The present invention relates to a protection system for an electric network of a vessel. A short circuit or over current in a bus bar (5, 6, 7, 8) can be detected if current values through the interfaces of the bus bars are measured and the measured data is transmitted to a segment protection unit (19). The unit sums the measured current values. If the sum exceeds a threshold value, it means that a short circuit or over current is present in the segment, and the circuit breakers (9, 15, 23) in the interfaces are commanded to open.
Protection system of an electric network of a vessel

Field of technology

The invention relates to a protection system of an electric network of a vessel. The protection systems are used for protecting the electric networks and elements connected to the networks against abnormal conditions.

Prior art

The electric network transmits electrical power to consumer devices that are usually called loads. The electric power is generated in one or several generators that prime movers run. The combination of one generator and one prime mover is usually called a generator set. The prime mover can, for example, be a diesel engine or another type of a combustion engine.

A typical electric network of a vessel is divided into different sub networks based on different voltage areas such as 690 V, 440V and 230V. The different voltage areas can be divided into separate parts for providing redundancy to the power distribution or providing better maintenance and distribution properties for each separate area. Further, the network, having the same voltage value, may be divided into at least two separate segments. In this way it is possible to achieve a better reliability with respect to fault situations of the electric network. As can be noted the whole electric network can be divided in many different ways, and the network may be seen as a combination of several sub networks.

In this description the segment means a part of the network that is connected to input and output interfaces of the segment for transmitting the electric power. The input interface means an interface that either transmits the power to the segment or transmits power from the segment, depending on the transmission conditions. The output interface means an interface that transmits the power from the segment to a load. So, the segment can, for example, be a transmission line, a bus bar, a contactor
rail in a switchboard etc. As can be noted the segment can be seen as a node in the electric network through which the electric power is transmitted from the generator or generators to the loads. A network architecture having at least two segments provides redundancy and safety for the network. For example, if one segment is down due to a fault, other segments still running may be arranged to take care of at least a part of the tasks of the faulted segment.

A typical protection system for the electric network comprises voltage and current transformers for measuring voltages and currents, protective relays to sense faults and initiate disconnection function or functions, and circuit breakers to disconnect/connect a network device or a part of the network based on relay and auto closer commands. The auto closer commands maybe used to close the circuit breakers automatically after certain delay from the disconnection (opening) moments.

The aim of the protection system is to narrow the fault situation to the faulted part/s of the network, and also to as minor area as possible in order to keep the rest of the network in operation. Therefore the protection system works selectively. It means that the circuit breaker/s near the faulted part opens first and the rest of the circuit breakers remain closed (if it is their initial mode). If the nearest circuit breakers do not work properly, then the next nearest circuit breakers act instead. International Electrotechnical Comission has published a number of standards relating to the protection systems of the electric networks and their selective operation. Although, the present protection systems operate well, there may exist situations wherein a fault or faults produce significant restrains for operation of the entire network. For example, the system can not restrict the fault to as limited area as desirable, but to a larger area. Especially on vessels these restraint conditions can be very harmful or even fatal due to weather conditions.

**Short description**

The object of the invention is to obtain an improved protection system for the electric network of the vessel. The objective is achieved as described in the independent claim. The dependent claims describe different embodiments of the
invention. The idea of the invention is that a separate protection system can provide more redundancy and reliability for the whole network.

In more detail, the idea of the invention is to protect an electric network segment, like a bus bar, separately. The segment is typically a part of the electric network that breaks down seldom, and has been allocated, in some way, to belong to protection zones of a normal protection system. In order to protect the segment separately a special type of arrangement is needed that takes into account present protection system and a node nature of the segment.

As already said the segment can be seen as the node in the electric network connected to several interfaces. These interfaces are inputs and outputs to transmit electric power through the node, i.e. the segment. The inputs and outputs comprise circuit breakers that belong to the normal protection system.

A short circuit or over current in the segment can be detected if currents through the interfaces are measured and the measurement data is transmitted to a segment protection unit. The unit sums the measured current values. If the sum exceeds a threshold value, it means that a short circuit or over current exist in the segment, and the applicable circuit breakers in all or a part of the input interfaces are commanded to open, which means that the segment is disconnected at least partly from the rest of the network. In order that the segment protection system runs properly with the normal protection system, it is arranged to work selectively.

