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Developing a power monitoring and protection system for the junction boxes of an experimental seafloor observatory network

Key words: Power monitoring and protection, Embedded processor, Seafloor observatory network, IEEE 1588, Junction boxes

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Introduction

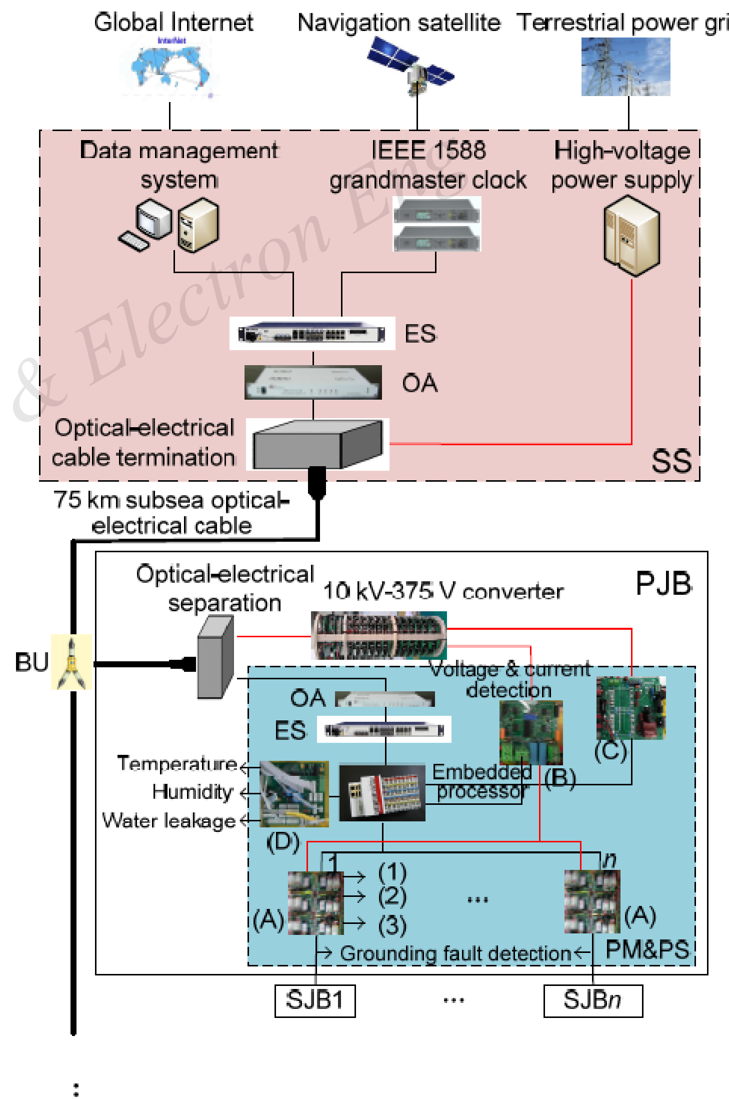
- Seafloor observatory networks have developed rapidly because of their advantages in terms of providing real-time, long-term, and continuous observation data.

- Junction boxes function as intermediate processing nodes between science instruments and shore station in power transmission and communication.

- This paper presents a power monitoring and protection system that exhibits reliable power management and general monitoring, exact grounding fault detection, and accurate time synchronization.

Framework of our method

- An overview of the seafloor observatory network and of the power monitoring and protection system

