基于 ARM 平台的 Xenomai 实时操作系统在压力条件下的稳定性优化研究

Stability Optimization of the Xenomai Real-Time Operating System on ARM Platforms Under Stress Conditions

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Agenda

01 Real-time Applications in Siemens

02 What is real-time?

03 Real-time Operating Systems in general

04 Xenomai in particular

05 Research higher latencies but still correct behavior

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01 Real-time Applications in Siemens

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01 Real-time Applications in Siemens

Programmable Logic Controllers (PLC)

Importance of Real-Time Systems in Siemens PLCs:

- **Timely Response:** Real-time systems ensure that the PLC can process and respond to external events, such as sensor signals and control commands, within a specified time frame.
- **High Precision Control:** By using precise scheduling and priority control, real-time systems ensure that the PLC can execute high-precision control tasks.
- **System Stability:** With real-time operating systems, Siemens PLCs can ensure stable operation in complex and dynamic environments, avoiding system crashes caused by delays or errors.

Media-voltage Relay Protection

In **Siemens medium-voltage relay protection**, the role of **real-time systems** is critical, especially in the protection, fault detection, and rapid response of electrical systems.

- Timely Response and Fault Isolation
- High Reliability and Fault Tolerance
- Data Acquisition and Monitoring
- Fault Diagnosis and Optimization

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02 What is real-time?

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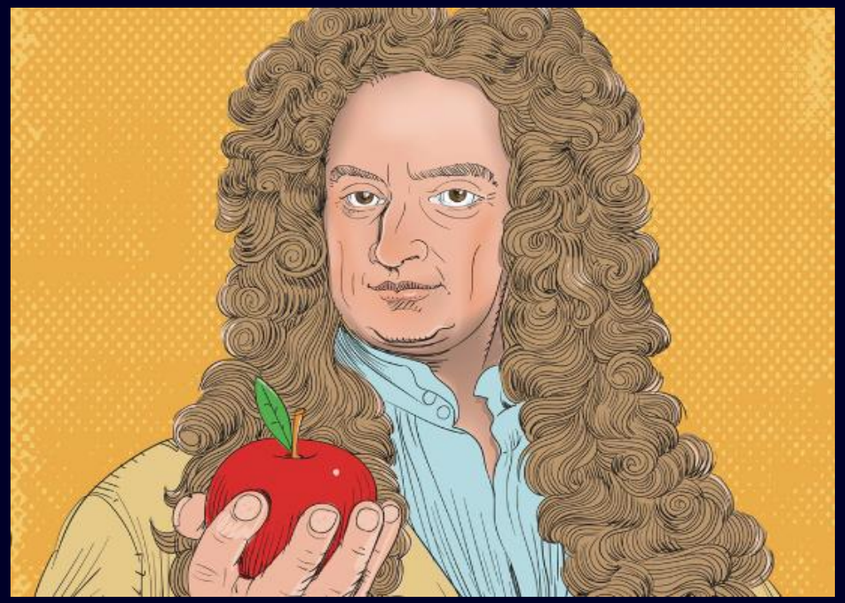
02 What is Real-time? – A Definition

In a Real-Time System the correctness of the system behavior depends not only the logical results of the computations, but also on the physical instant at which these results are produced.

- Physical instant refers to an extremely short period of time in which a physical event occurs or a state is observed.
- **Real-time** does not necessarily equate to high speed or high performance. Instead, it is about **time precision** — the ability of a system to respond and execute tasks within a strictly defined time frame, meeting deadlines with accuracy.

