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Distributed Insulation Monitoring Strategy (DIMS) for High Stray Capacitance Systems

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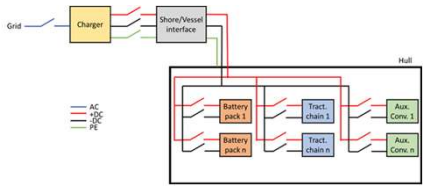
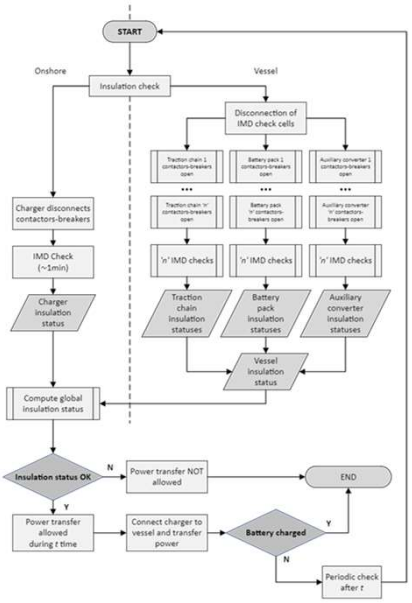
Abstract:

Climate change is a global phenomenon which is becoming increasingly concerning. Efforts in this area are working forward to full electric vessel to become a reality. These systems have great amounts of energy storage. Together with electric machinery, EMI filters and distribution grids usually can sum up to some mF capacitance to earth, becoming a problem when detecting faults to ground, and therefore, a safety issue.
To detect earthing faults insulation monitoring devices (IMD) are used, but as of Jan. 2024, the commercial IMDs available are not able to make a good measurement at stray capacitances (CS) above 3000µF [3], and all the devices in the mF range have response times of >100s.
A new **Distributed Insulation Monitoring Strategy (DIMS)** approach is proposed in this paper, with simulation results, to make a faster and more reliable measurement of earthing faults in isolated terra (IT) systems with stray capacitances in the range of the hundreds of µF. The impedance to ground is measured in isolated parts of the whole system and then a higher-level logic is implemented to compute a total safety status.

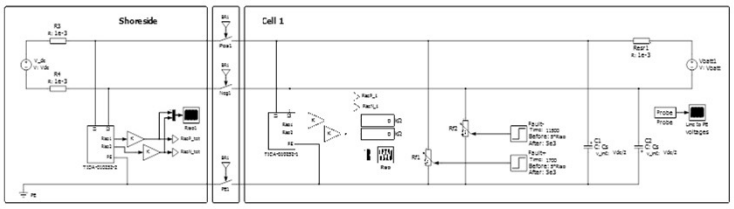
Presented concept and simulations:



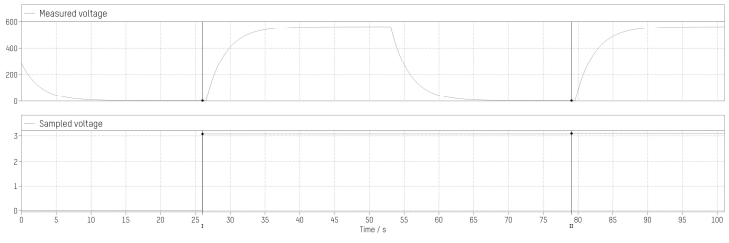
Commercial IMD devices have response times of several tens of seconds and that is not acceptable in charging applications that require keeping up to a planned schedule.
One could take advantage of the switching gear both in the ship side and shore side and perform insulation checks disconnecting circuit parts to limit stray capacitances below some tens of µF before connecting ship and shore. This way, system is split into smaller monitoring cells and check can be performed quicker and in a safe manner.
Assuming continuity of operation can be assured, the system could be divided into multiple cells and measurement would be done to every single cell, while the vessel is not connected to shore. As a result, this decouples charger isolation issues with respect to vessel issues. A full insulation check should not reduce effective charging time by a significant amount of. Two way 'handshake' can be implemented to allow charging or not by checking onshore and vessel insulation statuses increasing security. Vessel insulation check should be managed by onboard BMS and/or main control computer and communicated to the shore.



A reference design by Texas Instruments has been simulated. It is only valid for DC lines.
This design needs a sampling time long enough to consider the stray capacitance, so the measurement precision is enough.
Response time in these simulations is linearly proportional to the stray capacitance. This is because no current limitation was implemented in the measurement. In commercial devices different strategies are considered when it comes to current and voltages levels, this is why a practical use case was studied using available device information.



C_s[µF]		50	100	200	500
t_{Res}[s]	1 cell	159.10	318.21	636.42	1591.06
	2 cells	79.55	159.10	318.21	795.53
	3 cells	53.03	106.07	212.14	530.35



Conclusion:

In this paper a new DIMS has been proposed and validated in simulation, demonstrating an improvement for specific applications where the capacity is large and commercial products are limited. Stray capacitance clearly affects the time requirements in IMD schemes. DIMS strategy presented in this paper has demonstrated to reduce the effective stray capacitance in the measuring circuit and, thus, reduces the time needed to provide a safety check proportionally.
In applications with tight time and safety constraints this novel strategy can become crucial.
The most limiting aspect would be the need of physically switching the architecture, and this would require further analysis to determine the feasibility of the DIMS in each singular application.

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HYPBATT
Hyper powered vessel battery charging system