

COMMUNICATION CONTROL METHOD, COMMUNICATION CONTROL PROGRAM
AND MASTER COMMUNICATION SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

5 This application claims the foreign priority benefit under Title 35, United States Code, §119(a)-(d) of Japanese Patent Application No. 2010-052562, filed on March 10, 2010, the contents of which are hereby incorporated by reference.

10 [FIELD OF THE INVENTION]

 The present invention relates to a communication control method, communication control programs and a master communication system used for a master-slave communication system which is configured in such a manner that a plurality
15 of slave communication devices are connected to the master communication system through a communication network.

[RELATED PRIOR ART]

 A master-slave communication system is often used for monitoring and controlling a plant. The master-slave
20 communication system is configured, for example, in such a manner that a plurality of slave communication devices which are disposed at distant places are connected to a master communication system installed in a monitoring center. In the master-slave communication system, for example, MODBUS
25 (registered trade mark) protocol is used. According to the communication method of the MODBUS protocol, functions of the

master communication system and the slave communication devices are defined as follows.

(1) A master communication system has functions to assign a slave communication device and to transmit a query to the assigned slave communication device for controlling a surveillance device and for collecting data from the surveillance device.

(2) A slave communication device has functions to receive a query from a master communication system, and after executing a predetermined processing indicated by the query, to transmit information of the processing result to the master communication system as a response. However, the slave communication device has no function to autonomously transmit a query to the master communication system.

Conventionally, in the foregoing master-slave communication system, the master communication system cyclically assigns a slave communication device to which a query is transmitted in a predetermined sequence at predetermined time intervals with respect to a plurality of slave communication devices, transmits the query to the assigned slave communication device and receives a response returned from the slave communication device to which the query was transmitted. In a series of the foregoing processing, if the response is not returned from the slave communication device within a predetermined time, the master communication system retransmits a query identical to the query transmitted

in the previous round and waits the response from the slave communication device. When the response is not returned from the slave communication device even if the same query is transmitted more than a predetermined number of times, the
5 master communication system determines that the slave communication device is in failure (error).

The foregoing conventional method for determining the error of the slave communication device has the following problems. In the conventional error determination method
10 described above, first, if the response is not returned from a slave communication device, the master communication system is required to repeat retransmission of the same query and to wait for reception of the response to the retransmitted query, several times. Therefore, this might cause a transmission
15 delay of a query to each of the other slave communication devices in some cases. As a result, a processing delay and a shortage of processing time might be caused in each of the other slave communication devices in some cases.

Second, in the conventional error determination method,
20 since the master communication system executes the error determination within a relatively short time, there is a possibility to misjudge a temporary error (errors that recover naturally, for example, communication error due to noises and an incidental processing delay in the slave communication
25 device) of the slave communication device as a permanent error (all errors other than the temporary error). If the error is

a permanent error, some work by a maintainer is required.
However, if the error is a temporary error, it may be left as
it is. Therefore, if a temporary error is misjudged as a
permanent error, a workload of the maintainer increases due to
5 the maintenance work of the slave communication device that is
not in failure (error).

Japanese Patent Publication No. 2002-26908 discloses a
technology for shortening a waiting time of the master
communication system waiting for the response after the second
10 round, in order to solve the first problem described above.

[SUMMARY OF THE INVENTION]

However, the technology disclosed in Japanese Patent
Publication No. 2002-26908 is not a solution of the foregoing
15 second problem. Since an error of the slave communication
device is determined in a shorter time in the technology, a
possibility to misjudge a temporary error as a permanent error
may rather increases.

Therefore, it is an object of the present invention to
20 provide a communication control method, a communication
control program and a master communication system which are
capable of error determination that prevent the master
communication system from misjudging a temporary error of a
slave communication device as a permanent error in a
25 master-slave communication system.

The present invention is inventions of a communication

control method, a communication control program and a master communication system of a master-slave communication system which is configured in such a manner that a plurality of slave communication devices are connected to the master

5 communication system through a communication network, and the master communication system repeatedly executes communication apparatus assignment processing for assigning one slave communication device among the plurality of the slave communication devices, query transmission processing for
10 transmitting a query to the assigned slave communication device and response reception processing for receiving a response from the slave communication device to which the query was transmitted, in the master-slave communication system as a series of a communication processing unit.

15 The master communication system is characterized as follows.

(1) The master communication system includes a timeout error monitoring timer that detects whether or not a response to the transmitted query is received and a timeout error counter that
20 counts a number of detection times of successive timeout errors for each of the slave communication devices.

(2) When the master communication system receives a response from a slave communication device assigned in the previous communication apparatus assignment processing, the master
25 communication system resets a timeout error counter corresponding to the slave communication device to zero, and

when a timeout error is detected based on a notification from the timeout error monitoring timer, the master communication system: increases a count value of the timeout error counter corresponding to the slave communication device by one; then, 5 terminates the communication processing unit immediately; determines whether or not the error count of the error counter reaches a predetermined count value concurrently with the termination; and outputs error information that indicates a error of the slave communication device if the count value of 10 the error counter reaches the predetermined count value.

According to the present invention, in a master-slave communication system, an error determination that prevents a master communication system from misjudging a temporary error of a slave communication device as a permanent error may be 15 achieved.

