Resonant Link Technology

Offshore wind power for oil production platforms

What is Resonant Link technology?

Resonant Link technology is a **21st Century power conversion technology** which originates from the US Star Wars programme.

Resonant Link technology provides the following salient benefits to offshore wind (Summarized):

Very high-power density

All equipment, including high frequency transformers can be installed in the nacelle (AC-DC) and on the platform (DC-AC).

High efficiency

98% across the load range.

No harmonic or EMC filtering required

Direct AC-DC and DC-AC conversion with THDi <1-2%.

Complete fault-immune

Natural fault current limiting (AC and DC). All AC and DC faults are turned off in less than 1ms i.e., 1/20th of a cycle.

Modular system

AC-DC and DC-AC conversions based on parallel 2.5MW power modules.

Hot swappable

System can continue to operate during of replacement of power module.

Main benefits of Resonant Link converters: Part -I

Very high-power density (~5.5MW/cu.m.)

Resonant Link converters are ~40-70% smaller than conventional systems of the same MW rating). This results in more space in the nacelle (all AC-DC equipment per turbine integral to the nacelle).

Modular system

Construction for floating and fixed wind is currently 2.5MW per power module (e.g. a 15MW turbine utilises 6 x 2.5MW power modules).

Sinusoidal voltages and currents

Input and output (AC) around 1-2% THDi.

High conversion efficiency (~98%)

Due to soft-switching technology, the high efficiency of Resonant Link results in significant MW power savings over the life of the wind turbines/farms.

No harmonic or EMC filtering required

Direct power conversion with less than 1-2% total current harmonic distortion (THDi) at input and output of the converter is standard with Resonant Link.

Main benefits of Resonant Link converters: Part -II

Low du/dt (rate of change of voltage)

Resonant Link converters have a very low du/dt (<15V/µs at 4.16kV, for example), thus reducing generator insulation failure and cable problems.

No VAR compensation required

Resonant Link does not require any VAR control. Thereby size and weight of equipment in the nacelle are all minimized. Therefore, the overall costs and space are significantly reduced compared to conventional systems.

No derating

With conventional rectification, the generator often requires a 22% derating. This results in the generator being oversized. This is not required for Resonant Link systems.

Patented soft switching technology

‘Soft switching’ enables full converter power throughput from 6-20 kHz. High efficiency operation at medium voltage input and 150kVDC is based on IGBTs and silicon carbine switches. Resonant Link technology can convert significantly more power per cu.m. than conventional PWM systems.

Main benefits of Resonant Link converters: Part -III

Use of high frequency nanocrystalline transformers

Voltages, AC and DC, can be transformed without conventional transformers by utilizing integral nanocrystalline types operating at 6-20kHz. The diameter of transformer core is inversely proportional to the frequency. (For example, a 1MVA high frequency transformer version weighs around 45kg).

Multi-port operation

Multi-port operation yields instantaneous redirection of power flow.

Highly scalable

Scalable with time-interleaved module switching operation. Resonant Link technology can be applied to wind power and other applications up to 30MW per MV turbine.

No AC/DC breakers required!

Resonant Link converters offer complete fault-immune operation and natural fault current limiting (zero-current turn-off). No AC or DC circuit breakers are required for short circuit protection, only isolating switches.

Hot swappable

The 2.5MW modules (AC-DC and DC-AC) can be ‘hot swappable’ (i.e. full system does not have to be shut down to replace a faulty module) .

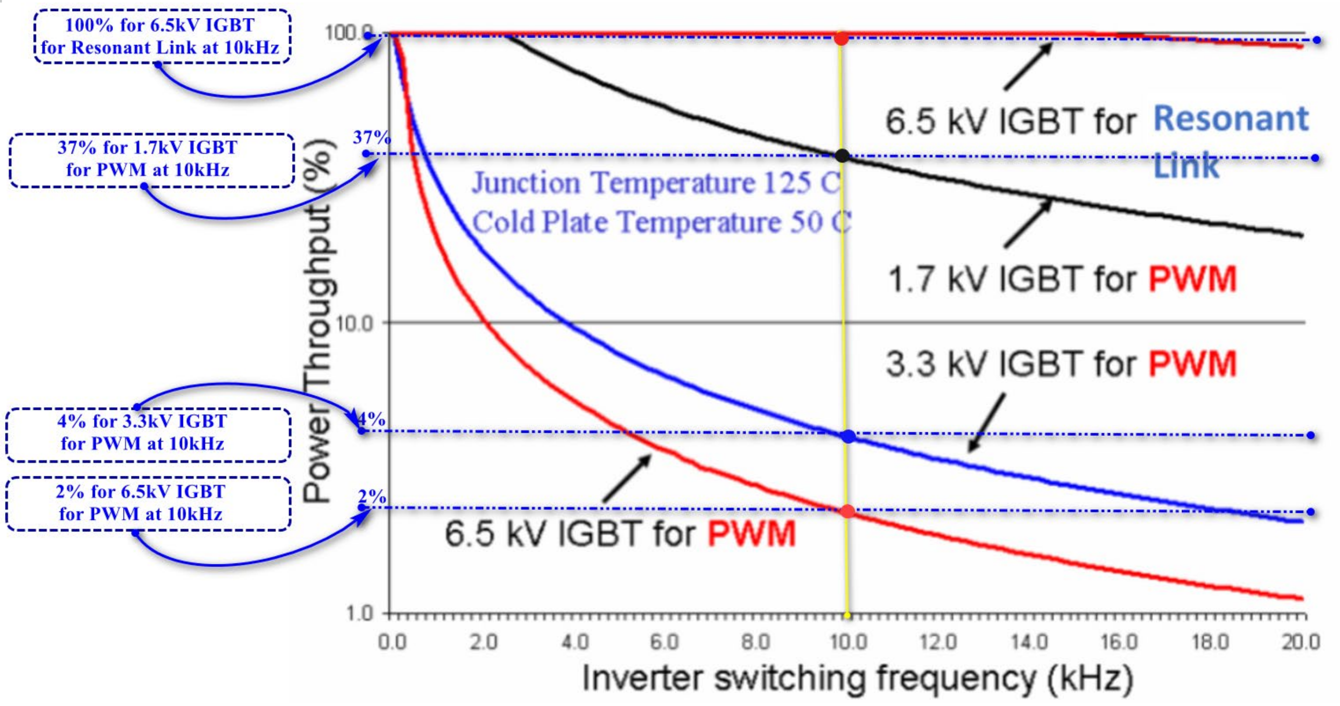
Soft switching – *The key to very high-power density*

