Claims

1. A fault protection system of a power system of a dynamically positioned vessel, wherein the power system is separated into two or more power system sections each comprising a bus section of a power distribution bus, wherein the bus sections are connected by bus ties in a ring configuration, and wherein each power system section comprises two or more power system subsections each comprising a bus subsection of the power distribution bus, the bus subsections of the same power system section being connected by one or more bus couplers, wherein each bus subsection comprises a connection to a generator and a connection to a thruster drive of the dynamically positioned vessel, wherein the fault protection system comprises:

a fault isolation system including for each power system section (a) a bus tie circuit breaker for breaking the connection provided by a respective bus tie to another power system section, and (b) one or more bus coupler circuit breakers for breaking one or more connections provided by one or more bus couplers between the two or more power subsections of the respective power system section, the fault isolation system being configured to implement a differential over-current protection scheme for operating at least the bus tie circuit breaker and the one or more bus coupler circuit breakers,

a generator ride through system comprising for each power system subsection an excitation limiter for the generator coupled to the respective bus subsection, the generator ride through system being adapted to limit the excitation field current provided to the generator upon occurrence of a fault, and

a thruster drive ride through system comprising at least one thruster drive power source distinct from the generators of the power system and configured to provide electric energy to a DC bus of a variable frequency drive (VFD) of the thruster drive of each power system subsection during a temporary post-fault period after occurrence of a fault so as

to maintain the voltage on the DC bus above a predetermined voltage threshold, such that a respective thruster drive power source is configured to supply electrical energy to a respective DC bus of the VFD of a respective thruster drive during the temporary post-fault period to maintain the voltage on the DC bus above a defined minimum threshold,

wherein the fault protection system is configured, upon the occurrence of a fault in the power system, to isolate the fault by tripping the component of the power subsection in which the fault occurred and/or by opening one or more circuit breakers in the power system subsection in which the fault is located, and to continue operation of the power system with the remaining bus tie circuit breakers and bus coupler circuit breakers closed.

2. The fault protection system of claim 1, wherein the fault isolation system is configured to implement a differential over-current protection and/or a directional over-current protection against faults for at least the bus ties and the bus subsections.

3. The fault protection system of claim 2, wherein the fault isolation system comprises protection relays for operating at least the bus tie circuit breakers and the bus coupler circuit breakers, the protection relays implementing the differential over-current protection and/or the directional over-current protection for the bus ties and the bus subsections.

4. The fault protection system of claim 2, wherein the fault isolation system is further configured to implement a short circuit and over-current protection by means of at least the bus tie circuit breakers and the bus coupler circuit breakers.

5. The fault protection system of claim 1, wherein the fault isolation system further comprises for each power subsection, a generator circuit breaker for breaking the

connection to the generator and a thruster drive circuit breaker for breaking the connection to the thruster drive.

6. The fault protection system of claim 1, further comprising an automatic voltage regulator containing the excitation limiter, the automatic voltage regulator being adapted to automatically adjust the voltage provided by the respective generator to keep the voltage within an operation band.

7. The fault protection system of claim 6, wherein the automatic voltage regulator is adapted to detect the occurrence of a fault by detecting a drop in the voltage at the generator output or at the power distribution bus, the automatic voltage regulator being adapted to decrease a voltage setpoint for the generator after the detection of a fault and to control the output voltage of the generator in accordance with the reduced voltage setpoint, so as to limit voltage overshoot after the occurrence of a fault.

8. The fault protection system of claim 1, wherein the thruster drive ride through system comprises a variable frequency drive controller for the variable frequency drive of each thruster drive, the variable frequency drive controller being adapted to decrease the output frequency of the respective variable frequency drive upon a drop in voltage on the DC bus of the variable frequency drive, thereby causing the variable frequency drive to operate in a generating condition in which electric energy is generated by an electric motor of the thruster drive and is fed back to the DC bus to maintain the voltage on the DC bus above the voltage threshold.

9. The fault protection system of claim 1, wherein the thruster drive ride through system comprises a power storage device, such as a battery, which is coupled to the DC bus of the variable frequency drive, the power storage device being adapted to supply electric power to the DC bus in case of a

drop of voltage on the DC bus in order to maintain the voltage on the DC bus above the voltage threshold.