[BRIEF DESCRIPTION OF THE DRAWINGS]

FIG. 1 is an illustration showing an example of a configuration of a master-slave network system according to an 20 embodiment of the present invention;

FIG. 2 is an illustration showing transmission and reception of a query and a response between a master communication system and four slave communication devices according to the embodiment;

25 FIG. 3 is an illustration of a COMPARATIVE EXAMPLE showing transmission and reception of a query and a response between

a master communication system and four slave communication devices according to a conventional technology;

FIG. 4 is an example of a flowchart of a communication control processing to be executed by a communication control processor of a master communication system according to the
5 embodiment;

FIG. 5 is an illustration showing an example of a configuration of a master-slave network system according to a modified example of the embodiment; and

10 FIG. 6 is an example of a flowchart of a communication control processing to be executed by a communication control processor of a master communication system according to a modified example of the embodiment.

15 [DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT]

Hereinafter, explanations will be given of an embodiment of the present invention in detail by referring to drawings.

FIG. 1 is an illustration showing an example of a configuration of a master-slave network system according to an
20 embodiment of the present invention. As shown in FIG. 1, a master-slave network system 10 is configured in such a manner that a plurality of slave communication devices 4 are connected to a master communication system 2 through a communication network 3. In addition, a master processing device 1 configured
25 with, for example, a general personal computer and a workstation is connected to the master communication system 2.

Furthermore, various devices are connected to the slave communication device 4. When the master-slave network system 10 is, for example, a plant supervisory system, a surveillance device 5 consisting of various kinds of sensors and the like is connected to the slave communication device 4.

Here, as the network 3, for example, Ethernet (registered trade mark) or RS485 is used, and as a communication method thereof, generally, a communication method, a so-called master-slave communication such as MODBUS (registered trade mark) protocol is used. Meanwhile, the MODBUS protocol mounted on TCP/IP protocol of Ethernet is called as MODBUS-TCP, however, a basic communication method thereof is sorted into the master-slave communication.

A communication between the master communication system 2 and the slave communication device 4 in the master-slave communication proceeds according to a communication control processing that is executed by the initiative of the master communication system 2. Namely, the communication control of the master communication system 2 is achieved by repeatedly executing the following three-step processing as a processing unit.

(1) Processing for assigning a destination slave communication device 4.

(2) Processing for transmitting a query, which is information instructing a processing to be executed by the assigned slave communication device 4, to the assigned slave communication

device 4.

(3) Processing for receiving information of results of the processing executed by the assigned slave communication device 4, since the slave communication device 4 received the query
5 executes the processing instructed by the query and transmits the information of the processing results to the master communication system 2 as a response.

Here, a query to be transmitted to the slave communication device 4 by the master communication system 2 is, for example,
10 the query to instruct acquiring data of a temperature of a boiler by the surveillance device 5, or to instruct reducing a flow rate of a gas by throttling a valve in the surveillance device 5. On the other hand, for example, information of the temperature of the boiler and information that a gate opening
15 of the valve was lowered from 4 to 3 are included in the response in response to the query. In addition, error information such as a failure in acquiring data of the temperature of the boiler may be included in the response.

The master communication system 2 that executes a
20 communication control of the foregoing master-slave communication includes a communication control processor 21, a network interface 22, a timeout error monitoring timer 23, and a timeout error counter 24 which is disposed corresponding to each of a plurality of slave communication devices 4.

25 Here, the communication control processor 21 includes CPU (Central Processing Unit), which is not shown, and a memory,

and programs for actualizing a communication control function of the master communication system 2, as well as a query and a response transmitted and received between the master communication system 2 and the slave communication device 4 are stored in the memory. In addition, the network interface 22 is connected to the communication network 3 and interfaces electrically between the master communication system 2 and the communication network 3, while generating/delivering a transmission frame and detecting a reception frame.

10 It is noted that address information assigning a destination slave communication device 4 is included in the transmission frame which is generated by the network interface 22, and that a processing that the master communication system 2 (that is, the communication control processor 21) assigns a slave communication device 4 is the processing to set the address information of the slave communication device 4 included in the transmission frame.

20 The timeout error monitoring timer 23 is a timer for monitoring a time until the communication control processor 21 receives a response to be transmitted from a slave communication device 4 after the network interface 22 delivered a query. Namely, when the query is transmitted to the slave communication device 4 through the network interface 22, the timeout error monitoring timer 23 starts monitoring the time and stops the monitoring when the communication control processor 21 received the response to the query. If the

communication control processor 21 does not receive the response within a predetermined time, that is, if the monitoring time of the timeout error monitoring timer 23 is not stopped beyond the predetermined time, a timeout error
5 indicating no reception of the response is notified to the communication control processor 21.

The timeout error counter 24 is disposed corresponding to each of a plurality of slave communication devices 4, and in the embodiment, the timeout error counter 24 is disposed in a
10 memory, not shown, within the master communication system 2. Namely, when the communication control processor 21 receives a response from a slave communication device 4, the communication control processor 21 resets a timeout error counter 24 corresponding to the slave communication device 4
15 to zero, and when the communication control processor 21 is waiting for reception of the response from the slave communication device 4, if a timeout error is notified from the timeout error monitoring timer 23, the communication control processor 21 increases a count value of the timeout error
20 counter 24 corresponding to the slave communication device 4 by one.