Resonant Link is 'soft switching' (i.e., no switching losses).

As depicted in the illustration the Resonant Link 6.5kV IGBTs can operate at higher switching frequencies (6-20kHz), although as shown the optimum switching frequency is 10kHz.

The power throughput is much higher than conventional power conversion systems (~5.5MW cu.m at MV)

For similar conventional 6.5kV IGBTs power-throughput starts to decline on switching frequencies above 1kHz.

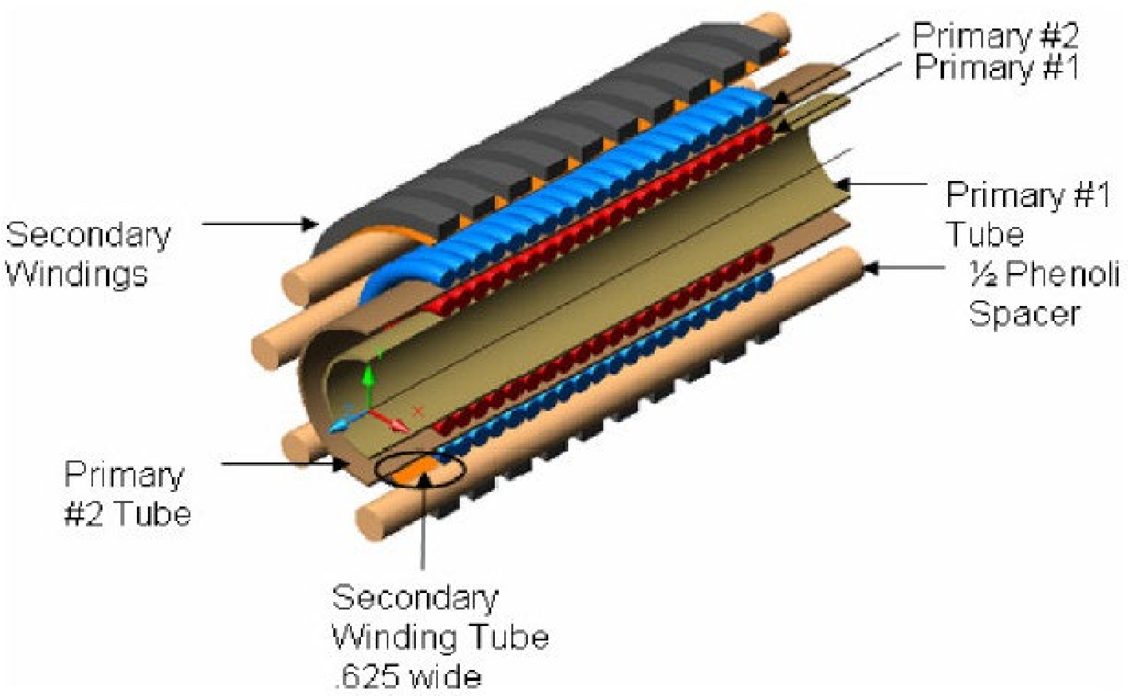


Nanocrystalline transformers

- These are a fundamental component in the Resonant Link system for MV/HVDC wind and other applications.
- As Resonant Link operates on high frequencies it can use much smaller transformer sizes.
- Nanocrystalline transformers offer best performance on higher frequencies.

