting a time required until the apparatus is restored to a predetermined state in response to the predetermined signal, and a device for reporting the predicted recovery time to outside. And, preferably, the device for predicting a recovery time should include a device for detecting a temperature of the apparatus and a step for calculating a recovery time from the detected temperature. The hard disk drive of the present invention provided with a spindle motor for rotating a disk includes a device for receiving a predetermined signal from a host system, a device for detecting the rotation speed of the spindle motor, a device for calculating a hard disk drive recovery time from the detected rotation speed, and a device for reporting the calculated recovery time to the host system. In any cases, the method of the present invention for predicting a recovery time can be realized in a preferred embodiment.

[0010]

[Preferred embodiment]

Figure 1 is a flowchart showing an example of a recovery time

predicting method of the present invention, employed for a system provided with a hard disk drive. According to the explanation of this invention with respect to Figure 1, at first, the host system requests the hard disk drive (described as HDD in Figure 1) in a stand-by state to exit the stand-by state (step S1). Actually, the host system issues a power save reset request or a read/write request to the hard disk drive in a power save state. Then, receiving a restart request from the host system via an interface, the hard disk predicts a recovery time of the power supply required to be restored from the stand-by state to a usable state (step S2). In this case, the hard disk drive predicts a power supply recovery time by itself with reference to the current state and the past operation history thereof. After that, the hard disk drive reports the predicted recovery time of the power supply to the host system (step S3), then exiting the processing.

[0011]

This completes the description of the recovery time predicting method of the present invention, employed for a system provided with a hard disk drive. Receiving such a predicted recovery time of the power supply, the host system can thus know a time required until, for example, the hard disk drive is enabled for a read/write operation. Consequently, at the time of considering the whole system it is possible to allocate tasks efficiently in a system with use of a method for allocating a task to be ended before the power supply is recovered so as to be finished within the time of period. Consequently, the present invention can speed up the processing in the whole system provided with a hard disk drive. If the host system is, for example, a personal computer, then the user can be notified of the time when the build-up of the hard disk drive is completed with use of a method for displaying the remaining time of the power supply recovery time in real time on the display unit.

[0012]

Hereunder, a description will be made in detail for how to request restarting, how to report a predicted value, and how to predict a recovery time of a power supply according to the present invention. When a host system requests a hard disk drive to restart, the host system sends a dedicated command (ex., '84h') to the hard disk drive first. The command is added newly to that processing. In the above embodiment, a recovery time of a power supply was a total time required until the spindle motor was restarted and the actuator was moved to a predetermined cylinder. If such a power supply recover time is assumed to include a specific time in addition to the above two times in a read operation, a write operation, or another operation, then it is possible to design the recovery time predicting method of the present invention so that a type of a power supply recovery time that the host system wants to know, for example, the type of a power supply recovery time in a read operation, a write operation, or another operation is sent back to the host system just when the host system sends the above dedicated command to the hard disk drive. On the other hand, the hard disk drive can send a predicted power supply recovery time to the host system, for example, a value can be sent as one-byte information in units of 100 msec via sector count register.

[0013]

Next, how to predict a power supply recovery time will be described. As described above, a power supply recovery time is predicted by predicting both of a time required for restarting the spindle motor and a time required for moving the actuator to a predetermined cylinder, then adding up both of the times. More concretely, if it is assumed that a power supply recovery time is  $t_r$ , a time required for restarting the spindle motor is  $t_s$ , and a time required for moving the actuator to a predetermined cylinder is  $t_v$ , then the following expression is given and the power supply recovery time  $t_r$  can be described.

$$t_R = t_s + t_v \quad \dots (1)$$

And, the power supply recovery time  $t_R$  can be predicted from this expression (1).

[0014]

In the above expression (1), the time  $t_v$  for moving the actuator to a predetermined cylinder is considered to be always fixed. The time  $t_v$  actually measured at the delivery time from the factory is stored and used. On the other hand, the time for restarting the spindle motor is varied according to the rotation speed of the spindle motor when the restarting begins. In other words, the restarting time  $t_s$  is varied between when the spindle motor is stopped completely (rotation speed: 0) and when the spindle motor is still rotating. The  $t_s$  should preferably be calculated by the following expression (2).

$$t_s = f(Rc) \quad \dots (2)$$

Where  $Rc$  is the current rotation speed and  $f(Rc)$  is a time required for restarting the spindle motor at  $Rc$  and at a reference temperature (ex., 25°C).