FIG. 2 is an illustration showing an example of transmission and reception of a query and a response between a master communication system and four slave communication
25 devices according to the embodiment of the present invention. In FIG. 2, the left half indicates contents of a communication

control processing of the master communication system 2, and the right half indicates a slave communication device 4 corresponding to a destination slave communication device 4 of a query and an originating slave communication device 4 of a response by a direction of an arrow.

As shown in FIG. 2, the master communication system 2 assigns (circled 1) a slave communication device 4 (#1) in the first block, transmits (circled 2) a query (1, 1) prepared in advance to the assigned slave communication device 4 (#1), and receives (circled 3) a response (1, 1) returned from the slave communication device 4 (#1) to which the query was transmitted.

Similarly, in the next block, the master communication system 2 assigns (circled 1) a slave communication device 4 (#2), transmits (circled 2) a query (2, 1) prepared in advance to the assigned slave communication device 4 (#2), and receives (circled 3) a response (2, 1) returned from the slave communication device 4 (#2) to which the query was transmitted. In addition, the master communication system 2 assigns a slave communication device 4 (#3) and a slave communication device 4 (#4), and executes similar processing.

As described above, in the master-slave network system 10, the master communication system 2 repeatedly executes the following processing as a series of a processing unit. Namely, the master communication system 2 assigns one by one a plurality of slave communication devices 4 connected to the communication network 3, transmits a query prepared in advance to the assigned

slave communication device 4, and receives a response returned from the assigned slave communication device 4. Meanwhile, in the example in FIG. 2, a number of slave communication device 4 connected to the communication network 3 is four, however, the number is not limited to four.

When the master communication system 2 completes a round of processing of transmission of the query and reception of the response for the four slave communication devices 4 connected to the communication network 3, subsequently, the master communication system 2 executes the second round of the communication control processing. It is noted that in the first round of the communication control processing, since the master communication system 2 received the responses (1, 1), (2, 1), (3, 1) and (4, 1) from the respective slave communication devices 4, the timeout error counters 24 (#1), (#2), (#3) and (#4) are reset to zero.

As shown in FIG. 2, in the second round of the communication control processing, the transmission and the reception of the query and the response are also executed between the master communication system 2 and the slave communication devices 4 (#1), (#2), (#3) and (#4), as with the first round of the communication control processing. However, in the example of FIG. 2, the master communication system 2 failed to receive a response (2, 2) from the slave communication device 4 (#2) within a predetermined time (the master communication system 2 received a timeout notification from the

timeout error monitoring timer 23). Then, a count value of the timeout error counter 24 (#2) corresponding to the slave communication device 4 (#2) is increased by one, and the count value is set to 1. This is indicated by "EC=1" in FIG. 2.

5 In the following third round of the communication control processing, the transmission and the reception of the query and the response are also executed between the master communication system 2 and the slave communication devices 4 (#1), (#2), (#3) and (#4), as with the second round of the communication control
10 processing. In this case, however, the query transmitted to the slave communication device 4 (#2) from the master communication system 2 is the query (2, 2). This means that the query (2, 2) identical to the query (2, 2) in the second round is transmitted to the slave communication device 4 (#2).
15 Namely, since the master communication system 2 failed to receive the response (2, 2) from the slave communication device 4 (#2) in the second round, the master communication system 2 retransmitted (retried to transmit) the query (2, 2) which is identical to that in the second round.

20 Meanwhile, in the example of FIG. 2, the master communication system 2 failed again to receive the response (2, 2) from the slave communication device 4 (#2) in the third round of the communication control processing. Therefore, the count value of the timeout error counter 24 (#2) is increased again
25 by one, and the count value becomes 2. This is indicated by "EC=2" in FIG. 2.

Furthermore, in the fourth round of the communication control processing, the transmission and the reception of the query and the response are also executed between the master communication system 2 and the slave communication devices 4 (#1), (#2), (#3) and (#4), as with the third round of the communication control processing. However, since the master communication system 2 failed to receive the response (2, 2) from the slave communication device 4 (#2) in the previous round, the master communication system 2 transmitted the query (2, 2) which is identical to those in the second round and the third round.

In the example of FIG. 2, the master communication system 2 failed again to receive the response (2, 2) from the slave communication device 4 (#2) even in the fourth round. Therefore, the count value of the timeout error counter 24 (#2) was increased again, and this is indicated by "EC=3" in FIG. 2. As described above, if the master communication system 2 failed to receive the response more than a predetermined number of times (for example, not less than three) in spite of transmission of the same query to the same slave communication device 4, the master communication system 2 determines that the slave communication device 4 is in failure (error).

Meanwhile, in the foregoing explanation, queries to be transmitted in the third round and the fourth round are identical to the query (2, 2) in the second round where the master communication system 2 failed to receive the response

for the first time. However, the query may not be always limited to the same query. Namely, in FIG. 2, the communication control processing of the master communication system 2 may be described as "transmits a query (2, 3) to the slave communication device 4 (#2), and failed to receive a response (2, 3)" for the third round and "transmits a query (2, 4) to the slave communication device 4 (#2), and failed to receive a response (2, 4)" for the fourth round, respectively.