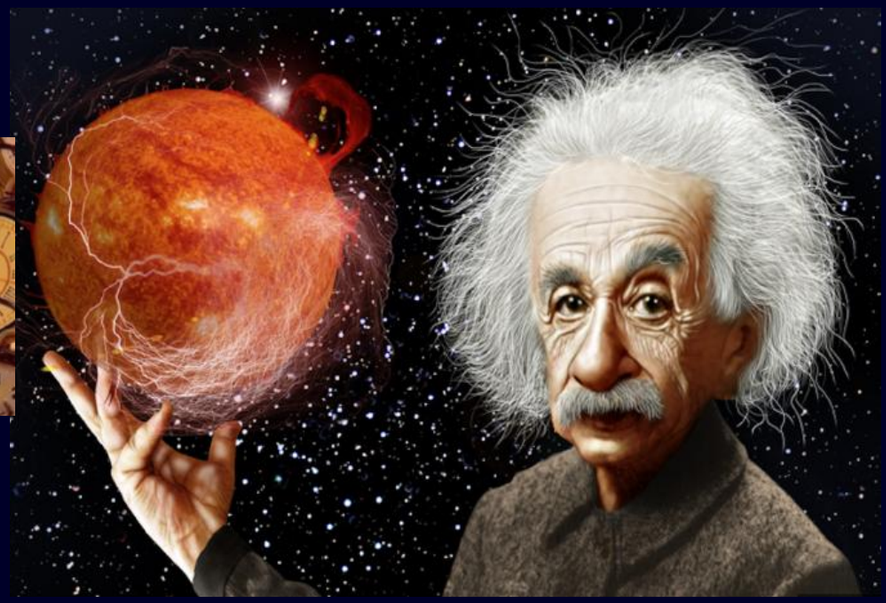
Real-time systems can be divided into two categories:
Hard Real-time: Missing a deadline in hard real-time systems can result in catastrophic failure (e.g., life-support systems, flight control).
Soft Real-time: Missing a deadline may degrade system performance but doesn't necessarily cause failure (e.g., video streaming, online gaming).

02 Run Tasks from Non-Real-time to Real-time? – Physics from Newton to Einstein



Matter, time and space are not related.

Non-Real-time
pure computational correctness



Matter, time and space are related.

Real-time
Adherence to expected operating times in terms of timing and reaction times

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02 Why Tasks Runs on Operating System?

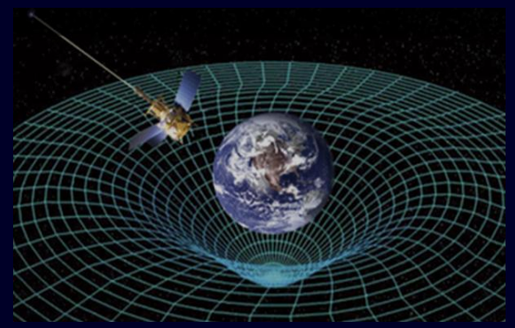
The main purpose of introducing the operating system is to enable programs to be executed concurrently and to describe the dynamic execution process of the program.

Life is so short, do more meaningful things.

Non-Real-time Operating System

Windows
By Microsoft

Linux
Open Source



Real-time Operating System

VXWorks
By Wind River

Xenomai
Open Source

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03 Real-time Operating Systems in General

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03 Real-time Operating System (RTOS) – A Definition

RTOS are specialized operating systems designed to process data and respond to inputs within strict time constraints, making them crucial for applications where timing is critical.

Real-time operating systems are event-driven and preemptive, meaning the OS can monitor the relevant priority of competing tasks, and make changes to the task priority. Event-driven systems switch between tasks based on their priorities, while time-sharing systems switch the task based on clock interrupts.

