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Improved Model Analysis and Current-Loop Design for Marine Controlled Source Electromagnetic Transmitter

Jianzhi Ding*, Yiming Zhang

Beijing University of Technology, 100 Ping Le Yuan,Chaoyang District, Beijing and 100124, China

Abstract

The marine controlled source electromagnetic transmitter is a crucial device of marine electromagnetic method, its transient state and steady state is followed with interest. In this paper, an improved model of the phase-shifted full-bridge converter is minutely described on the basis of some specific challenges of electromagnetic transmitter based on full-bridge structure, such as power losses and duty-cycle loss. Then, an efficient current-loop compensator designed with improved model proposed in this paper is mentioned. The comparative analysis and simulation results of the improved model and the traditional model could prove the superiority of the improved to the system response speed and control stability. The electromagnetic transmitter could achieve better transient state and steady state characteristics by the compensator designed with the improved model.

Keywords: marine controlled source electromagnetic transmitter, phase-shifted full-bridge, AC small-signal model, current-loop compensator;

1. Introduction

Marine electromagnetic method have been used to identify the electrical and magnetic properties of a wide range of sub-seafloor targets, such as oil, gas, and gas hydrates. It typically uses a drag electrical current dipole marine controlled source electromagnetic transmitter (MCSET) near the seafloor and measures the electrical and magnetic fields using a receiver array placed on the seafloor. The submarine geological structure is identified by the difference of formation conductivity and permeability, to achieve the purpose of geological survey [1].

* Corresponding author. Tel.: +86-15510372308.
E-mail address: djzh5@163.com

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MCSETs currently have low energy utilization, low switching frequency, poor transient and steady-state performance of the emission current, and limited exploration range or depth. Therefore, a high efficiency, excellent transient performance and strength emission current, strong anti-interference MCSET to meet the high precision of marine exploration become an urgent problem.

Phase-shifted full-bridge (PSFB) widely known as one of the converter topologies used in high power converters [2-3]. The MCSET of PSFB structure can raise the power density and ensure its output power. The earlier PSFB converter model has been mentioned in [4], where the converter AC small signal model has been gained as a modified version of the buck converter model. It hasn't taken into account the effect of component parasitic resistance on this model, only analyzed the impact of the input voltage and filter inductor current on the secondary side of the transformer duty-cycle. On this basis, a further model considering the significant effect of the output filter capacitor equivalent resistance has been suggested in [5]. An enhanced model for AC small-signal analysis of the PSFB converter has been given in [6]. This method has presented the impact of power losses on the PSBF model and validated its effectiveness by voltage-loop compensator, but output inductor current-to-control transfer function and current-loop compensator hasn't described. Based on the literature [6], output inductor current-to-control transfer function and current-loop compensator of PSBF are proposed in this paper. The controller achieved with these conclusions could guarantee stable output voltage and current for MCSET of PSBF circuit structure.

2. MCSET System

Figure 1 is the MCSET system architecture, it can be divided into two sections: the part of shipborne and the part of underwater. The former includes shipborne generator, rectifier, monitoring platform and DC carrier communication unit. The latter includes PSFB converter, emission bridge, transmitting antenna, voltage/current sense circuit, central control unit and DC carrier communication unit. The DC power cable is used as both power transmission and communication cable without the need for specialized communication cables or optical fibers. The data exchange between shipborne platform and the underwater central control unit is realized by the DC carrier communication method.

DC voltage converted by the three-phase rectifier bridge is provided to the PSFB converter at the rectifier bridge output terminal. The PSFB converter adjusted DC output voltage by controller. Finally, the MCSET emits artificial polarity alternating current pulses of different frequencies into seawater, and emission bridge adjusts the emission frequency. In particular, PSFB converter as adjusting output voltage and current key circuit, its transient and steady state characteristics directly affect the performance of MCSET system. The PSFB converter controls the emission current and voltage through the double closed-loop average current control strategy.

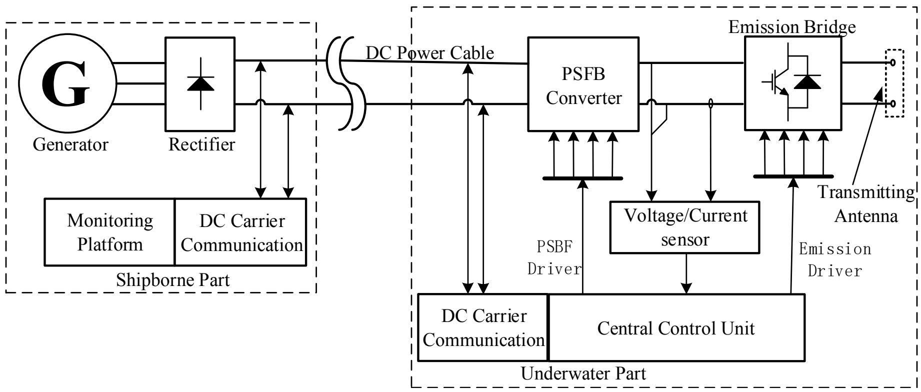

Fig. 1. System diagram of MCSET.