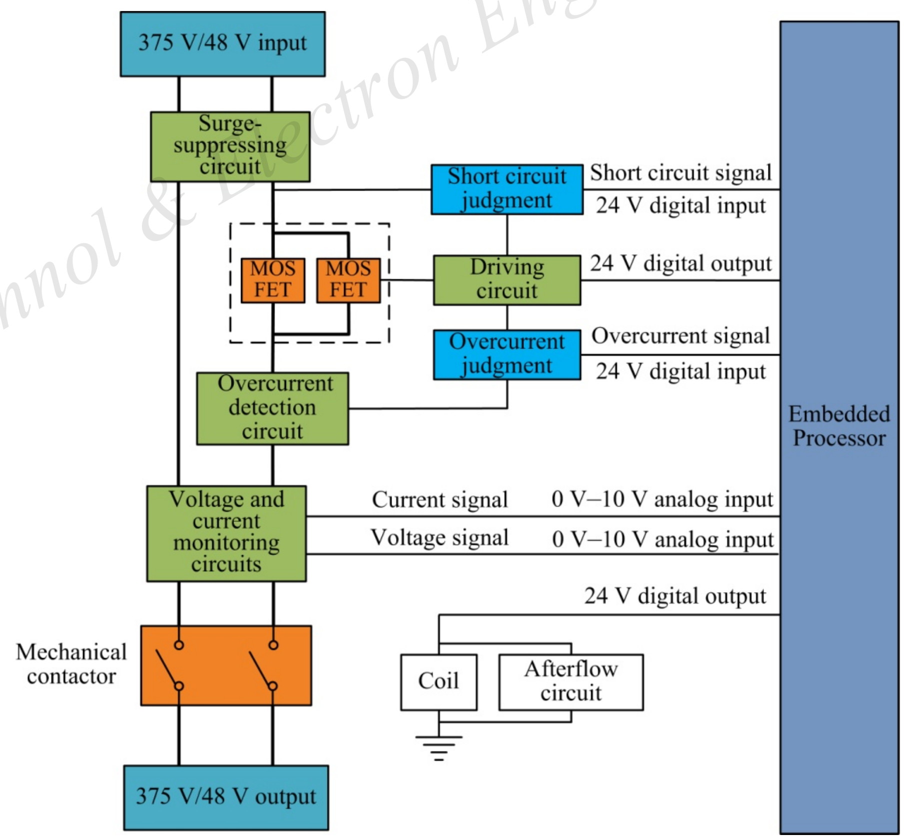


SS: shore station PJB: primary junction box
BU: branching unit SJB: secondary junction box
OA: optical amplifier ES: Ethernet switch
PM&PS: power monitoring and protection system
(A): power management module
(B): voltage and current detection module
(C): grounding fault detection module
(D): environmental monitoring module
(1): power management (2): short circuit protection
(3): overcurrent protection

Design method (I)

- Power management method

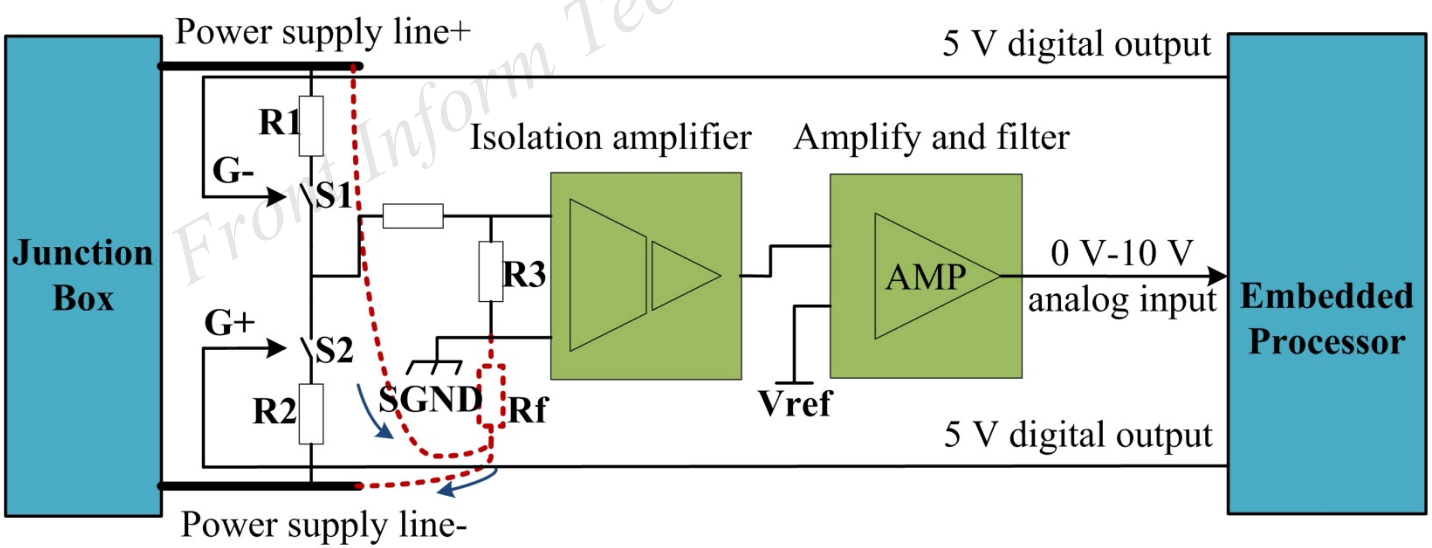
A two-step power management method that uses metal–oxide–semiconductor field-effect transistors (MOSFETs) and a mechanical contactor in series was adopted to generate a reliable power switch, to limit surge currents, and to facilitate automatic protection.