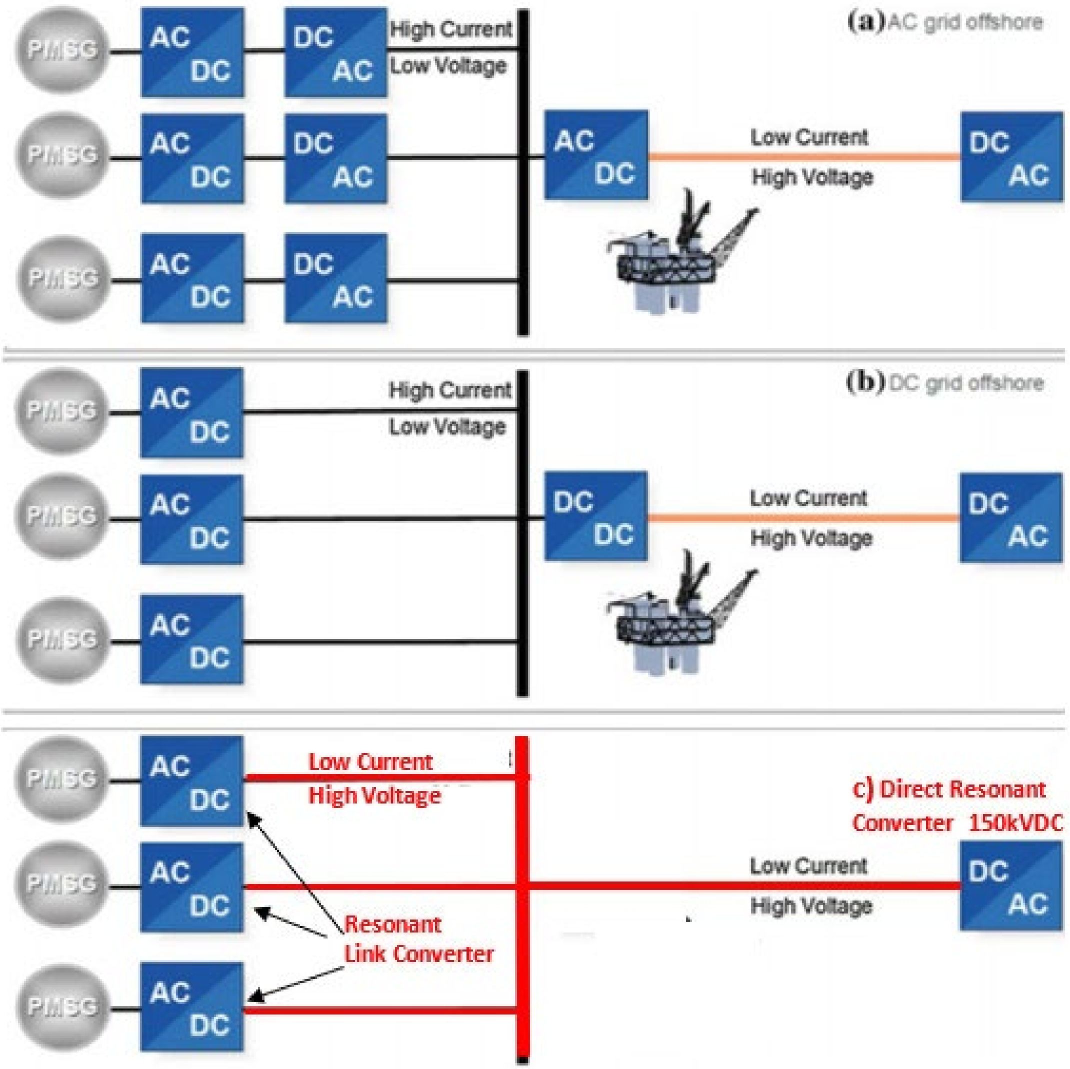
Note:

- Transformer core cross-section is inversely proportional to frequency, (i.e. higher frequency means smaller transformer size).
- A Resonant Link transformer can be smaller by a factor of 100 depending on the design parameters like switching frequency.



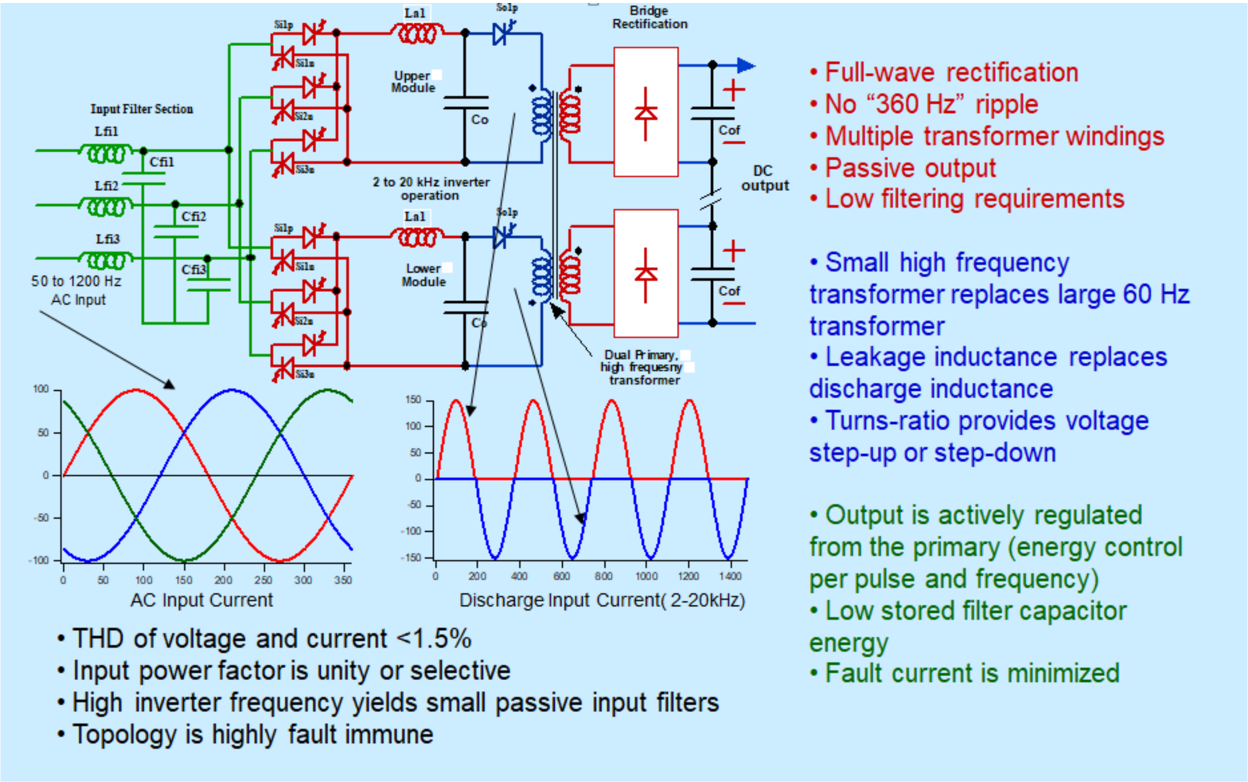
Example of high frequency nanocrystalline transformer