03 How to Develop a Real-Time Operating System

Newtonian mechanical vs Einstein’s Theory of Relativity

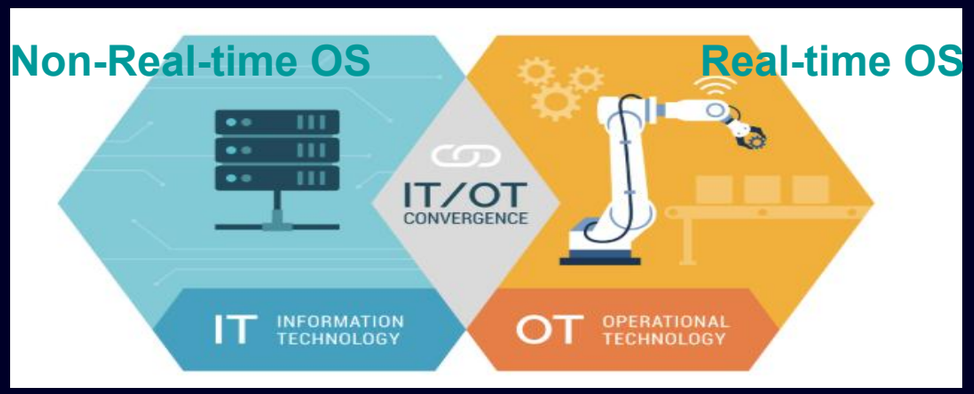
The theory of relativity mainly explains that it is applied in physical scenarios at high speed or in microscopic environments. In our daily lives, there are very few scenarios where the theory of relativity can be used. In fact, Newton's classical mechanics still plays a role. Whether it is architecture, mechanics, optics or other fields, the basic formulas of Newtonian mechanics are used.

IT vs OT

From the perspective of functions and application scenarios, Non-Real-Time Operating Systems (Non-RTOS) mainly serve the IT (information technology) field, while Real-Time Operating Systems (RTOS) used more in the OT (Operational Technology) field.

IT actually has more business than OT.

Real-time Linux, such as Xenomai, is becoming a key technology for delivering OT-level real-time capabilities in traditional IT environments.



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04 Xenomai in Particular

Real-time capability is indeed a systemic issue that requires comprehensive consideration from three aspects: hardware, operating system, and application. This comprehensiveness ensures that the entire system can meet strict time constraints and maintain stability and reliability in actual operation.

History / facts:

- License: GPLv2 (kernel space), LGPL V2.1 for libraries
- Current lead maintainer Jan Kiszka (Siemens Technology)

Operating system:

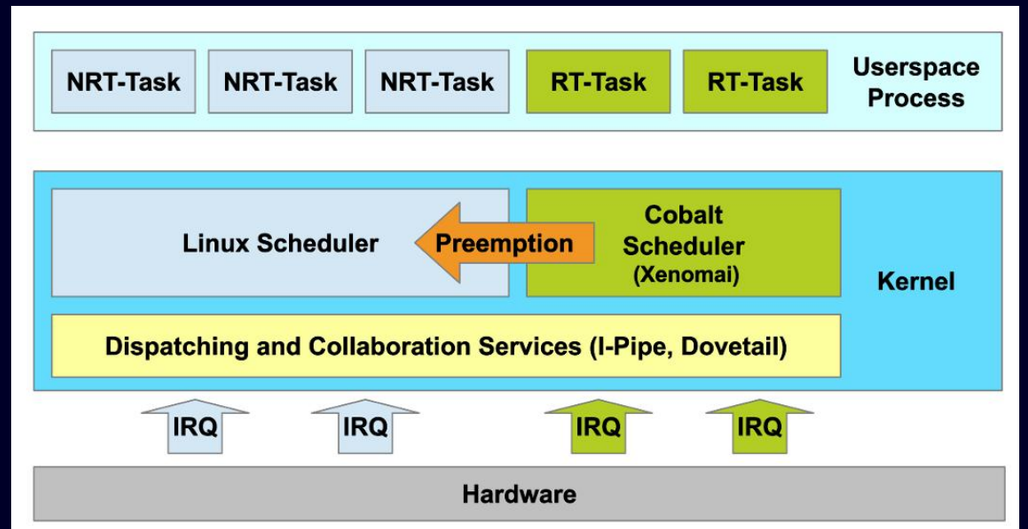
- Xenomai is a real-time development framework that enhances the Linux kernel by providing a dual-kernel architecture

Hardware Compatibility:

- Xenomai supports various architectures, including ARM (e.g., Raspberry Pi) and X86.