Design method (II)

- Grounding fault detection method

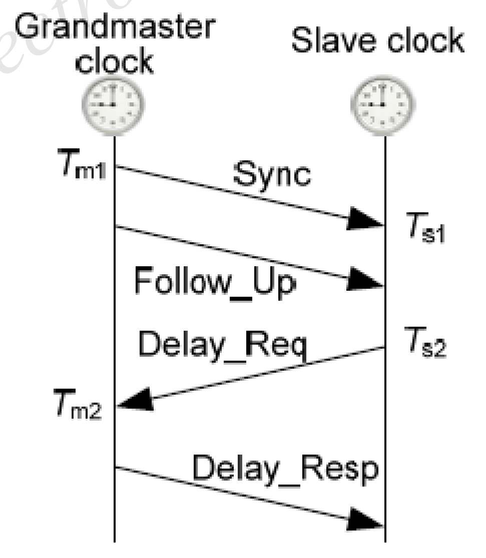
Grounding faults occur when a single wire comes into contact with seawater or with the cavity of the JBs, as well as when the relative impedance between the wire and seawater is too small.



Design method (III)

- Time synchronization method

The data collected from the JBs must be time-stamped for analysis and for correlation with other events and data. A highly precise system time, which is necessary for synchronizing the times within and across nodes, was generated through the IEEE 1588 (Precision clock synchronization protocol for networked measurement and control systems) time synchronization method.



Design method (IV)

- General variable monitoring method

In voltage detection, a special high-precision divider resistance is adopted to divide voltage accurately. In current detection, a highly accurate constantan resistance is used to convert a current signal directly into a voltage signal within a particular input range.

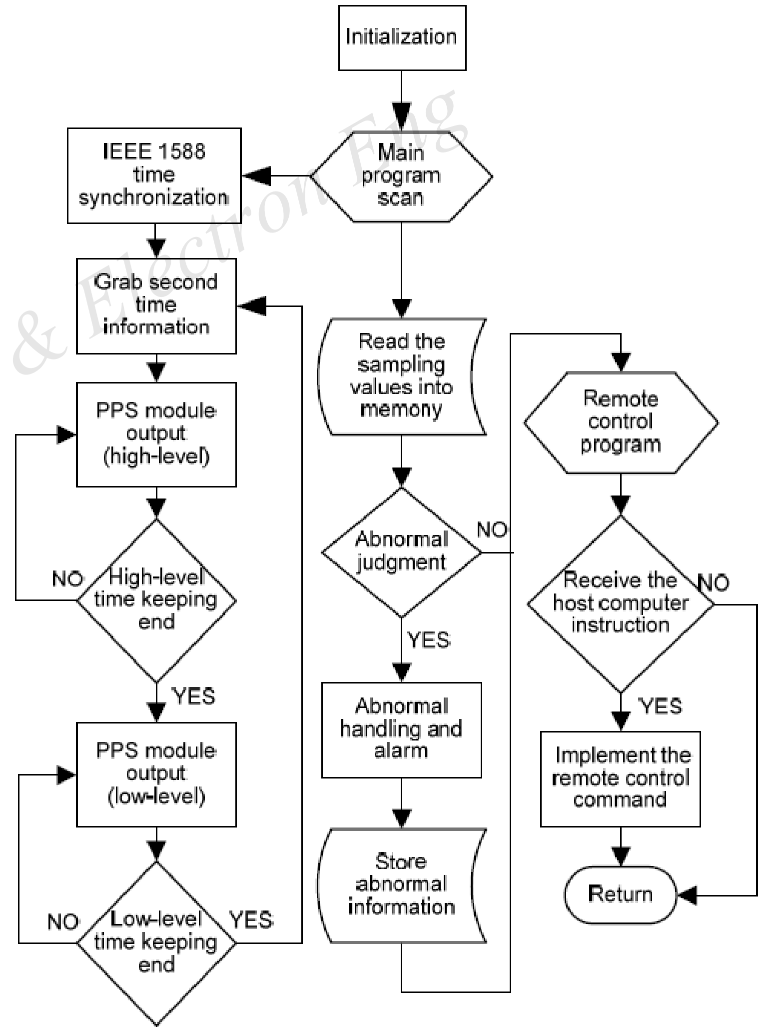
Temperature and humidity can be monitored using off-the-shelf sensors. Water leakage can be detected with a leakage-sensing wire, which is composed of a fluoropolymer material and produced through conductive polymerization technology