Meanwhile, in the example such as a plant supervisory system to which the master-slave network system 10 is applied, it is not always uncommon that a query which instructs "acquire a temperature of the boiler" is transmitted every time to a slave communication device 4. In this case, it is unnecessary that the master communication system 2 retransmits a query identical to that of the previous round in the next round even if the master communication system 2 failed to receive a response from the slave communication device 4 in some round. The query to be transmitted in the next round is "acquire a temperature of the boiler (at the time)", which was prepared in advance.

Therefore, for example, when it is planned that a query which instructs "acquire a temperature of the boiler" is transmitted to a slave communication device 4 in odd round and a query which instructs "acquire a pressure of the boiler" is transmitted in even round to the slave communication device 4, the master communication system 2 may transmit the query which

instructs "acquire a pressure of the boiler" that was planned to transmit in advance in the next round, instead of retransmission of the query which instructs "acquire a temperature of the boiler" even if the master communication
5 system 2 failed to receive a response to the query which instructs "acquire a temperature of the boiler" in some round.

As described above, the error of the slave communication device 4 that is detected by a count value beyond a predetermined value by counting a number of rounds that
10 successively failed to receive a response for each of the slave communication devices 4 may be caused by an error that the slave communication device 4 is unable to receive a query or transmit a response since the slave communication device 4 is not operated normally by some reasons. However, the case that the
15 query does not reach the slave communication device 4 due to a trouble of the communication network 3 and a communication trouble that the response transmitted from the slave communication device 4 does not reach the master communication system 2 are also detected as the error. Generally, a
20 communication trouble in the communication network 3 is a temporary error in most cases.

FIG. 3 is an illustration of a COMPARATIVE EXAMPLE showing transmission and reception of a query and a response between a master communication system and four slave
25 communication devices according to a conventional technology. As shown in FIG. 3, the transmission and the reception of the

query and the response between the master communication system 2 and the slave communication devices 4 (#1), (#2), (#3) and (#4) are executed almost in a similar manner to the embodiment of the present invention shown in FIG. 2. The difference from
5 the embodiment is a processing to be executed when the master communication system 2 fails to receive a response from the slave communication device 4.

In the example of FIG. 3, the master communication system 2 failed to receive a response (2, 2) to a query (2, 2) which
10 was transmitted to the slave communication device 4 (#2) in the second round. Then, in this case, the master communication system 2 immediately retries to receive the response (2, 2) by retransmitting the same query (2, 2) to the slave communication device 4 (#2). The master communication system 2 repeats the
15 retry a predetermined number of times (for example, three times). If the master communication system 2 is unable to receive the response (2, 2) in spite of the retry of the predetermined number of times, the master communication system 2 determines that the slave communication device 4 (#2) is in
20 failure (error).

Comparing the example of FIG. 3 with the example of FIG. 2, the following difference can be seen between the two samples. Namely, in FIG. 3 (COMPARATIVE EXAMPLE), when the master communication system 2 failed to receive a response from a slave
25 communication device 4, the master communication system 2 immediately retries a predetermined number of times. On the

other hand, in FIG. 2 (embodiment of the present invention), the master communication system 2 does not retry the predetermined number of times immediately, but reties once in the next round of the transmission and the reception between the master communication system 2 and the slave communication device 4 and reties once again in the round after the next, and so on.

Therefore, a time from the first reception error of a response of the master communication system 2 to the determination of error of a slave communication device 4, which is the slave communication device 4 to transmit the response, through a predetermined number of retries in the case of FIG. 3 (COMPARATIVE EXAMPLE) is shorter than that in the case of FIG. 2 (embodiment of the present invention). Assuming that a timeout error time of a response reception in a slave communication device 4 (for example, #2) is two seconds and a time interval for repeating a processing of the transmission and the reception of a query and a response between the master communication system 2 and the slave communication device 4 is one minute, a time until the determination of the error of the slave communication device 4 in the case of FIG. 3 (COMPARATIVE EXAMPLE) is six seconds, and the time in the case of FIG. 2 (embodiment of the present invention) is three minutes.

In this case, in the case of FIG. 3 (COMPARATIVE EXAMPLE), the master communication system 2 can detect the error of the slave communication device 4 in a shorter time, and for this

reason, there is a possibility to misjudge a temporary error as a permanent error. On the other hand, in the case of FIG. 2 (embodiment of the present invention), a time until detection of the error of the slave communication device 4 is longer than that in the case of FIG. 3. However, the possibility to misjudge a temporary error as a permanent error becomes to be small. For example, even if there is the case that a temporary error continues six seconds, a possibility that the temporary error continues three minutes is very small.

In addition, if a timeout error of a response reception in the master communication system 2 is caused by a transmission delay due to an incidental processing congestion in the slave communication device 4, in the case of FIG. 3 (COMPARATIVE EXAMPLE), the slave communication device 4 is immediately requested to transmit a reply by the retry of query transmission of the master communication system 2. Then, the processing congestion in the slave communication device 4 may become worse. In this case, even if the query is transmitted the predetermined number of times from the master communication system 2, the slave communication device 4 is unable to transmit a response, and finally, the slave communication device 4 is misjudged as "the slave communication 4 is in permanent error".