Jitter for (Applications):

- Designed for applications requiring consistent task execution, Xenomai significantly reduces jitter compared to standard Linux.



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05 Research higher latencies but still correct behavior

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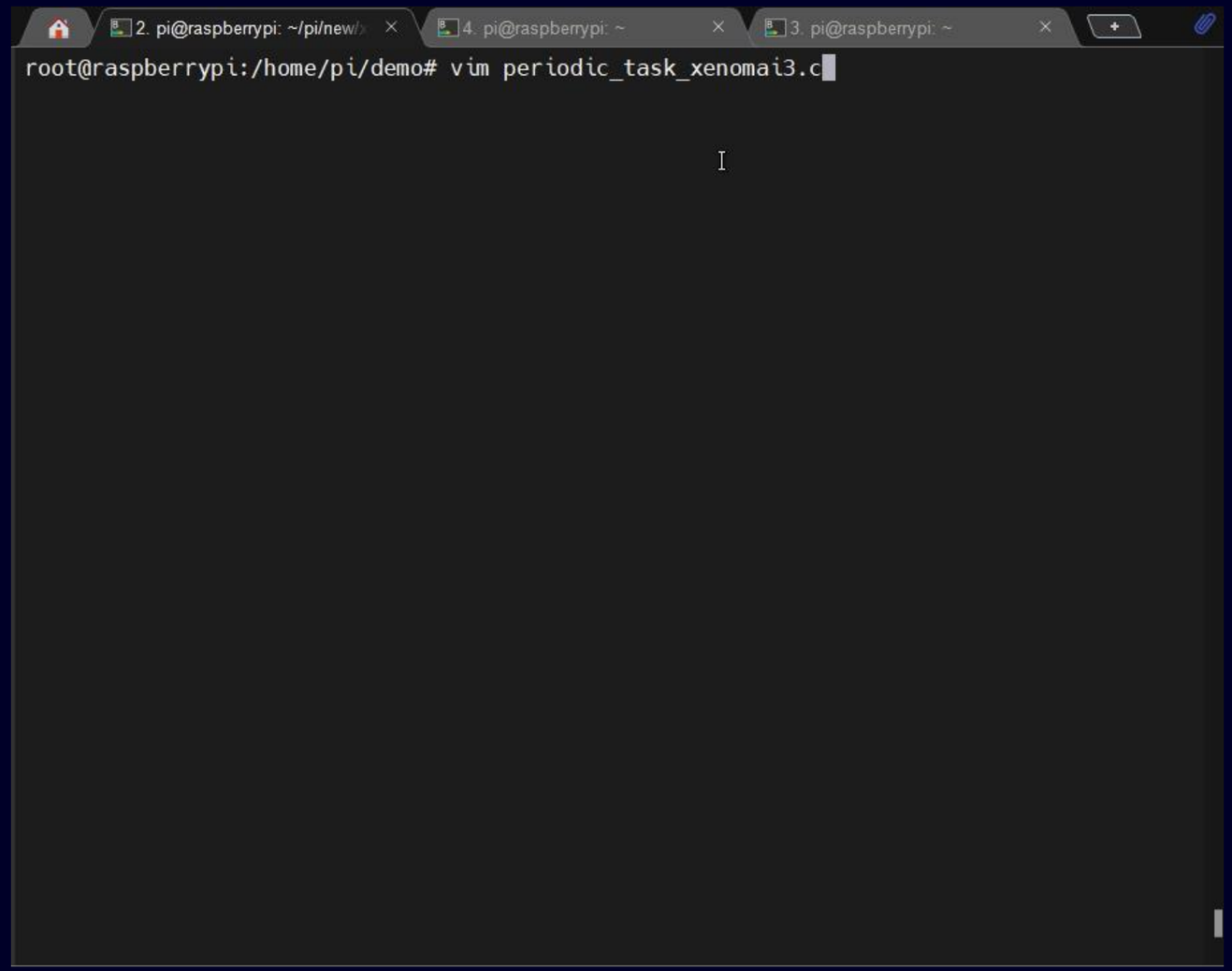
05 Demo