Design method (V)

- Software design method

Communication between the embedded processor and the port modules is transmitted via an Industrial Ethernet protocol called Ethernet Control Automation Technology (EtherCAT).

The software of the node controller is written in structured text language in combination with a ladder diagram



Major results

(1) Power management and protection against short circuiting and overcurrents

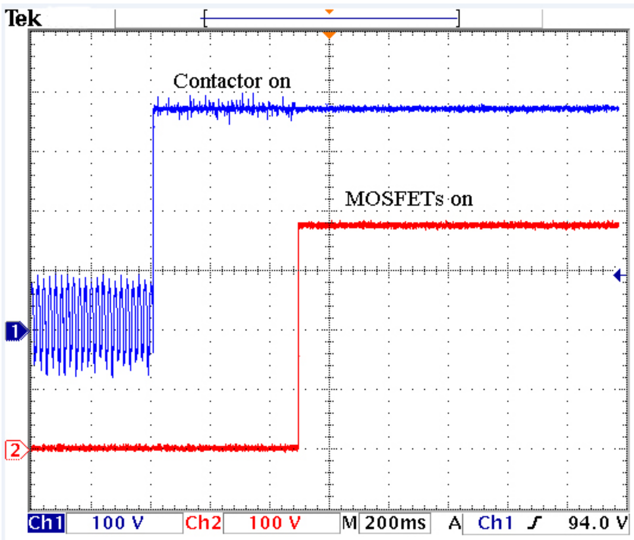


Fig. 7a Results of the action sequence when turning the switch on

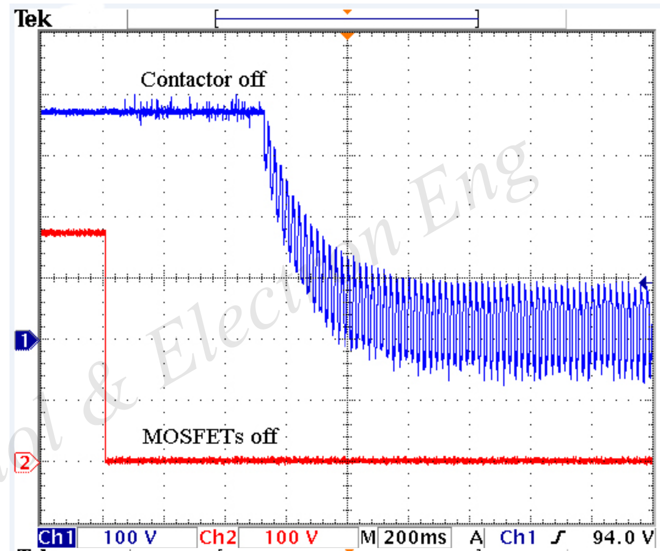


Fig. 7b Results of the action sequence when turning the switch off

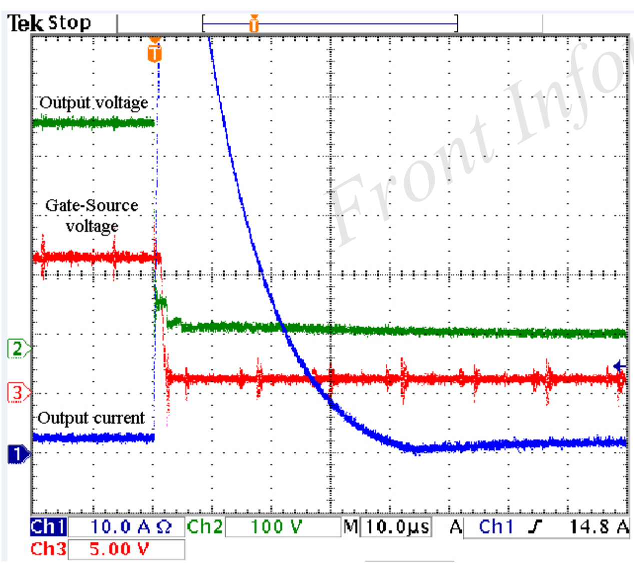


Fig. 8a Curves of short-circuit protection

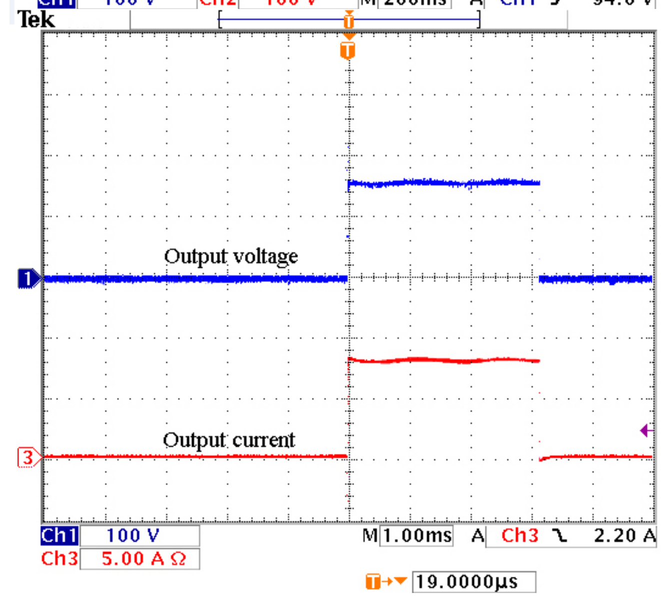


Fig. 8b Curves of overcurrent protection

Major results (Con'd)

(2) The actual resistance values of the potentiometer coincide well with the calculated grounding resistance values, and the errors are within 2%