Three HVDC options for powering floating and floating wind farms



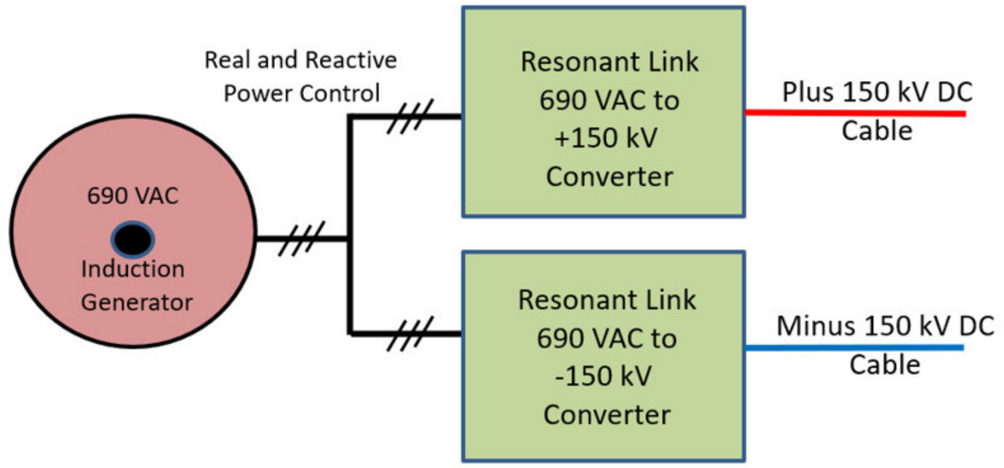
Generic Resonant Link AC-DC converter circuit with waveforms

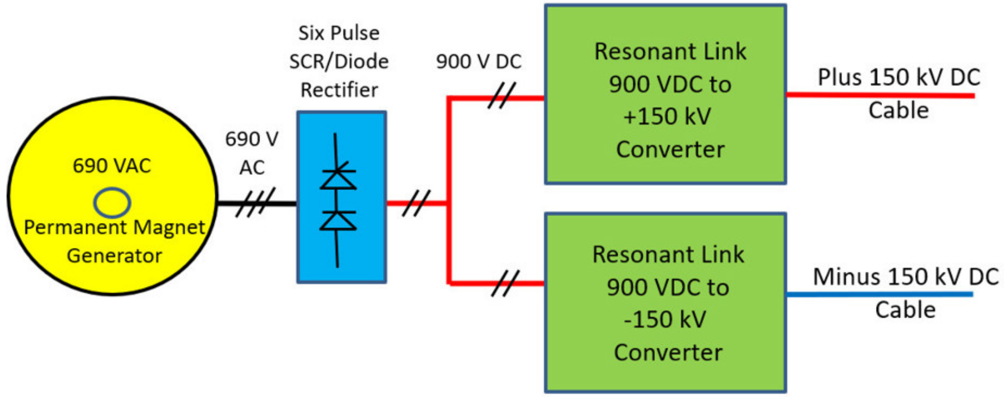
AC voltage (ideally to 3-4kV, 6.5kV IGBTs and +/-150kVDC transmission voltage)



Options for permanent magnet and induction generators

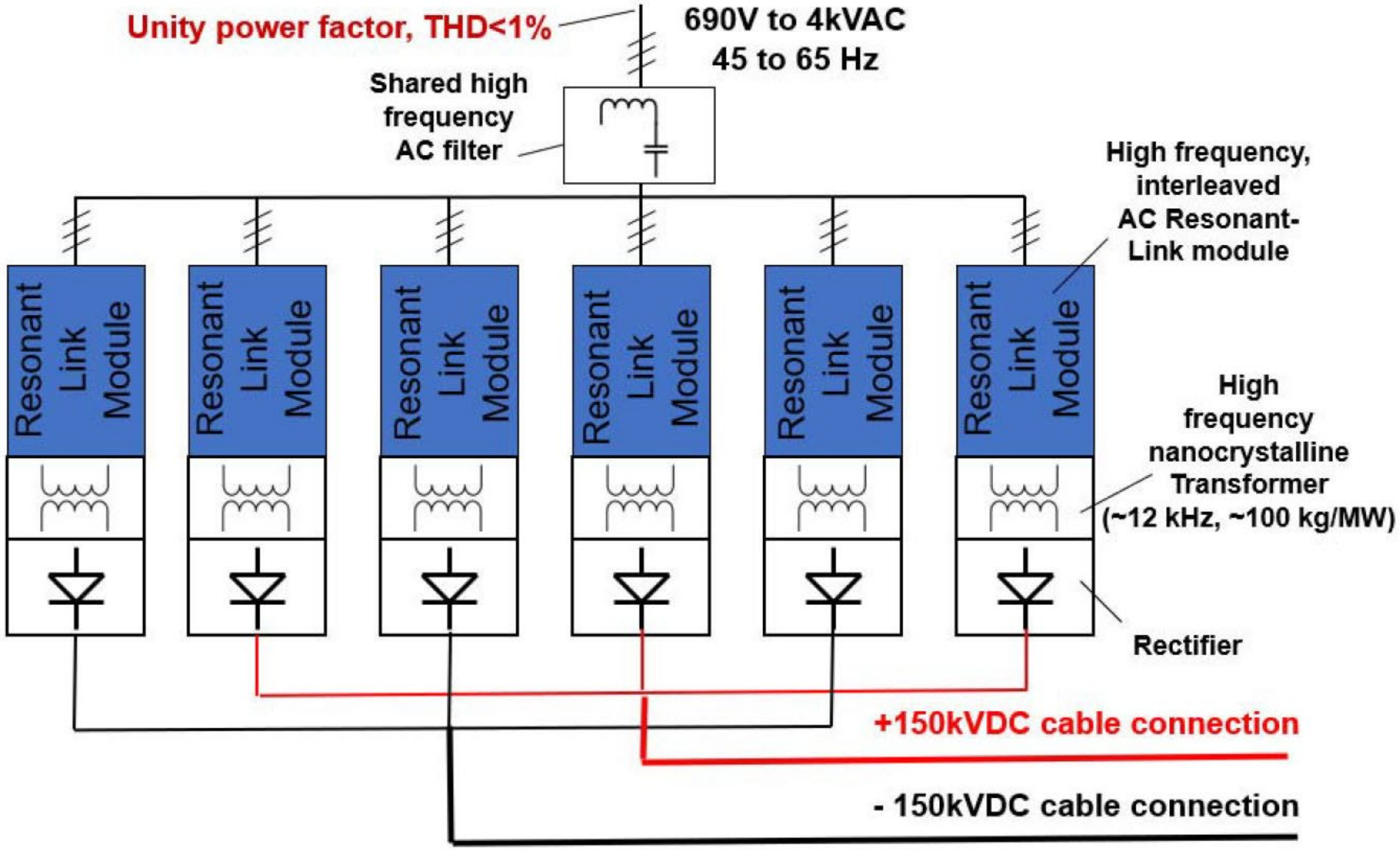
Presumes 690VAC but for compactness.
(3kV-4kV generator voltage recommended for optimisation of the IGBTs).



