Numerical Modeling and Hardware-in-the-Loop Simulation of Undersea Networks, Ocean Observatories and Offshore Communications Backbones

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Abstract

This paper discusses the importance of taking a systems engineering approach when designing undersea networks, ocean observatories and offshore communications backbones. A design that utilizes modular components and systems, and places diligence in modeling and testing communications, power and data bandwidth requirements is essential for sustained operation and economic feasibility. An example is the modular seafloor communications network described – CSnet's Offshore Communications Backbone (OCB). The systems engineering approach that shaped OCB's design, the modeling, simulation, testing as well as data collected during the test and development phases is presented. Subsea networks present the inherent challenge that complete system testing is normally impossible as key elements, such as the telecommunications cable, are only integrated at deployment. Even had the cable been available for integration testing, its reactive properties are different deployed than at a test facility. The potential cost implications of such an unexpected interaction post deployment could result in unrecoverable loss. To mitigate these risks, a rigorous systems engineering approach must be adopted that includes system level studies, analysis and theoretical, numerical and physical models of key areas such as power distribution and communications. The OCB seafloor element consists of both submarine cabling and multiple nodes. The nodes are modularly designed; independent of location and position. The network is redundant and expandable to accommodate additional nodes and buoys. Discussed is the theoretical analysis performed of the system architecture to determine the optimal selection of fiber type and network equipment to ensure robust and reliable communications. Also described is the thorough optical budget analysis conducted taking into account optical link loss, dispersion and optical signal-to-noise (OSNR). Computer simulation and Hardware-in-the-Loop Simulation (HILS) testbeds using the actual hardware being considered in the nodes were employed to validate the theoretical findings. Ethernet benchmark tests were performed to analyze throughput, back-to-back testing, latency and frame loss in the network. Attenuators as well as full scale network fiber lengths measuring hundreds of kilometers were used to test and evaluate multiple fiber types. Results are presented of the power system analysis and transient study utilizing computer models, critical in determining "worst case" voltage and current transients. By using an accurate representation of the cable parameters and system variables, an optimal design of the medium voltage converter (MVC) and high voltage power supply (HVPS) is achieved. Protective measures intended to prevent single point failures, particularly those that may short the backbone cable and bring down the entire network, are evaluated. Physical cable modeling and seawater return analysis were

included in the analysis and simulations. Instrument loading (power and data bandwidth) in a hierarchy of combinations intended to simulate the range of possible user applications were simulated to ensure the network's robustness through future expansions. Although the capital expenditure (CAPEX) associated with the rigorous process described of this initial design is significant, the potential cost avoidance and savings over the deployment and operation of both the initial and future network's operational expenditure (OPEX) more than justifies this investment.

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