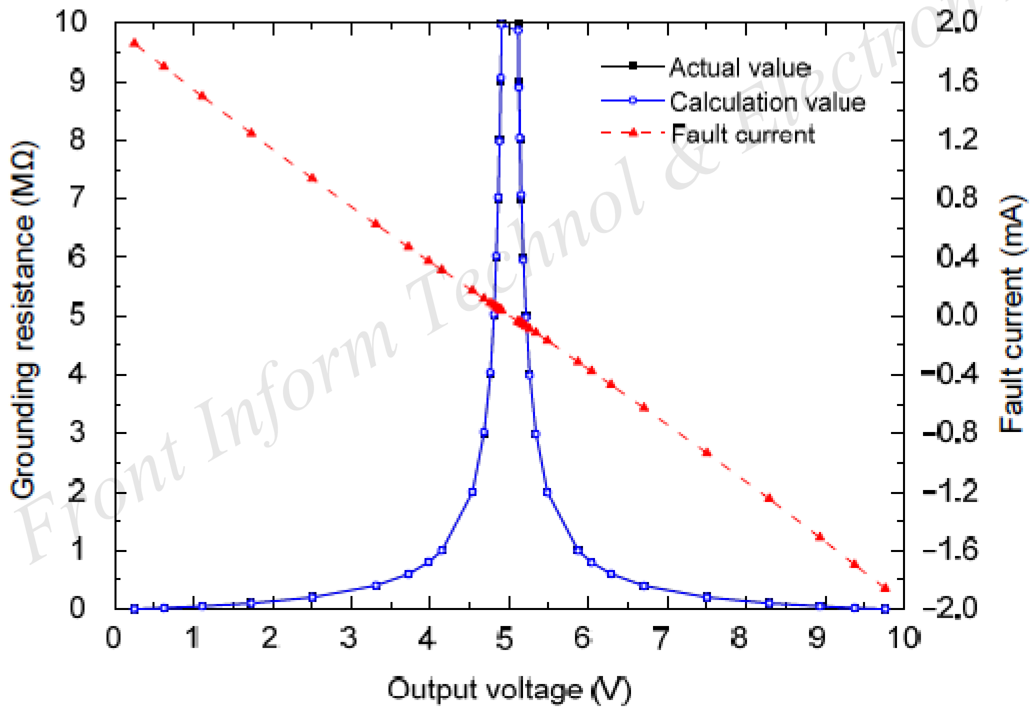


Fig. 9 Curves of the grounding resistance values and fault current under different voltages

Major results (Con’d)

(3) Time synchronization: the increasing edge deviation of the