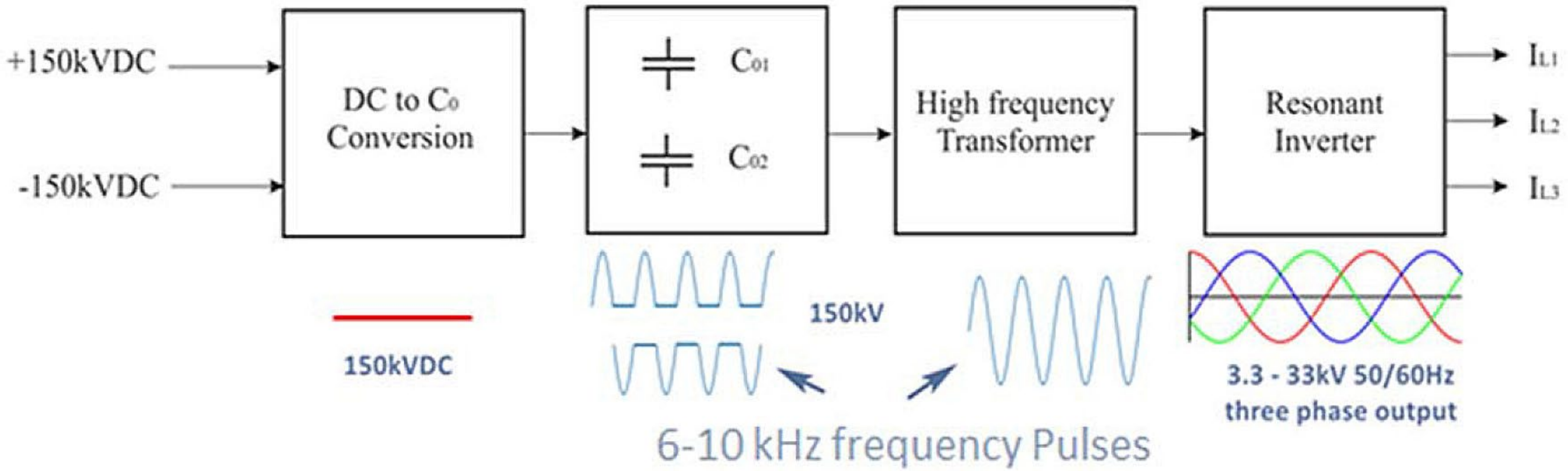


Schematic of 6 module 15MW AC-DC converter

Note : 150kVDC collector could be located subsea



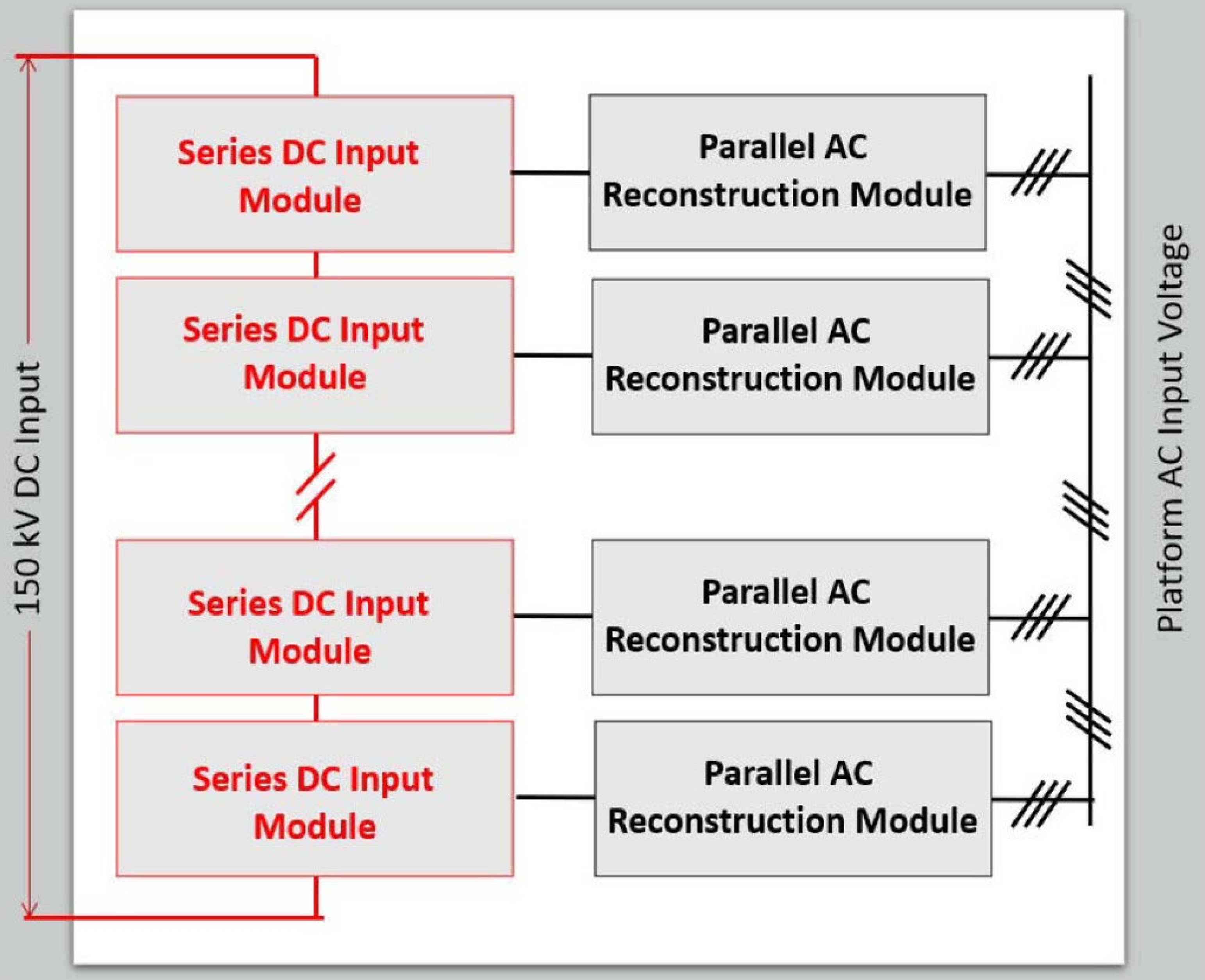
Note : All +150kV and -150kV cables are connected to the collector, which could be subsea