On the other hand, in the case of FIG. 2 (embodiment of the present invention), the query is not retransmitted immediately, and the query is retransmitted to the slave communication device 4 in the next round. Therefore, since a

possibility that the incidental processing congestion in the slave communication device 4 disappears until the next round is large, the slave communication device 4 is able to transmit the response within a predetermined time. As a result, a possibility that the slave communication device 4 is misjudged as "the slave communication device 4 is in permanent error" becomes very small. In addition, a delay of processing of transmission and reception of a query and a response for the following slave communication devices 4 also becomes very rare.

FIG. 4 is an example of a flowchart of a communication control processing to be executed by a communication control processor 21 of a master communication system according to the embodiment of the present invention. The communication control processor 21 can achieve, for example, a communication control processing of the master communication system 2 shown in FIG. 2 by executing the communication control processing.

Hereinafter, explanations will be given of the communication control processing to be executed by the communication control processor 21 in reference to FIG. 4 and FIG. 1.

The communication control processor 21 of the master communication system 2: first assigns (step S11) a slave communication device 4 to communicate with; acquires (step S12) a count value of a timeout error counter 24 corresponding to the assigned slave communication device 4; and determines (step S13) whether or not the count value is "0". Meanwhile, an initial count value of a timeout error counter 24 corresponding

to each of the slave communication devices 4 is set to "0".

Next, if the count value of the timeout error counter 24 is "0" in the step S13 (step S13: Yes), that is, when a response to the query transmission was successfully received in the previous round, the communication control processor 21 transmits a predetermined query to a slave communication device 4 assigned in the step S11 (step S14). On the other hand, if the count value is not "0" (step S13: No), that is, when the response to the query transmission in the previous round was not received, the communication control processor 21 transmits a query identical to the query transmitted in the previous round to the slave communication device 4 assigned in the step S11 (step S15).

Meanwhile, as described above, in the application to, for example, a plant supervisory system, an originally predetermined query may be transmitted instead of the query identical to the query transmitted in the previous round. Therefore, in this case, since the processing in the step S15 becomes identical to the step S14, the processing of the steps S12, S13 and S15 may be omitted from the flowchart of FIG. 4.

Meanwhile, in the foregoing processing, information for indicating a slave communication device 4 and a query to be transmitted to the slave communication device 4 depending on the assigned slave communication device 4 may be stored in advance in a memory, not shown, of the communication control processor 21, or may be supplied in each case from the master

processing device 1.

Subsequently, the communication control processor 21 determines whether or not a response transmitted from the slave communication device 4 is received in response to the query transmitted in the step S14 or S15 (step S16). According to
5 a result of the determination, when the response is received (step S16: Yes), a timeout error counter 24 corresponding to the slave communication device 4 assigned in the step S11 is reset to zero (step S17). The response received in the step
10 S16 is, for example, transmitted to the master processing device 1 after the response is once temporarily stored in the memory, not shown, of the communication control processor 21.

After the step S17, the processing returns to the step S11, and the communication control processor 21 executes again the
15 processing following the step S11.

Next, according to the result of the determination in the step S16, when the response is not received (step S16: No), the communication control processor 21 determines whether or not a timeout error is notified from the timeout error monitoring
20 timer 23 (step S18), and if the timeout error is not notified (step S18: No), the processing returns to the step S16 that determines whether or not the response is received. On the other hand, if the timeout error is notified (step S18: Yes), a count number of a timeout error counter 24 corresponding to
25 the slave communication device 4 assigned in the step S11 is increased by one (step S19).

Next, the communication control processor 21 determines (step S20) whether or not the count value of the timeout error counter 24 reached a predetermined value N (for example, $N=3$), and if the count value is not reached the predetermined value N (step S20: No), the processing returns to the step S11 and the processing following the step S11 is executed again. On the other hand, if the count value reached the predetermined value N in the step S20 (step S20: Yes), the communication control processor 21 determines that the slave communication device 4 assigned in the step S11 is in failure (error), and outputs error information that indicates to be in error (step S21). The output destination of the error information may be, for example, the master processing device 1, or may be a display if the master communication system 2 is provided with some kind of display.

After the step S21, the processing returns to the step S11, and the communication control processor 21 executes again the processing following the step S11.

Meanwhile, in the step S13 of the communication control processing which was explained using FIG. 4, the communication control processor 21 determines whether or not the response to the previous query transmission is successfully received by determining whether or not the count value of the timeout error counter 24 is "0". However, the method for the determination is not limited to this. For example, a timeout error flag corresponded to each of the slave communication devices 4 may

be disposed in the master communication system 2 independently from the timeout error counter 24, and success and failure of reception of the response may be determined by the timeout error flag.

5 In this case, if the timeout error flag is set to "0" when the communication control processor 21 of the master communication system 2 successfully received the response and if the timeout error flag is set to "1" when the communication control processor 21 failed to receive the response, the "0"

10 of the timeout error flag means "success" of the reception of the response and the "1" means failure of the reception of the response.