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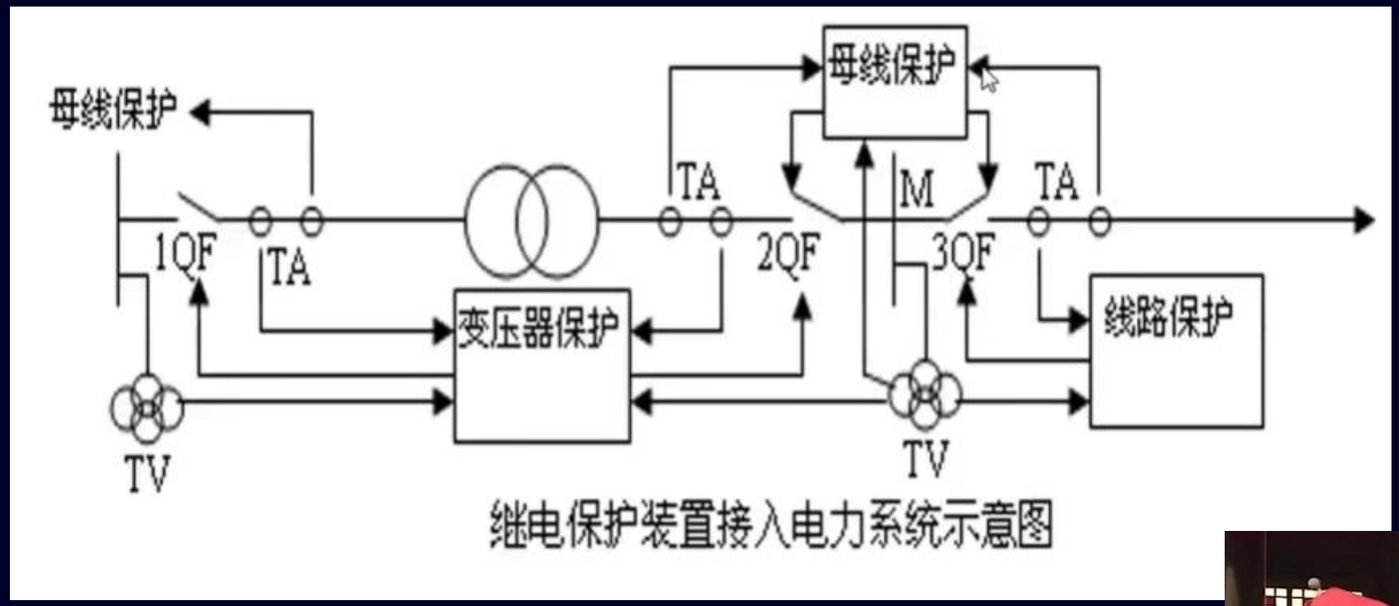
05 Media-voltage Relay Protection



Low Power Consumption: ARM processors are renowned for their high energy efficiency, with power consumption much lower than that of x86. This is especially important for medium-voltage protection devices, as these devices typically operate in unmanned substations or distribution network environments, where low power consumption reduces operating costs and minimizes the need for cooling systems.

A few years ago, we investigated using Xenomai to replace VxWorks, which could reduce costs, enhance customization capabilities, or take advantage of the open-source ecosystem.