List of figures

In the following, the invention is described in more detail by reference to the enclosed drawings, where

Figure 1 illustrates an example of an electric network of a vessel showing a short circuit in one segment,

Figure 2 illustrates the example of figure 1 with several short circuit possibilities,
Figure 3 illustrates the example of figure 1 with short circuit in a feeder connected to the segment, and
Figure 4 illustrates an example of the segment protection unit of the invention.

Description of the invention

Figure 1 illustrates an embodiment of an electric network of a vessel. The network is divided into different voltage areas: 690 V, 440 V and 230 V. As can be seen the network is also divided into two parts that are connectable to each other through bus links 22. The 690 voltage areas on both sides of the bus links comprise two separate segments 5, 6, 7, 8. In this example, each segment is a bus bar that is connected through several interfaces to other parts of the network. The interfaces are, as said above, input interfaces and output interfaces. The input interfaces comprise circuit breakers 9, 15, 23. In this example, these circuit breakers protect generator sets 1, 2, 3, 4, transformers 14 and the bus links 22 against abnormal conditions such as short circuits, over currents, and over voltages. The output interfaces comprise also circuit breakers 10. In this example, these circuit breakers protect loads, such as frequency converters 11, thrusters 13 of the vessel and electric motors 12 running the thrusters.

In addition, figure 1 shows the 440 V areas 16 and circuit breakers 16A, 16B, 16C, 16D, 16E of these areas for disconnecting/connecting 440 V feeders, transformers and connections lines to these areas. Further, figure 1 shows an emergency system 17 comprising an emergency generator and transformers for supplying power in emergency situations. The areas 18 of 230 V are also showed.

The network has been protected in a normal way according to the IEC standards, for example. The circuit breakers 9, 10, 23, 15, 16A, 16B, 16C, 16D, 16E etc. have been arranged to open selectively in fault situations to restrict the faulted part from the rest of the network in order that the rest of the network could operate at least satisfactorily.

The circuit breakers are showed in an open position for clarity reasons, but it is assumed that all circuit breakers are closed i.e. they are in a connection position
(except the second load specific circuit breakers 10). Having a short circuit 30 in segment 5, all generator sets 1, 2, 3, 4 supply power into segment 5, i.e. into bus bar 5 through the input interfaces. The arrows 31, 32, 33 indicate the currents transmitting the power into the segment. Depending on the protection system the generator sets 2 and 3 with generator set 1 or all the generator sets maybe disconnected from the electric network due to the short cut 30. This can happen in the electric network without the inventive protection system. Therefore power supply to the whole electric network may be disconnected because of short circuit in one of the segments. This fault condition may continue for a while before the operation of the network can be returned.

If the electric network is protected by the invention, only the faulted segment 5 having the short circuit 30 is disconnected from the network, even with a hidden failure in the circuit breaker selective protection system. Generator sets 2, 3 and 4 continue to supply power to the network, and all thrusters 13 run. This means that steerability of the vessel remains.

The protection system according to the invention comprises a segment protection unit 19 that is arranged to receive current data relating to currents in the input interfaces of the segment 5, 6, 7, 8. The unit is also arranged to sum the received current data, compare the sum to a threshold value, and transmit control signals for all or a part of the circuit breakers 9, 15, 23 of the input interfaces for opening the circuit breakers in case the sum reaches the threshold value.

Considering the short circuit 30 situation of Fig. 1 in more detail it can be noted that the currents 31, 32, 33 flow into the faulted segment 5 through the input interfaces. The values of these currents are summed in the segment protection unit 19 and compared to the threshold value. The threshold value is set to a current value that indicates existence of a short circuit or an over current situation inside the network segment. It can, for example, be the minimum value of a maximum allowable load current in the segment or the highest starting current in the segment. If the sum reaches the threshold value, the segment protection unit provides the control signals to the circuit breakers 9, 15, 23 in the input interfaces of the faulted segment 5 for disconnecting the segment from the contributing power courses. The contributing
power courses are in this case generator set 1, the transformer 14 next to the faulted segment 5 through which generator set 2 and 3 supply power, and the bus link 22 between the faulted segment 5 and segment 7 which link supplies power of generator set 4 to the faulted segment.