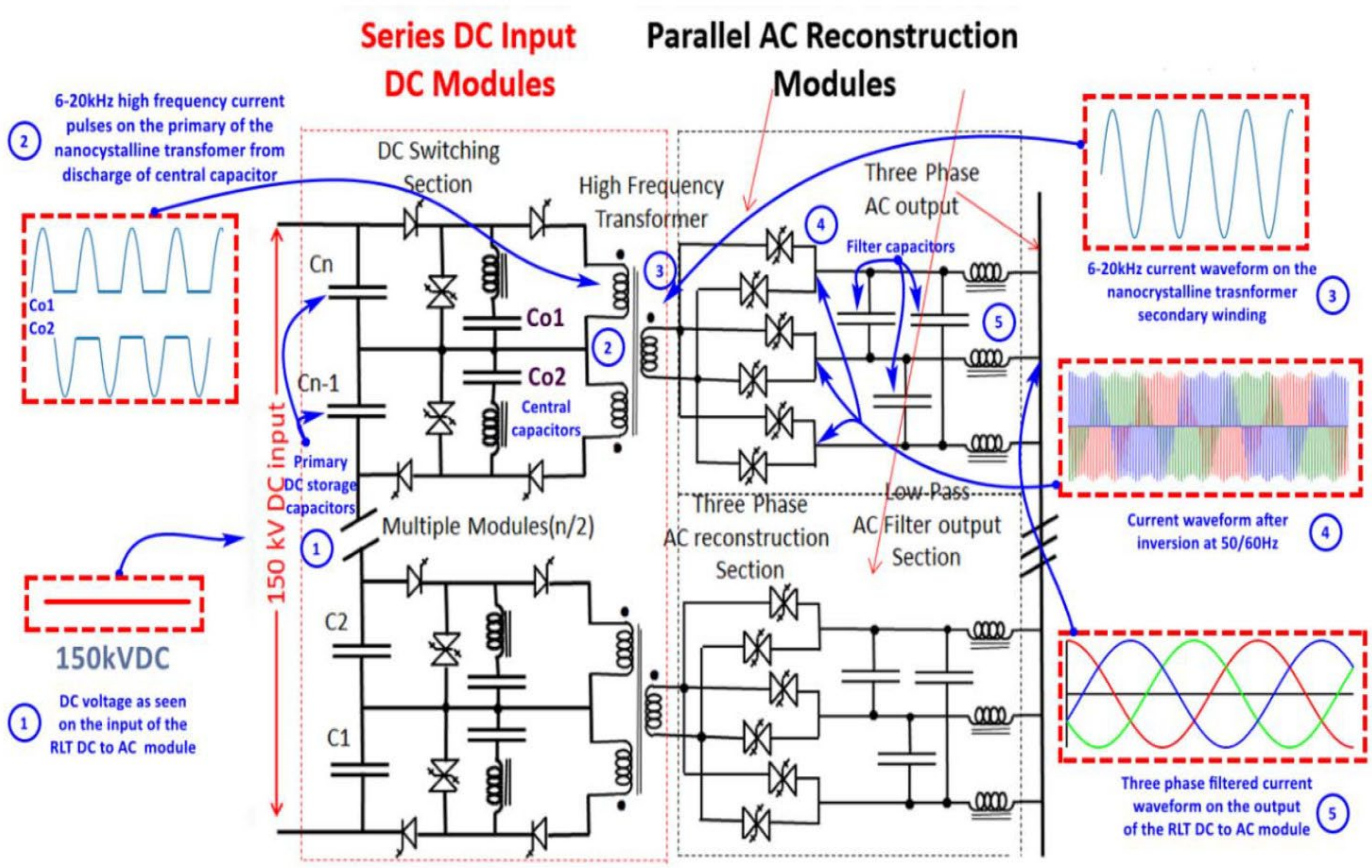
Block diagram depiction of the DC-AC conversion process from 150kVDC to required AC voltage on platform(s). Process is similar to AC-DC conversion but in reverse