[0015]

Furthermore, because the time  $t_s$  required for restarting the spindle motor is varied according to the ambient temperature, the time  $t_s$  should preferably be calculated by the following expression (3).

$$t_s = k \cdot f(Rc) \quad \dots (3)$$

Where  $k$  is a temperature coefficient ( $k = g(T)$  and  $T$  is the current temperature.

[0016]

The above expressions (1) and (2) or (3) are combined as needed so as to predict the power supply recovery time  $t_r$ . Next, how to realize this power supply recovery time  $t_r$  concretely will be described. At first, an example for calculating the  $f(R_c)$  value by making approximations for a line graph will be described. In this example, a graph is created first according to a time required for restarting the spindle motor at a certain temperature ( $T$ ) and at a certain rotation speed ( $R_c$ ) found in a test performed before the delivery from the factory. The graph indicates the relationship between  $f(R_c)$  and  $R_c$  at a reference temperature (ex.,  $25^\circ\text{C}$ ). Figure 2 shows such a graph. In Figure 2, there are already test data of  $R_c$  found at each of 0,  $R_1$ ,  $R_2$ ,  $R_3$ ,  $R_4$ , and  $R_5$ . Then, a linear function slope and an intercept in each section of the rotation speed  $R_c$ , that is, in each of the sections 0 to  $R_1$ ,  $R_1$  to  $R_2$ ,  $R_2$  to  $R_3$ ,  $R_3$  to  $R_4$ , and  $R_4$  to  $R_5$  are stored in a table format beforehand in the hard disk drive. In this case, it is premised that the table held in the hard disk drive is updated at every measurement time by measured values of both the rotation speed  $R_c$  measured actually after the delivery from the factory and the time  $f(R_c)$  required for restarting the spindle motor. Then, when the host system issues a restart command, the rotation speed  $R_c$  of the spindle motor is read by any means and the  $f(R_c)$  value, that is, the  $t_s$  value is calculated from the line graph shown in Figure 2 with reference to the table according to the read  $R_c$  value. Then, the  $t_s$  value is added to  $t_v$  calculated beforehand, thereby predicting the power supply recovery time  $t_r$ .

[0017]

To correct the temperature, a graph for indicating the relationship between the temperature  $T$  and  $g(T)$  is created according to the values measured at the delivery time from the factory. At this time,  $k = g(T)$  at the reference temperature in Figure 2 is assumed as 1. Figure 3 shows such a graph. The range of the temperature  $T$  should be decided so as to cover the

guaranteed temperature of the hard disk drive, for example, 5 to 55°C. Just like the example shown in Figure 2, the graph shown in Figure 3 is held in the hard disk drive so that both linear function slope and intercept in each section are tabulated. Then, when the host system issues a restart command, the temperature  $T$  is read by any means and the  $g(T)$ , that is, a temperature correction coefficient  $k$  is calculated with reference to the table according to the read temperature  $T$  value, thereby the power supply recovery time  $t_r$  can be predicted with use of the temperature correction coefficient found as described above. In this case,  $f(Rc)$  described above is assumed as  $k \cdot f(Rc)$ .

[0018]

The power supply recovery time  $t_r$  can also be concretely realized in another way, for example, from a lookup table. In such an example, the lookup table is created according to the time required for restarting the spindle motor at a certain temperature and at a certain rotation speed, both found in the test performed at the delivery time just like in the above example. Figure 4 shows part of such a lookup table. And, when the host issues a restart command, the temperature and the rotation speed of the spindle motor are read by any means, then the lookup table is referenced according to the read temperature and the rotation speed of the spindle motor, thereby calculating the time  $t_s$  for restarting the spindle motor. This  $t_s$  value is added to  $t_v$  calculated beforehand, thereby the power supply recovery time  $t_r$  can be predicted.

[0019]

An example of the dependency of the restarting time  $t_s$  of the spindle motor on the temperature is as shown below.