signals output by the PTP grandmaster clock and by the PPS output module ranges in −20 – 200 ns

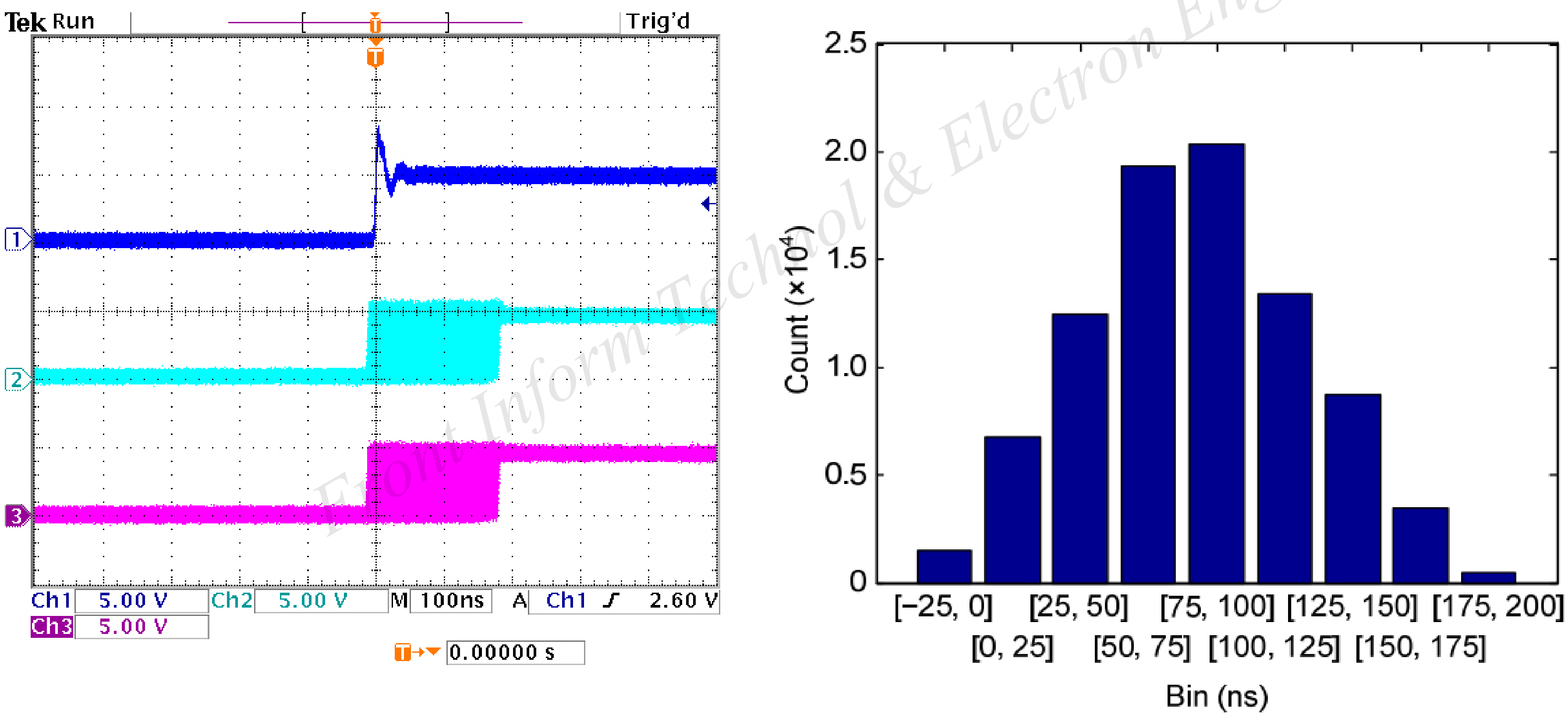


Fig. 10 Results of long-term PPS signals (left) and PPS signal delay histogram (right)