Generic Modular DC-AC Converter

- Example of multi-module Resonant Link converter system (DC-AC) configuration for 150kVDC to three phase AC to platform.
- Input (DC-AC) modules in series. Output modules in parallel.
- AC voltage to be determined according to platform requirements.

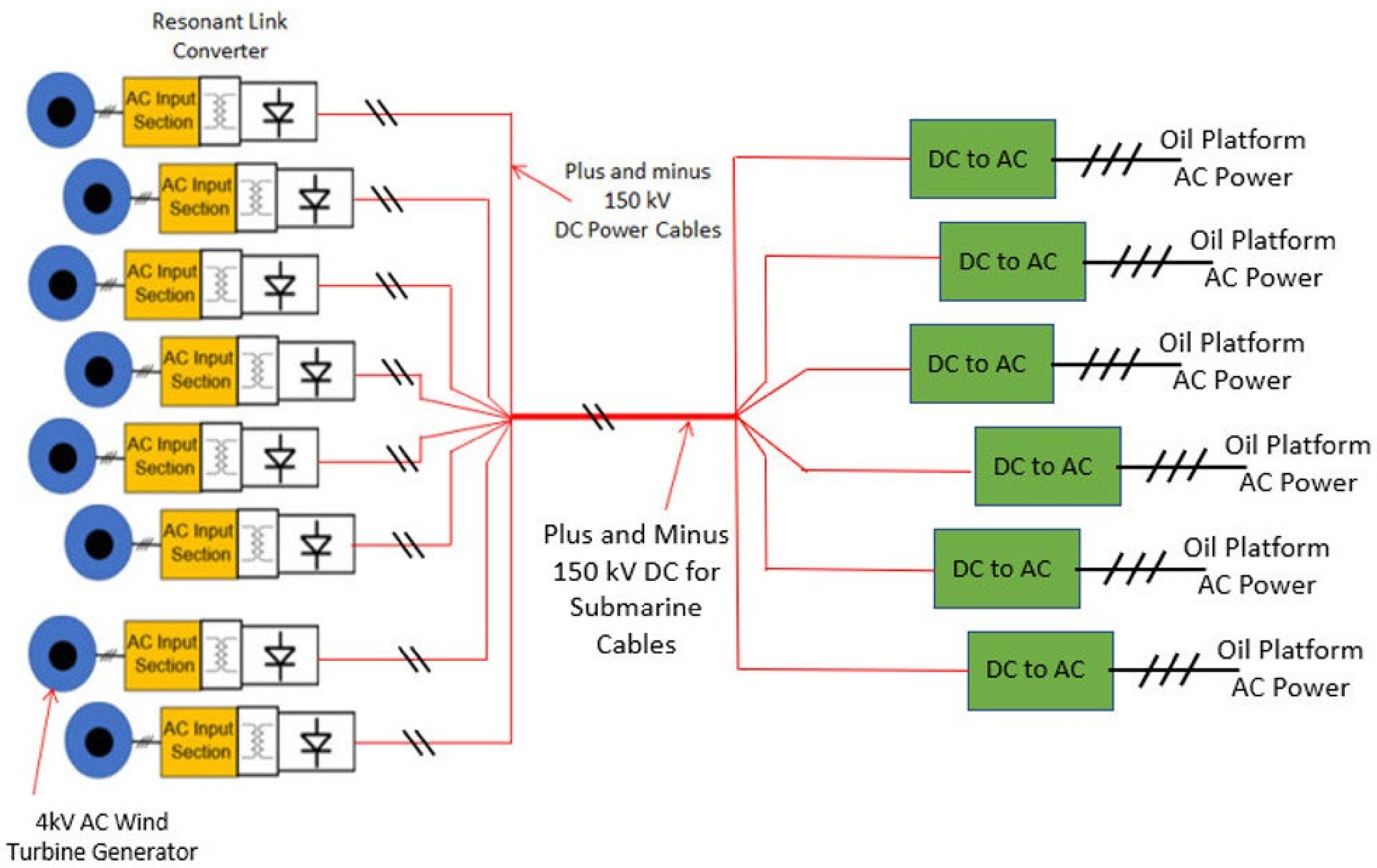


Schematic (with waveforms) of modular DC-AC converters installed on platforms



Note : 150kVDC and -150kVDC supplies require discrete modules

Overview of power transmission from wind farm to platform(s)