5°C → 10.2 sec  
 25°C → 10.4 sec  
 55°C → 11.6 sec

[0020]

This completes the description for how to predict a power supply recovery time of the present invention. The recovery time predicting apparatus and the hard disk drive of the present invention are thus composed so as to predict the recovery time of the present invention in a preferred embodiment as described above. More concretely, the recovery time predicting apparatus of the present invention is composed so as to include a device for receiving a predetermined signal from outside, a device for predicting a time required for recovering the apparatus to a predetermined state in response to the predetermined signal, and a device for reporting the predicted recovery time to outside. And, preferably the recovery time predicting device should include a device for detecting a temperature of the apparatus and a step for calculating a recovery time from the detected temperature. In addition, the hard disk drive of the present invention has a spindle motor for rotating a disk. The hard disk drive is composed so as to include a device for receiving a predetermined signal from a host system, a detecting a rotation speed of the spindle motor, a device for calculating a recovery time of the hard disk drive from the detected rotation speed, and a device for reporting the calculated recovery time to the host system.

[0021]

[Advantages of the invention]

As to be understood evidently from the above description, according to the present invention, the host system can know how much time is required until the power supply is recovered. It is thus possible to schedule a task to be ended within the power recovery processing so that it is executed before the hard disk drive is restarted. It is thus possible that scheduling of all the tasks in the host system can be optimized. Consequently, the processing speed of the whole

system provided with a hard disk drive can be speeded up significantly. In addition, depending on the type of the host system, the host system can notify the user of the time required until the user receives the object response.

#### 4. Brief Description of the Drawings:

Figure 1 is a flowchart showing an example of how to predict a recovery time according to the present invention in a system provided with a hard disk drive;

Figure 2 is a graph indicating the relationship between  $f(R_c)$  and  $R_c$  at a reference temperature,  $f(R_c)$  is a time required for restarting the spindle motor and  $R_c$  is a rotation speed;

Figure 3 is a graph indicating the relationship between  $T$  (temperature) and  $g(T)$  (temperature correction coefficient); and

Figure 4 shows part of an example of a lookup table.

Claims:

- (1) A method for predicting a recovery time, comprising the steps of:

predicting a recovery time of a power supply from a stand-by state to a usable state of a hard disk drive when a host requests to exit said stand-by state of said hard disk drive; and

reporting said predicted recovery time of said power supply to said host.

- (2) The method for predicting a recovery time according to Claim 1;

wherein said hard disk drive predicts said recovery time of said power supply by itself with reference to the current state and the past operation history thereof.

- (3) The method for predicting a recovery time according to Claim 1;

wherein said recovery time of said power supply is predicted by calculating

$$t_R = t_s + t_v$$

when it is assumed that a time for restarting a spindle



motor of said hard disk drive is  $t_s$ , a time for moving an actuator of said hard disk drive to a predetermined cylinder is  $t_v$ , and a time for recovering said power supply is  $t_R$ .

- (4) The method for predicting a recovery time according to Claim 3;

wherein said time  $t_s$  required for restarting said spindle motor of said hard disk drive is calculated as follows;

$$t_s = f(Rc)$$

where  $Rc$  is a current rotation speed and  $f(Rc)$  is a time required for restarting said spindle motor at  $Rc$  and at a reference temperature.

- (5) The method for predicting a recovery time according to Claim 3;

wherein said time  $t_s$  required for restarting said spindle motor of said hard disk drive is calculated as follows;

$$t_s = k \cdot f(Rc)$$

where  $k$  is a temperature correction coefficient at  $k = g(T)$  and  $T$  is a current temperature value,  $Rc$  is a current rotation speed, and  $f(Rc)$  is a time required for restarting said spindle motor at  $Rc$  and at a reference temperature.

- (6) An apparatus for predicting a recovery time, comprising:

a device for receiving a predetermined signal from outside;

a device for predicting a recovery time of said apparatus to a predetermined state in response to said predetermined



signal; and

a device for reporting said predicted recovery time to outside.

- (7) The apparatus for predicting a recovery time according to Claim 6,

wherein said device for predicting said recovery time includes,

a device for detecting a temperature of said apparatus, and

a step for calculating a recovery time from said detected temperature.

- (8) A hard disk drive having a spindle motor for rotating a disk, comprising:

a device for receiving a predetermined signal from a host;

a device for detecting a rotation speed of a spindle motor; and

a device for calculating a recovery time of said hard disk drive from said detected rotation speed; and

a device for reporting said calculated recovery time to said host.