10. The fault protection system of claim 1, wherein the power system further comprises for each power system subsection a connection to a thruster utilities switchboard electrically coupled to the generator of the respective power system subsection for providing electric power to utilities of the thruster drive, and a connection to an engine support switchboard electrically coupled to the generator of the respective power system subsection for providing electric power to utilities of the engine operating the generator of the power system subsection, and

wherein the fault protection system further comprises for each power system subsection a circuit breaker for breaking the connection to the thruster utilities switchboard and the engine support switchboard.

11. The fault protection system of claim 10, further comprising an uninterruptable power supply for each power system subsection, the uninterruptable power supply being coupled to the thruster utilities switchboard and/or the engine support switchboard.

12. The fault protection system of claim 11, further comprising an electric interlink connection from the thruster utilities switchboard or the engine support switchboard of one power system subsection to the uninterruptible power supply of another power system subsection.

13. A power system of a dynamically positioned vessel, comprising:

two or more power system sections, each comprising a bus section of a power distribution bus, wherein the bus sections are connected by bus ties in a ring configuration, and wherein each power system section comprises two or more power system subsections each comprising a bus subsection of the power distribution bus, the bus subsections of the same power system section being connected by one or more bus couplers, wherein

each bus subsection comprises a connection to a generator and a connection to a thruster drive of the dynamically positioned vessel, and

a fault detection system comprising:

a fault isolation system including for each power system section (a) a bus tie circuit breaker for breaking the connection provided by a respective bus tie to another power system section, and (b) one or more bus coupler circuit breakers for breaking one or more connections provided by one or more bus couplers between the two or more power subsections of the respective power system section, the fault isolation system being configured to implement a differential overcurrent protection scheme for operating at least the bus tie circuit breaker and the one or more bus coupler circuit breakers,

a generator ride through system comprising for each power system subsection an excitation limiter for the generator coupled to the respective bus subsection, the generator ride through system being adapted to limit the excitation field current provided to the generator upon occurrence of a fault, and

a thruster drive ride through system configured to provide electric energy to a DC bus of a variable frequency drive of the thruster drive of each power system section upon occurrence of a fault so as to maintain the voltage on the DC bus above a predetermined voltage threshold,

a thruster drive ride through system comprising at least one thruster drive power source, distinct from the generators of the power system, configured to provide electric energy to a DC bus of a variable frequency drive (VFD) of the thruster drive of each power system subsection during a temporary post-fault period after occurrence of a fault so as to maintain the voltage on the DC bus above a predetermined voltage threshold, wherein the thruster drive ride through system is configured to detect a voltage drop on the power distribution bus during the temporary post-fault period, and in response, activate a respective thruster drive power source for delivering electrical energy to the DC bus of the VFD of at least one respective thruster drive,

wherein the fault protection system is configured, upon the occurrence of a fault in the power system, to isolate the fault by tripping the component of the power subsection in which the fault occurred and/or by opening one or more circuit breakers in the power system subsection in which the fault is located, and to continue operation of the power system with the remaining bus tie circuit breakers and bus coupler circuit breakers closed.

14. The power system according to claim 13, further comprising for each power system subsection a connection to a thruster utilities switchboard for providing electric power to utilities of the thruster drive, and a connection to an engine support switchboard for providing electric power to utilities of the engine operating the generator of the power system subsection, and

the power system further comprising a transformer for each power system subsection connected to the respective bus subsection, the transformer providing electric power to a respective thruster drive coupled to the bus subsection, wherein the transformer comprises an additional secondary winding electrically coupled to the thruster utilities switchboard and the engine support switchboard of the power system subsection for providing electric power to both switchboards.

15. A method of operating a fault protection system of a power system of a dynamically positioned vessel, wherein the power system is separated into two or more power system sections each comprising a bus section of a power distribution bus, wherein each power system section comprises two or more power system subsections each comprising a bus subsection of the power distribution bus, the bus subsections of the same power system section being connected by one or more bus couplers, wherein each bus subsection comprises a connection to a generator and a connection to a thruster drive of the dynamically positioned vessel, the method comprising:

detecting a fault in the power system,

localizing the fault in the power system,

electrically isolating a component in which the fault occurred from the remaining power system by opening a circuit breaker coupled to the component or isolating a power system subsection in which the fault occurred from the remaining power system by opening bus tie and/or bus coupler circuit breakers of the respective bus subsection, and

after electrically isolating the component in which the fault occurred, determining whether the fault is still present,

if it is determined that the fault is still present after electrically isolating the component in which the fault occurred, opening all circuit breakers in the power system subsection in which the fault occurred,

continuing operation of the power system with the remaining bus tie circuit breakers and bus coupler circuit breakers closed.