Major results (Con’d)

(4) Software testing

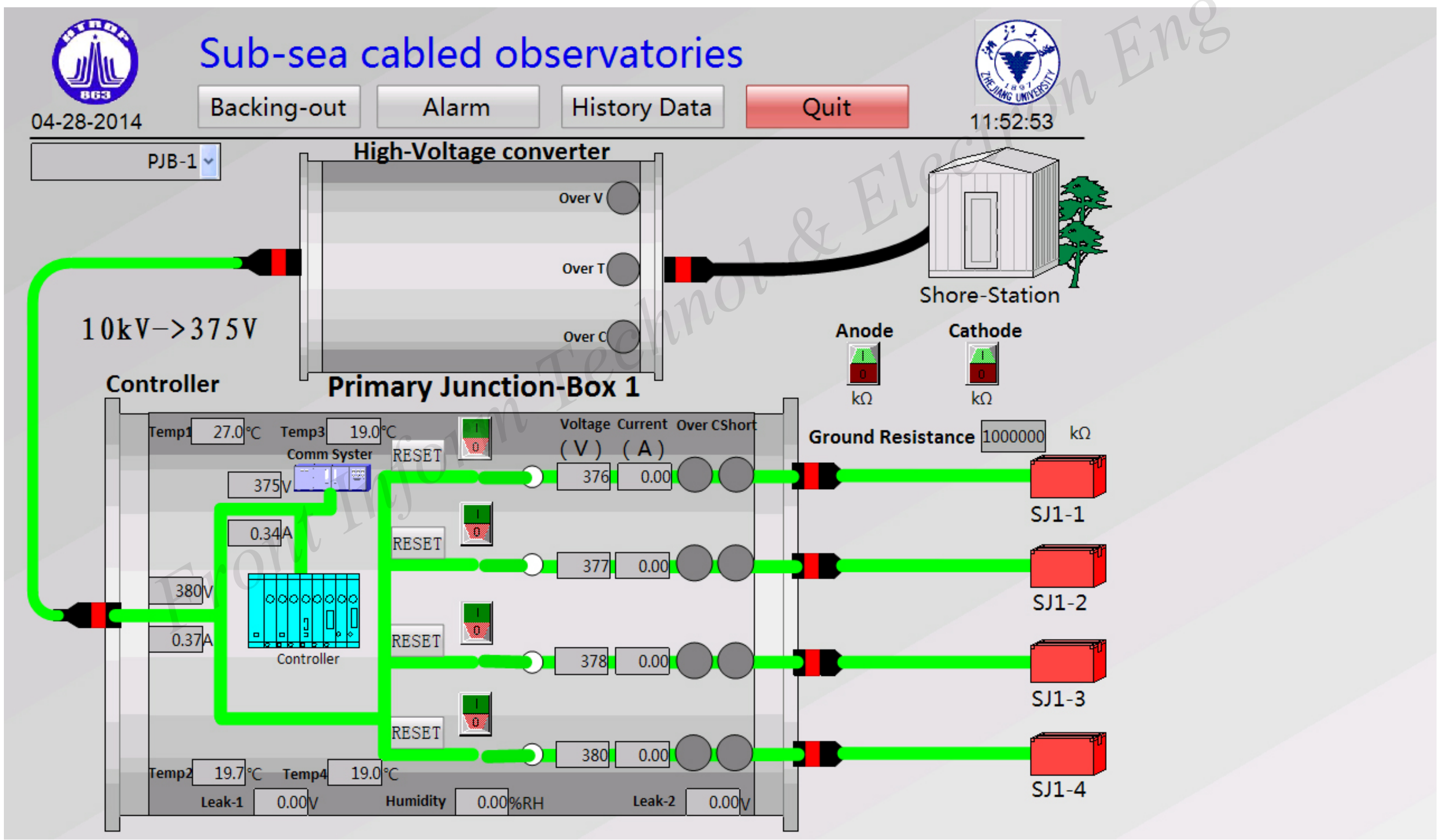


Fig. 11 Software interface during system operation

Major results (Con'd)

