Electronic Design

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# Lesser-Known High-Voltage Methods: From X-rays to Offshore Wind Farms

**HV techniques discussed include neutral grounding reactors for transmission lines, X-rays for flaw detection, and DC offshore wind farms.**

The International Electrotechnical Commission (IEC) definition of high voltage (HV) is any voltage from 1 to 100 kV for AC systems and 1.5 to 100 kV for DC systems. The term "HV" may also refer to voltages that can be as low as 50 V for some safety regulations, depending on the context. A good example is defined by the U.S. Occupational Safety and Health Administration (OSHA) guidelines: HV can be 600 V or higher.

Let's look at a few important high-voltage applications.

### Flaw Detection in High-Voltage Transmission Lines

There are three types of neutral grounding: solid grounding, ungrounding (floating), and low-resistance grounding.[4,7] Each method has its pros and cons, which led to the development of a fourth option known as neutral grounding, which uses the neutral grounding reactor (NGR).

Power is generated in three phases in an electrical power system, and is usually referred to as the A, B, and C phases. These three phases are symmetrical and balanced. In a three-phase system, a neutral point is created as a reference potential for those three phases.

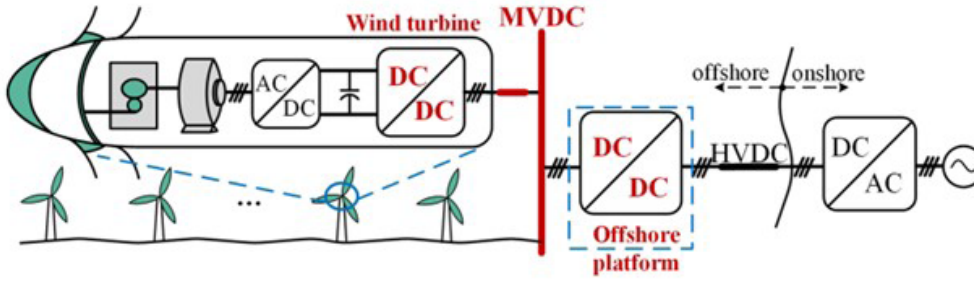
An NGR is a specialized electrical device that's typically used to control and limit ground fault currents, like a short circuit between a phase conductor and ground, within a power system via the introduction of a controlled impedance in the neutral path. This high-impedance device gets placed in series with the neutral line of the power transformer or generator.

For example, in ultra-high-voltage (UHV) AC substations, the NGR on a transmission line (typically referred to as neutral reactor) is a relatively small device in UHV AC primary equipment. The NGR function is to limit secondary arc current and recovery voltage of a transmission line, as well as overvoltage of open-phase standard frequency resonance. The operational safety of the neutral reactor has a very important role in UHV AC power systems.

### X-rays to Detect Line Defects

Due to the high material density of transmission lines, X-ray sources that have high energy and intensity are very much in demand. Power grid companies need to address this problem. One of the design schemes out there is for an X-ray generator with low radiation, low power consumption, and high voltage. The usefulness of a high-voltage X-ray detection technology to detect transmission line defects can be proven via experiment.

Power companies typically use a DC voltage method for testing, power maintenance, and fault detection in the pow-




**Shown is a schematic for an offshore all-DC wind power system. (Image courtesy of Reference 6)**

er distribution network. A DC withstand voltage can detect many of the defects on an AC or DC power cable; however, this method only uses a detection scheme after the occurrence of a fault. This method isn't able to troubleshoot hidden dangers or preventive maintenance.

Moreover, the DC withstand voltage method needs local high-voltage energization to properly test the cable performance. And this approach will likely cause damage to the cable coating.

Clamps on overhead transmission lines may very easily fall off. It will lead to a high danger level in the safety and operation of "three-span" UHV transmission lines that are placed over expressways, high-speed railways, and key transmission passage sections.

The machine patrol operation center of Guangdong power grid of China Southern Power Grid organized, in 2018, the live working team of Guangdong power transmission and Transformation Engineering Corporation. This group had the goal of achieving the first live, non-destructive, X-ray tests in China via the use of helicopters on transmission lines.

**DC Offshore Wind Farms**

All-DC offshore wind farm (OWF) power collection and transmission is a proposed scheme for long-distance, large-scale, offshore wind power development. Wind-turbine medium-voltage (MV) DC/DC is one of the key technologies *(see figure)*. [6]

Advantages of implementing an offshore all-DC offshore wind power solution include:

- A high-voltage DC transmission can adapt to the development trend of long-distance offshore wind power.
- A high-voltage DC-DC converter of an offshore platform can reduce its volume, weight, size, and cost.
- A wind-turbine MV DC-DC converter can adapt to the development trend of a large capacity and is able to reduce the volume and weight of the solution.
- A MVDC collection cable has low cost and low loss, and doesn't experience a capacitance rise effect problem.
- High efficiency.

The U.S.'s first large-scale offshore wind project is located off the coast of Massachusetts. This effort has started producing power for the first time in 2024. It began with five operational turbines and will eventually have 62 turbines as part of this project. The wind power project will produce enough electricity to power 400,000 homes.

The White House is setting a goal to deploy 30 GW of offshore wind by 2030. That's enough to power 10 million homes with clean energy; several more projects are now planned.

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