(Modified Example of the Embodiment)

FIG. 5 is an illustration showing an example of a

15 configuration of a master-slave network system according to a modified example of embodiment of the present invention. It is noted that in FIG. 5, a constituent identical to that in FIG. 1 is given the same reference number, and the explanation thereof will be omitted.

20 Differences between a master-slave network system 10A according to a modified example of the embodiment shown in FIG. 5 and the master-slave network system 10 according to the original embodiment shown in FIG. 1 are that configurations of the communication network 3 are different to each other and that

25 an exception error counter 25 is added in a master communication system 2A.

In the modified example of the embodiment, the communication network 3 is divided into two communication networks 3a, 3b by a network gateway 6. Here, the communication network 3a is, for example, a MODBUS-TCP network, and the communication network 3b is, for example, a RS-485 standard network of MODBUS protocol.

In FIG. 5, a slave communication device 4 is connected to each of the communication networks 3a, 3b. If necessary in the following descriptions of the specification, a slave communication device 4 connected to the communication network 3a is called an upper slave communication device 4a, and a slave communication device 4 connected to the communication network 3b is called a lower slave communication device 4b. In addition, as shown in FIG. 1, various kinds of surveillance devices are connected to each of the slave communication devices 4. However, drawing of the surveillance devices is omitted here.

The transmission and the reception of a query and a response between the master communication system 2A and the lower slave communication device 4b are executed through the network gateway 6. The network gateway 6 has a function, for example, to transform a protocol and an electric signal between the communication network 3a and the communication network 3b. The function is basically a simple transformation. Therefore, when the lower slave communication device 4b is normally operated, the network gateway 6 looks as if it is not existed when the network gateway 6 is seen from the side of the master

communication system 2A.

However, if the lower slave communication device 4b is in failure (error) and when the lower slave communication device 4b is unable to return a response to the query from the master
5 communication system 2A, a timeout error due to the not-returned response is detected by the network gateway 6. At this time, the network gateway 6 transmits information containing a timeout error (hereinafter, this timeout error is called as exception error) indicating that the response from
10 the lower slave communication device 4b was not received to the master communication system 2A.

Therefore, the communication control processor 21 of the master communication system 2A is notified that the response was not transmitted from the lower slave communication device
15 4b by the exception error transmitted from the network gateway 6 instead of notification from the timeout error monitoring timer 23. Meanwhile, after a query is transmitted to the lower slave communication device 4b, if the master communication system 2A is unable to receive any response including an
20 exception error from the network gateway 6 within a predetermined time, the master communication system 2A determines that the network gateway 6 itself is in failure (error).

In FIG. 5, the exception error counter 25 added to the
25 master communication system 2A is disposed corresponded to each of the lower slave communication devices 4b, and counts a number

of the exception errors transmitted from the network gateway 6 with respect to the each of the slave communication devices 4b. Meanwhile, the exception error counter 25 is also disposed in the memory within the communication control processor 21 as
5 with the timeout error counter 24.

FIG. 6 is an example of a flowchart of a communication control processing to be executed by a communication control processor 21 of a master communication system 2A according to a modified example of the embodiment of the present invention.
10 A basic configuration of the communication control processing is identical to the flowchart shown in FIG. 4. However, in the modified example of the embodiment, with respect to reception of a response from a lower slave communication device 4b, a timeout error is monitored by the network gateway 6, and the
15 timeout error is reported to the master communication system as an exception error. Therefore, in FIG. 6, a processing step (step S31-step S35) corresponding to the reception of the exception error is added to the flowchart of FIG. 4.

Below, explanations will be given of the flowchart of FIG.
20 6. A processing step identical to that of FIG. 4 is given the same step number, and the explanation of the same step will be omitted.

In the flowchart of FIG. 6, the processing of step S11-step S16 is identical to that of the flowchart of FIG. 4 except for
25 step S12a. In the step S12a, the communication control processor 21 acquires a count value of an error counter

corresponding to the slave communication device 4 assigned in the step S11. Here, the error counter indicates a timeout error counter 24 when the slave communication device 4 is an upper slave communication device 4a, and an exception error counter
5 25 when the slave communication device 4 is a lower slave communication device 4b.

In addition, as with the case of FIG. 4, in the application to, for example, a plant supervisory system, an originally predetermined query may be transmitted in the step S15 instead
10 of a query identical to the query transmitted in the previous round. In this case, since the processing in the step S15 becomes identical to that of the step S14, the processing of steps S12, S13 and S15 may be omitted from the flowchart of FIG.
6.

15 In addition, the communication control processor 21 determines whether or not a response from the slave communication device 4 is received in the step S16. If the response is not received (step S16: No), the processing to be executed in the following steps (step S18-step S21) is
20 identical to that of the flowchart of FIG. 4. In addition, according to a result of the determination in the step S16, if the response is received (step S16: Yes), the communication control processor 21 executes the processing following the step S17 because there is a possibility that an exception error is
25 included in the response.

Namely, the communication control processor 21 first

resets a count value of a timeout error counter 24 corresponding to the slave communication device 4 assigned in the step S11 to zero (step S17). Meanwhile, in this case, when the slave communication device 4 assigned in the step S11 is a lower slave communication device 4, since a timeout error counter 24
5 corresponding to the lower slave communication device 4b is not disposed, substantive processing is not executed.