The protection segment units 19 can be installed for the other segments as well for obtaining a similar protection level. Considering further the fault situation of Fig. 1 the healthy segments without faults remain to operate, because the faulted segment 5 is disconnected from them and the sums of the current levels of the input interfaces of the segments do on reach the threshold values of the segment protection units of the healthy segments. Therefore they do not provide the control signals for the disconnections.

Figure 2 shows three different short circuits outside the segments 5, 6, 7, 8. Considering that one short circuit happens at a moment figure 2 illustrates how the segment protection units 19 work under different situations and how they can be arranged to work simultaneously with the normal protection arrangement of the electric network.

When short circuit 40 occurs in generator set 1, the current 42 flows towards the short circuit through the input interface between generator set 1 and segment 5. Segment 5 transfers powers (current 41 from the transformer 14 and current 43 from the bus link 22) from generator sets 2, 3 and 4 towards generator set 1. The circuit breaker 9 in the input interface between generator set 1 and segment 5 is driven to open for disconnecting generator set 1 from the rest of the network. The normal protection system takes care of this action. Since the sum of the input and output currents of segment 5 is zero or near zero relatively, the segment protection unit 19 of segment 5 does not provide control signal for opening the circuit breakers. As can be noted the sum value depends on directions of currents in the input interfaces connected to the segment. It can be understood that positive current values are towards the segment and negative current values are away from the segment. Similarly the sums of the segment protection units of the other segments 6, 7, 8 are zero (or near zero), and they do not initiate any disconnection actions in this case. It
is noted that the arrow marks 41, 42, 43 illustrating the currents flowing towards generator set 1 relate to the short circuit 40 in generator set 1.

The second example is short circuit 50 on the bus link 22 between segments 5 and 7. The currents flow from the generator sets 1, 2, 3, 4 to the bus link towards the short circuit 50. The segment protection units 19 do not react for initiating any disconnection actions in this case, because the sums of the current values are zero (or near zero). The normal protection arrangement drives the circuit breakers next to the faulted bus link to open.

The third example is short circuit 60 in the transformer between segments 5 and 6. The currents flow from the generator sets 1, 2, 3, 4 towards the short circuit 60 of the transformer. Also in this case the segment protection units 19 do not react for initiating any disconnection actions because the sums of the current values are zero (or near zero). The normal protection arrangement drives the circuit breakers next to the transformer 14 to open.

As can be noted from these examples, currents flow always towards the place of short circuit. Therefore the calculated sum of the currents in the segment protection unit is zero or near zero. It means that the segment protection unit does not initiate disconnection actions but the normal protection system does. In the case wherein short circuit is in the segment (see Fig. 1), the segment protection unit 19 activates the disconnections before the normal protection system would do. So, the segment protection units operate selectively with the normal protection system.

Figure 3 shows a special fault that activates the segment protection system, but the fault is outside the segment. The fault, short circuit 70, is on the feeder supplying power to the thruster 12 and its motor 12 via the frequency converter 11. In spite of the fact that the segment protection system is activated, since the threshold value of the sum is reached, it does not initiate the disconnection actions. Instead the normal protection system opens the circuit breaker on the feeder for disconnecting the faulted part from the rest of the network. The activation of the segment protection system works like a backup for the normal protection system just in case the circuit breaker 10 or another part of the system does not work properly. Therefore the
disconnection actions by the segment protection unit 19 are delayed with respect to the opening of the circuit breaker 10.

So, the segment protection unit may comprise a delay function to adjust a moment or moments for transmitting the control signals. The delay function can be utilized by using a delay unit, for example a delay circuit. The delay function makes it possible to adjust the segment protection unit 19 for different electric networks, so it does not need to be manufactured for a certain network specifically.

