Construction of the Remote Welding System based on Power Line Communication

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Abstract. Remote welding technology plays an important role in the construction of national key projects. Instead of manual welding and full-autonomous welding, it is the best way to apply remote welding technology to practical engineering by employing a special robot. This study uses the remote welding power supply cables as the carrier to construct the power line communication network. The key technical problems of the power line communication for complicated electromagnetic environment are proposed in this paper. On this basis, the welding parameters and the environment parameters are transferred to the local control unit, by the power line communication network. The influence rule on weld formation, microstructure, mechanical properties, and welding defects can be revealed by analyzing the above factors. This study explores a feasible way for the robot remote welding by the way of integration innovation. It will lay a foundation for the application of the robot remote welding technology in the construction of national key engineering.

1. Introduction
Remote welding technology plays an important role in the construction of national key projects, such as underwater construction and emergency maintenance of marine engineering, exploitation and utilization of marine resources, disaster prevention and relief of nuclear power facilities etc. It is risky and difficult to conduct the welding task in the above environment [1-6].

Compared with the normal welding process, it is more difficult for the robot to complete the remote welding mission, due to the influence of hydrostatic pressure, subsurface disturbance or poor light conditions etc. Remote welding, with the aid of sensors such as vision, force sense, and sound perception, extends the operator’s perception ability, provides information for the operator to make judgments and decisions, and enables the operator to complete the welding task in environments away from harmful construction sites [7, 8]. However, the traditional remote equipment has a low level of integration. Each signal acquisition device requires several cables. For remote welding under extreme environments such as heavy pollution, nuclear radiation, and large water depth, there are large amount of information to be monitored and collected, and the system is highly redundant. With the increase in
the number of devices, the number of cables has increased geometrically [9, 10], which leads to a significant increase in the operational complexity and construction costs of remotely controlled underwater welding systems. On the other hand, the increase in the number of cables often leads to electromagnetic incompatibilities, cable interface errors, watertight joint failures, and many other conditions that reduce the reliability and stability of the entire system.

Power Line Communication (PLC) refers to the use of existing power lines to carry out high-speed transmission of analog or digital signals through carrier waves [11]. Compared to other communication technologies, power line communication has many advantages for achieving high-speed data transmission. First of all, the power line communication technology uses the existing power line as the transmission medium, no need to re- lay cables, which saves the cost of cable and construction costs. Secondly, power line communication technology communication is an energy integration technology, so it is not necessary to consider the power supply problem of communication equipment. Finally, the power line communication technology can be directly connected to the power equipment through the power line, which facilitates the interconnection and interconnection of the internal power equipment in the system and realizes unified management and resource sharing.

The usage of the power grid for control, maintenance, and charging purposes by the utility commodities has a long history [11], the idea is as old as the telegraph itself. The first remote electricity supply metering equipment was developed in 1838, and the first commercial production of electromechanical meter repeaters took place [12]. PLC applications have evolved constantly over the years, especially the last 20. Hou [13] designed a remote system based on power line communication for intelligent household. Y. P. Pramod etc. [14] make use of the already existing power lines as a physical medium to control the machines or electrical equipment. His research concluded that the PLC is surely a cheap way to be used for remote control, emergency alarms, and industrial automation. A power line carrier communication technology based on TMS320F4207 DSP control chip and ST7540 carrier modulation and demodulation chip is proposed by H. Shang and L. Li [15] to realize the communication system solution between the power supply and the wire feeder of the semiautomatic self-protected flux core welding supply. F. Su etc. [16] analyzed the mechanism system of long-distance PLC and the influencing factors of communication attenuation on the basic configuration of subsea control system. This study introduces the power line communication technology into the remote welding system. It is an effective and cheap way to achieve accurate control of underwater welding robots and underwater welding processes.

2. Scheme of the system

![Figure 1. Schematic diagram of the welding power source.](image-url)
This article divides the welding power into two parts: the primary circuit and the secondary circuit. As shown in Figure 1, the primary circuit is located at the local end and its function is to rectify the welding power supply input 220V/380V AC to 540V DC; while the secondary circuit is placed directly at the remote end, after a waterproofed treatment. It is responsible for rectifying the 540V DC to a 20-40V DC output. This structural improvement, on the one hand, reduces the volume and weight of the remote welding equipment. On the other hand, it shortens the length of the welding power supply output cable, thereby reducing the adverse effects due to resistance, inductance and voltage losses. Finally, and most importantly, the 540V DC power line between the primary circuit and secondary circuit can be used for PLC, to realize the remote control of welding power source and the monitoring of welding process parameters.