Next, the communication control processor 21 determines whether or not an exception error is included in the response
10 from the slave communication device 4 assigned in the step S11 (step S31). Then, according to the result of the determination, when the exception error is not included in the response (step S31: No), the communication control processor 21 resets an exception error counter corresponding to the lower slave
15 communication device 4b to zero (step S32), then, the processing returns to the step 11, and the communication control processor 21 executes again the processing following the step S11.

On the other hand, according to the result of the
20 determination in the step S31, when the exception error is included in the response from the slave communication device 4 assigned in the step S11 (step S31: Yes), the slave communication device 4 is a lower slave communication device 4b, then, the communication control processor 21 increases a
25 count value of the exception error counter corresponding to the lower slave communication device 4b by one (step S33).

Next, the communication control processor 21 determines (step S34) whether or not a count value of the exception error counter reached a predetermined value N (for example, N=3). If the count value is not reached the predetermined value N (step S34: No), the processing returns to the step S11 and the communication control processor 21 executes again the processing following the step 11. In addition, in the step S34, if the count value of the exception error counter reached the predetermined value N (step S34: Yes), the communication control processor 21 determines that the lower slave communication device 4b is in failure (error) and outputs error information indicating that the lower slave communication device 4b is in failure (error) (step S35). Meanwhile, the output destination of the error information may be, for example, the master processing device 1, or may be a display if the master communication system 2 is provided with some kind of display.

Subsequent to the step S35, the processing returns to the step S11 and the communication control processor 21 executes again the processing following the step S11.

As described above, since a basic configuration of the communication network 3 and processing contents of the communication control processor 21 in the modified example of the embodiment are identical to those in the original embodiment, when the master communication system 2A determines whether or not a slave communication device 4 is in failure (error), the master communication system 2A hardly misjudges

a temporary error as a permanent error, as with the original embodiment.

Claims

1.

A communication control method of a hierarchal type master-slave communication system,

the master-slave communication system comprising:

a master communication device;

a plurality of upper slave communication devices connected to the master communication device through a first communication network connected to the master communication device;

a network gateway connected to the master communication device through the first communication network; and

a plurality of lower slave communication devices connected to the network gateway through a second communication network connected to the network gateway,

wherein the master communication device comprises:

a timeout error monitoring timer that detects an unreceived response to the query transmitted to the upper slave communication device;

a timeout error counter that counts the number of detections of successive timeout errors for each of the upper slave communication devices; and

an exception error counter that counts the number of successive exception errors included in the response with respect to each lower slave communication device, where an exception error indicates that nothing is received from the lower slave communication devices, when the response corresponding to the query transmitted to the lower slave communication device has been transmitted from the network gateway and includes the exception error,

the communication control method comprising a communication unit processing of a series of steps which the master communication device repeatedly executes,

the steps comprising:

assigning one slave communication device among the plurality of the upper slave communication devices and the plurality of the lower slave communication devices with traveling around these devices;

transmitting a query to the assigned slave communication device; and

receiving a response with respect to the transmitted query from the slave communication device to which the query is transmitted,

wherein if the response is received from the upper slave communication device assigned by the communication device assignment processing, in the receiving step of the step of the response,

then the master communication device

resets to zero a count value of the timeout error counter corresponding to the upper slave communication device; and

terminates a series of the steps of the communication processing unit;

wherein if a timeout error notification is received from the timeout error monitoring timer without receiving the response from the upper slave communication device

assigned by the communication device assignment processing, in the receiving step,
then the master communication device
increases the count value of the timeout error counter corresponding to the upper slave communication device by one;
terminates a series of the steps of the communication processing unit immediately;
determines whether or not a count value of the timeout error counter has reached a predetermined count value, as soon as terminating a series of the steps of the communication processing unit; and
outputs error information indicating that the upper slave communication device is in failure when the count value of the timeout error counter has reached the predetermined count value;
wherein if the exception error is not included in the response corresponding to the query transmitted to the lower slave communication device assigned by the communication device assignment processing, in the receiving step,
then the master communication device
resets to zero a count value of the exception error counter corresponding to the lower slave communication device; and
terminates a series of the steps of the communication processing unit;
wherein if the exception error is included in the response corresponding to the query transmitted to the lower slave communication device assigned by the communication device assignment processing, in the step receiving,
then the master communication device
increases the count value of the exception error counter corresponding to the lower slave communication device by one;
terminates a series of the steps of the communication processing unit immediately;
determines whether or not a count value of the exception error counter has reached a predetermined count value, as soon as terminating the communication processing unit; and
outputs error information indicating that the lower slave communication device is in failure when the count value of the exception error counter has reached the predetermined count value.

2.