Figure 4 shows an example of one possible embodiment of the segment protection unit 19. It comprises receiving interfaces 80 to receive the current data relating to the currents in the input interfaces connected to the segment, a summing unit 81 to sum the received current data, a comparison unit 82 to compare the sum to the threshold value, a control unit 83 to provide the control signals, and at least one transmitting interface 84 to transmit the control signals. The segment protection unit and its said sub units can be realized by hardware, software or by combination of hardware and software. The sub units may also form an integrated entity. For example, the comparison unit 82 and the control unit 83 are integrated together, or all the sub units are integrated together.

Current transformers 20 can be used for measuring the current values in the input interfaces. The current transformers are connectable 21 to the segment protection unit 19 as figures 1 - 3 illustrate. The connection between the segment protection unit and the current transformer can be a wire connection or even wireless connection. Figures 1 - 3 show an installation situation wherein the current transformers are located to the input interfaces and connected to the segment protection unit. If the input interface comprises three phases, the current transformer is there phase current transformer.

In this description the above said receiving interfaces 80 should be understood to mean different ways to provide communication between the segment protection unit and the current transformers. So physically the receiving interfaces can be one physical element. The above said delay function can be located in the transmitter interface/s 84 or the control unit 83, for example.
So the invention provides an efficient protection against faults of a bus bar, a contactor rail or a similar element. It may, for example, happen when doing maintenance work for a switch board that short circuit occurs accidentally on the contactor rail or bus bar of the switch board. As already said even the whole electric network may shut down. The invention restricts the fault efficiently so that a great part of the network is capable to supply power to the loads. The invention takes care of a safe disconnection of a network segment, with a hidden failure in any of the applicable circuit breakers selective protection system. The segment protection units can be added into different voltage areas as well for protecting the segments in several voltage areas. For example, the segments 16, 18 of 440 V and 230 V illustrated in figures 1 - 2 can be equipped with the segment protection units (and also the current transforms for the input interfaces).

It is evident from the above that the invention is not limited to the embodiments described in this text but can be implemented in many other ways within the scope of the enclosed claims.
Claims

1. A protection system of an electric network of a vessel, the electric network comprising at least one segment (5, 6, 7, 8) having input and output interfaces that are provided with circuit breakers (9, 15, 23, 10), characterised in that the protection system comprises a segment protection unit (19) that is arranged to receive current data relating to currents in the input interfaces, sum the received current data, compare the sum to a threshold value, and transmit control signals for all or a part of the circuit breakers (9, 15, 23), of the input interfaces for opening the circuit breakers in case the sum exceeds the threshold value.

2. A protection system according to Claim 1, characterised in that the segment protection unit (19) comprises receiving interfaces (80) to receive the current data, a summing unit (81) to sum the received current data, a comparison unit (82) to compare the sum to the threshold value, a control unit (83) to provide the control signals, and at least one transmitting interface (84) to transmit the control signals.

3. A protection system according to Claim 1 or 2, characterised in that it comprises a delay function to adjust a moment or moments to transmit the control signals.

4. A protection system according to Claims 3 and 2, characterised in that the delay function is located in the transmitter interface/s (84) or the control unit (83).

5. A protection system according to Claim 1, 2, 3, or 4, characterised in that the threshold value is the minimum value of a maximum allowable load current in the segment or the highest starting current in the segment.

6. A protection system according to Claim 1, 4 or 5, characterised in that it comprises current transformers (20) for measuring currents in the input interfaces which transformers are connectable to the segment protection unit (19).

7. A protection system according to Claim 6, characterised in that the current transformers (20) are located to the input interfaces and connected to the segment protection unit (19).
8. A protection system according to Claim 6, **characterised** in that the current transformers (20) are three phase current transformers, comprising individual single phase measurements.
### INTERNATIONAL SEARCH REPORT

**International application No**
PCT/FI2012/050147

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. H02H7/26

ADD.

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)

H02H

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

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

EPO-Internal , WPI Data, IBM-TDB

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<td>WO 98/11641 A2 (GEN ELECTRIC [US]) 19 March 1998 (1998-03-19) page 6, line 21 - page 9, line 8; figure 1</td>
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**Date of the actual completion of the international search**

14 November 2012

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