(5) Sea trial

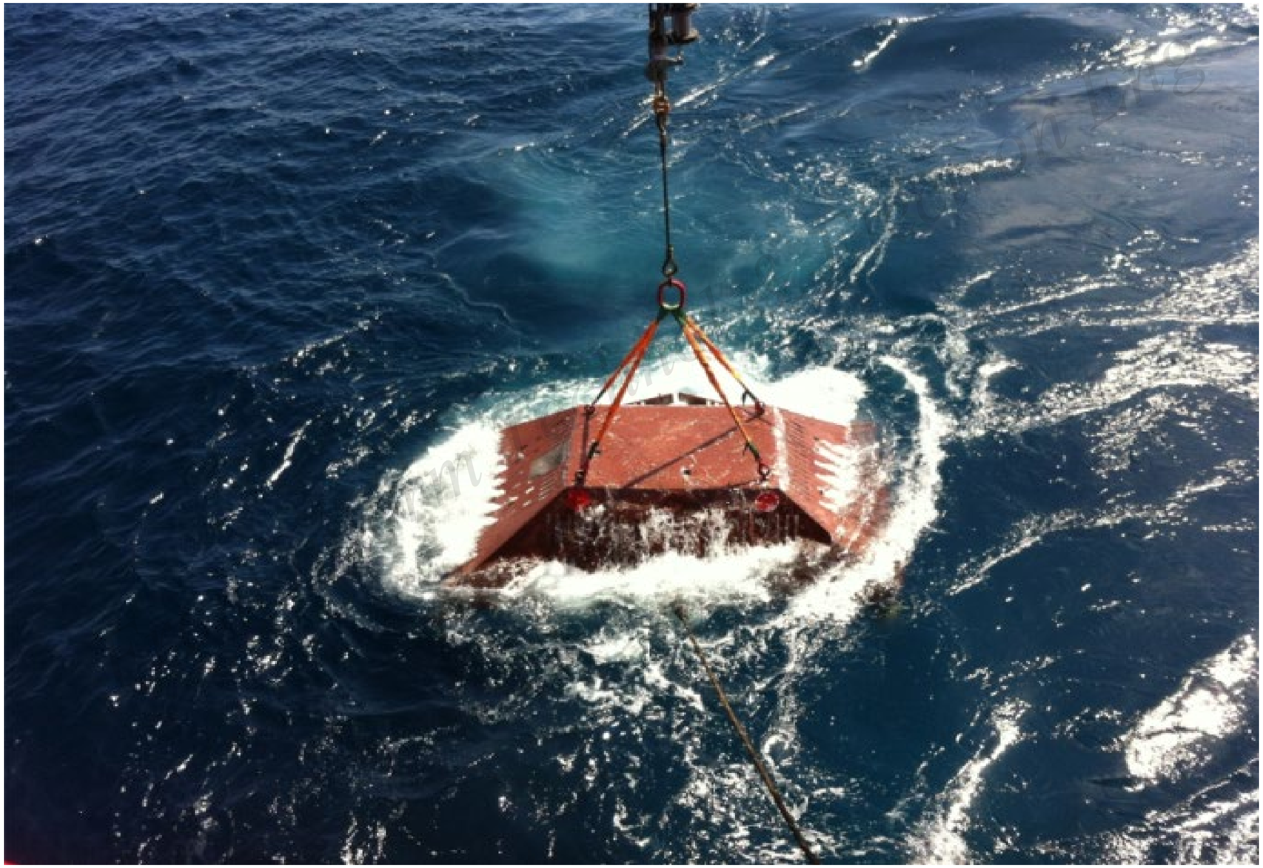


Fig. 13 Deployment of the experimental assembly system