A medium storing communication control programs for having a computer function as a master communication device of a hierarchal type master-slave communication system,

the master-slave communication system comprising:

a master communication device;

a plurality of upper slave communication devices connected to the master communication device through a first communication network connected to the master communication device;

- a network gateway connected to the master communication device through the first communication network; and
- a plurality of lower slave communication devices connected to the network gateway through a second communication network connected to the network gateway,

wherein the master communication device comprises:

- a timeout error monitoring timer that detects an unreceived response to the query transmitted to the upper slave communication device;
- a timeout error counter that counts the number of detections of successive timeout errors for each of the upper slave communication devices; and
- an exception error counter that counts the number of successive exception errors included in the response with respect to each lower slave communication device, where an exception error indicates that nothing is received from the lower slave communication devices, when the response corresponding to the query transmitted to the lower slave communication device has been transmitted from the network gateway and includes the exception error,

the communication control method comprising a communication unit processing of a series of steps which the master communication device repeatedly executes,

the steps comprising:

- assigning one slave communication device among the plurality of the upper slave communication devices and the plurality of the lower slave communication devices with traveling around these devices;
- transmitting a query to the assigned slave communication device; and
- receiving a response with respect to the transmitted query from the slave communication device to which the query is transmitted,

wherein if the response is received from the upper slave communication device assigned by the communication device assignment processing, in the receiving step,

then the master communication device

- resets to zero a count value of the timeout error counter corresponding to the upper slave communication device; and
- terminates a series of the steps of the communication unit processing;

wherein if a timeout error notification is received from the timeout error monitoring timer without receiving the response from the upper slave communication device assigned by the communication device assignment processing, in the receiving step,

then the master communication device

- increases the count value of the timeout error counter corresponding to the upper slave communication device by one;
- terminates a series of the steps of the communication processing unit immediately;
- determines whether or not a count value of the timeout error counter has reached a predetermined count value, as soon as terminating a series of the steps of the communication processing unit; and

outputs error information indicating that the upper slave communication device is in failure when the count value of the timeout error counter has reached the predetermined count value;

wherein if the exception error is not included in the response corresponding to the query transmitted to the lower slave communication device assigned by the communication device assignment processing, in the receiving step,

then the master communication device

resets to zero a count value of the exception error counter corresponding to the lower slave communication device; and

terminates a series of the steps of the communication unit processing;

wherein if the exception error is included in the response corresponding to the query transmitted to the lower slave communication device assigned by the communication device assignment processing, in the receiving step,

then the master communication device

increases the count value of the exception error counter corresponding to the lower slave communication device by one;

terminates a series of the steps of the communication unit processing immediately;

determines whether or not a count value of the exception error counter has reached a predetermined count value, as soon as terminating the communication processing unit; and

outputs error information indicating that the lower slave communication device is in failure when the count value of the exception error counter has reached the predetermined count value.

3.

A master communication device of a hierarchal type master-slave communication system,

the master-slave communication system comprises:

the master communication device;

a plurality of upper slave communication devices connected to the master communication device through first communication network connected to the master communication device;

a network gateway connected to the master communication device through the first communication network; and

a plurality of lower slave communication devices connected to the network gateway through second communication network connected to the network gateway,

wherein the master communication device comprising:

a timeout error monitoring timer that detects an unreceived response to the query transmitted to the upper slave communication device;

a timeout error counter that counts the number of detections of successive timeout errors for each of the upper slave communication devices; and

an exception error counter that counts the number of successive exception errors included in the response with respect to each lower slave communication

device, where an exception error indicates that nothing is received from the lower slave communication devices, when the response corresponding to the query transmitted to the lower slave communication device has been transmitted from the network gateway and includes the exception error,

the master communication device repeatedly executes a communication unit processing of a series of steps,

the steps comprising:

- assigning one slave communication device among the plurality of the upper slave communication devices and the plurality of the lower slave communication devices with traveling around these devices;
- transmitting a query to the assigned slave communication device; and
- receiving a response with respect to the transmitted query from the slave communication device to which the query is transmitted,

wherein if the response is received from the upper slave communication device assigned by the communication device assignment processing, in the receiving step,

then the master communication device

- resets to zero a count value of the timeout error counter corresponding to the upper slave communication device; and
- terminates a series of the steps of the communication processing unit;

wherein if a timeout error notification is received from the timeout error monitoring timer without receiving the response from the upper slave communication device assigned in the communication device assignment processing, in the receiving step,

then the master communication device

- increases the count value of the timeout error counter corresponding to the upper slave communication device by one;
- terminates a series of the steps of the communication processing unit immediately;
- determines whether or not a count value of the timeout error counter has reached a predetermined count value, as soon as terminating a series of steps of the communication processing unit; and
- outputs error information indicating that the upper slave communication device is in failure when the count value of the timeout error counter has reached the predetermined count value;

wherein if the exception error is not included in the response corresponding to the query transmitted to the lower slave communication device assigned by the communication device assignment processing, in the receiving step,

then the master communication device

- resets to zero a count value of the exception error counter corresponding to the lower slave communication device; and
- terminates a series of steps as the communication processing unit;

wherein if the exception error is included in the response corresponding to the query transmitted to the lower slave communication device assigned by the communication device assignment processing, in the receiving step,

the master communication device

increases the count value of the exception error counter corresponding to the lower slave communication device by one;

terminates a series of steps as the communication processing unit immediately;

determines whether or not a count value of the exception error counter has reached a predetermined count value, as soon as terminating the communication processing unit; and

outputs error information indicating that the lower slave communication device is in failure when the count value of the exception error counter has reached the predetermined count value.