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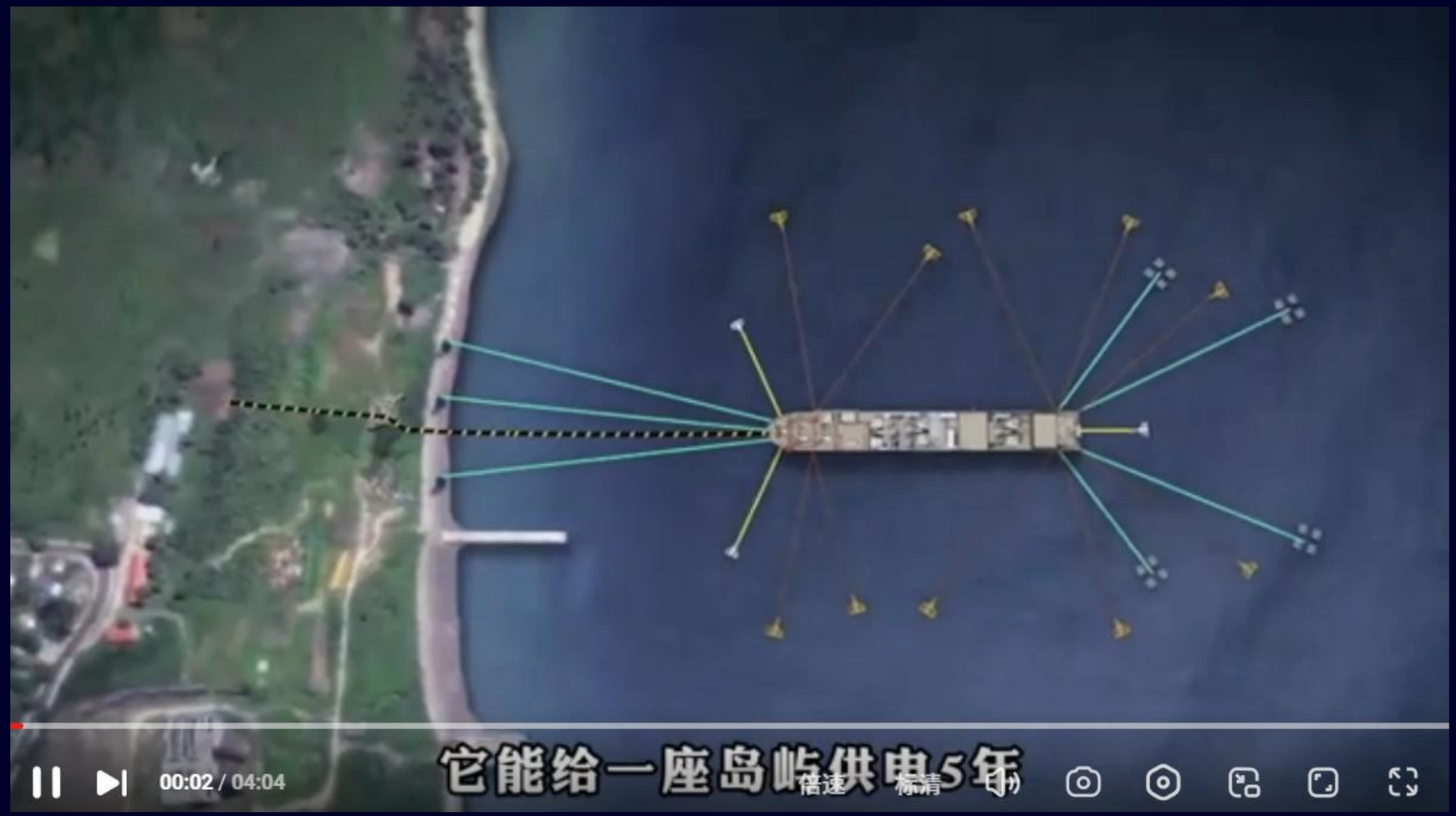
05 Media-voltage Relay Protection for Power Boat



- Current, it is still Vxworks.
- The Xenomai solution is being actively promoted and real-time assessment under stress is acceptable.

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Questions

Thank you!

Any questions?

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