On this basis, remote welding current, voltage and other process parameter information and environment information such as depth and temperature can be transmitted to the control unit. The information is always used to analyze the influence of the above factors on the remote weld formation, microstructure, mechanical properties, and welding defects.

3. System construction
The remote welding system based on power line communication established in this study is shown in Figure 2. The system consists of four functional units: decision unit, data transmission unit, parameter acquisition unit and remote welding unit.

The parameter acquisition unit monitors the 3D environmental information, hydrological information and welding parameter information of the remote welding task space through various sensing devices and transmits the above data information to the decision unit far from the task space through power line carrier communication. Based on the analysis and processing of collected information, the decision control unit controls the remote welding robot to complete the welding process through human-machine collaboration.

Figure 2. The underwater welding system based on PLC.

3.1. The PLC module
Power line communication refers to a technology that uses an existing power line to carry out high-speed transmission of an analog signal or a digital signal through a carrier wave. The key technologies mainly include digital frequency modulation technology, orthogonal frequency division multiplexing technology and direct sequence spread spectrum technology. The power line communication unit of the remote welding system is working in the environment of electromagnetic interference. The noise reduction of the power line communication is the first key problem to be solved.
This study uses spectrum sensing technology of cognitive radio to avoid noise interference in the channel, so as to achieve effective communication. The physical layer power line communication generally uses cognitive radio OFDM modulation. OFDM technology is a digital communication technology that has developed rapidly in recent years. This technology has significant anti-jamming and anti-multipath effect capabilities and is considered to be an ideal modulation method for power line carrier communication. This orthogonal frequency division multiplexing modulation method can divide a given channel into a number of orthogonal sub-channels, allocate one subcarrier for each sub-channel and modulate, and transmit each sub-carrier in parallel. Since the modulation carriers of the respective sub-channels in the OFDM system are orthogonal, their spectrums may overlap each other. This not only reduces the mutual interference between the subcarriers, but also improves the spectrum utilization of the channels. The communication noise reduction process is shown in Figure 3.

3.2. The welding power source module
The welding power module is the physical carrier of power line communication. As mentioned in section II, the secondary circuit of the welding power supply is connected to the primary circuit through a 540 VDC power cable. In addition to outputting the required voltage for welding, it also provides power for remote power line communication devices and external characteristic controllers.

The power line communication demodulator receives the carrier signal from the power cable, obtains the operator’s instruction, and feeds back to the primary circuit. The external characteristic controller obtains the output voltage amplitude $V_{set}$ of the welding machine, the no-load voltage $V_0$, the successful determination arc current $I_{min}$, and the maximum output current $I_{max}$. The external characteristic controller implements the regulation of the external characteristics as shown in Figure.4 according to a specific control algorithm.

3.3. The welding process sensing module
The welding metallurgical process is a typical multi-factor interaction dynamic physicochemical process. In addition to the components of the welding material itself, the environment characteristics of
the welding area and the system delay also affect the welding metallurgy process, which determines the quality of the welded joint. Therefore, it is necessary to collect the remote welding of electric signals, gun position signals, welding motion parameters, and workpiece thickness, temperature, etc. by various types of sensors. Then the power line communication is used to transmit the information to the decision units away from the work site. The information is always used to analyze the influence of the above factors on the remote weld formation, microstructure, mechanical properties, and welding defects.

On this basis, the stability assessment of the remote welding process reveals the intrinsic correlation between underwater welding arc characteristics, droplet transfer behavior, airbag protection characteristics, and stability of the welding process, and induces droplet transfer rules, shown as Figure 5. The signal characteristics of the main influencing factors are analyzed, real-time control of the droplet transfer mode is realized, accurate droplet transfer control is realized, and the stability of the welding process is improved.

![Figure 5. The metal transfer in underwater welding process.](image)

4. Design of the software

![Figure 6. The software flow chart of the system.](image)
Software design is another difficulty in the development of the entire system. The difficulty lies in coordinating the power line communication control chip to switch between multiple states while also performing signal processing. In order to ensure the real-time performance of the system, the carrier signal must be monitored and the control signal, display refresh, and AD sampling must be processed. In order to meet this requirement, the AD sampling, carrier monitoring and protection signals of the power supply control system are all interrupted. The software flow chart of the main program of the power control system is shown in Figure 6.

5. Conclusion
Power line communication has been widely used in power systems and home intelligence. In this study, the application of wire communication technology in the remote welding system will have a positive effect on improving the reliability of offshore construction and has broad application prospects.

This study explores a feasible way for the remote robot welding by the way of integration innovation and technological convergence of power line communication, and remote welding. It will lay a foundation for the application of the remote robot welding technology in the construction of national key engineering.

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