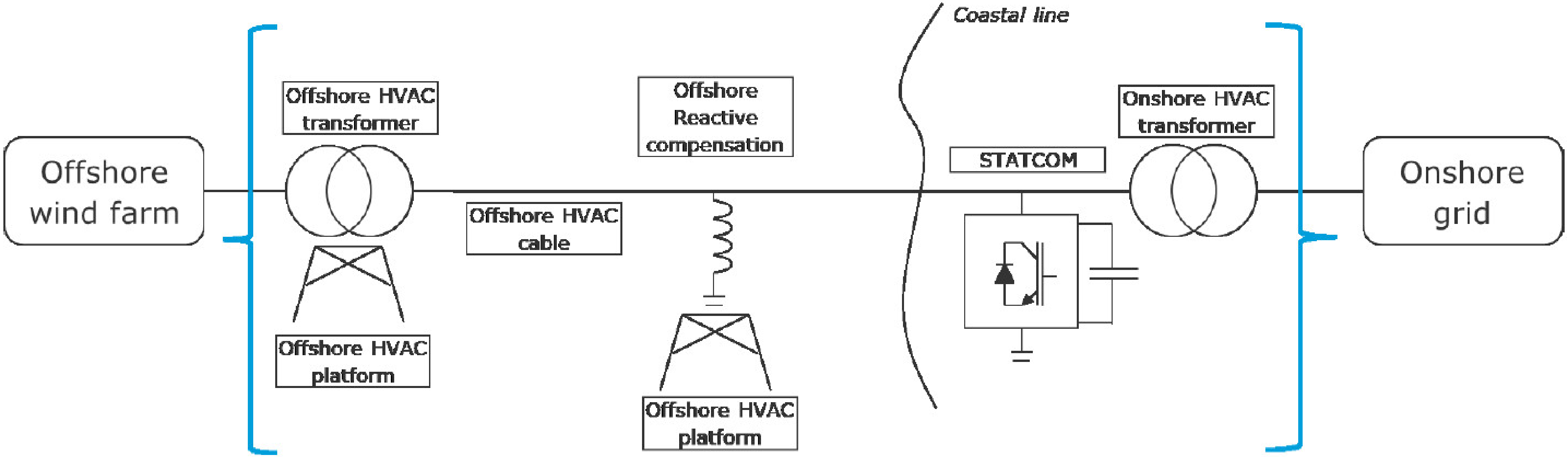
Overview of Resonant Link system from multiple windfarm 15MW AC generators via 150kVDC submarine cables to discrete platforms where AC voltage is reconstructed as per requirements.

Note : 4kV is optimum voltage for the IGBTs but any generator voltage can be utilised.

Comparison of Resonant Link technology for fixed or floating offshore wind with AC power transmission to shore or offshore platforms

With Resonant Link DC system, the high frequency transformer and rectifier would be housed inside each nacelle

- ❑ No Statcom (i.e .VAR control - reactive power compensation required).
- ❑ Offshore HVAC transformer platform not required (only DC bus common point connection, which could be subsea since all short circuit protection in integral to the Resonant Link system)

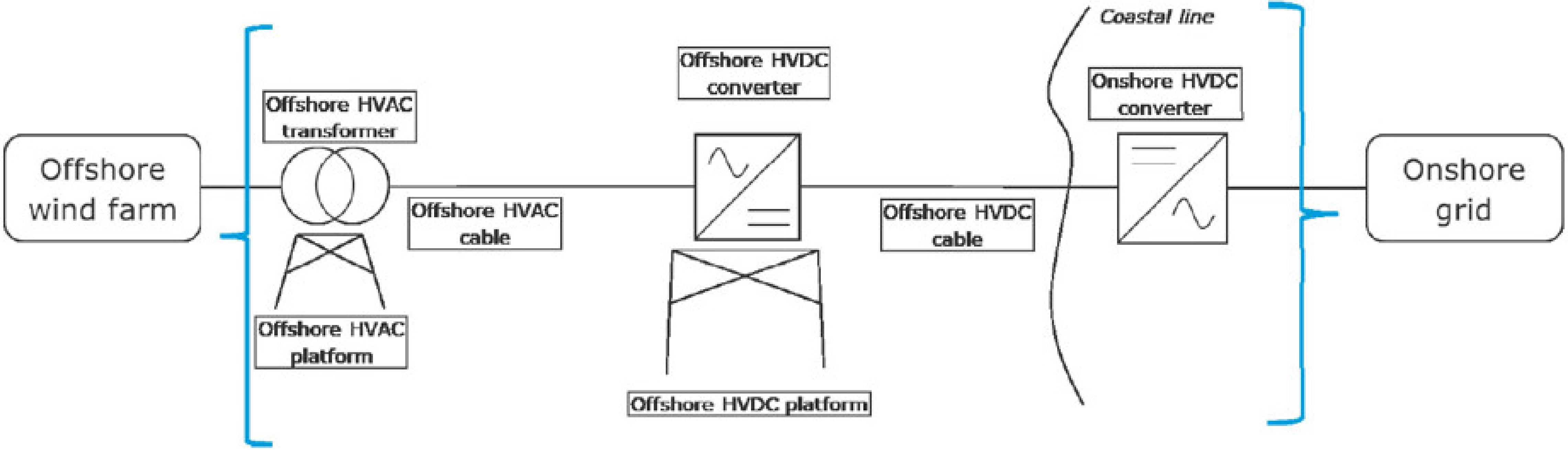


Example of AC system for short distance transmission.

Comparison of Resonant Link technology for fixed or floating offshore wind with DC power transmission to shore or offshore platforms

With Resonant Link the high frequency transformers and rectifiers would be housed in each nacelle

- ❑ No offshore HVAC platform required. Only a DC common bus gathering point.
- ❑ No offshore HVDC converters or harmonic filters required
- ❑ Resonant Link connect directly to platform via DC-AC converters and high frequency transformers



Typical conventional HVDC system for longer distances

Basic layout of Resonant Link direct DC connection from windfarm to platforms

- Each turbine nacelle would house the high frequency transformer and rectifier for 150kVDC.
- All HVDC would "gathered" at common point (possibly subsea).
- DC-AC inversion would take place on each platform.

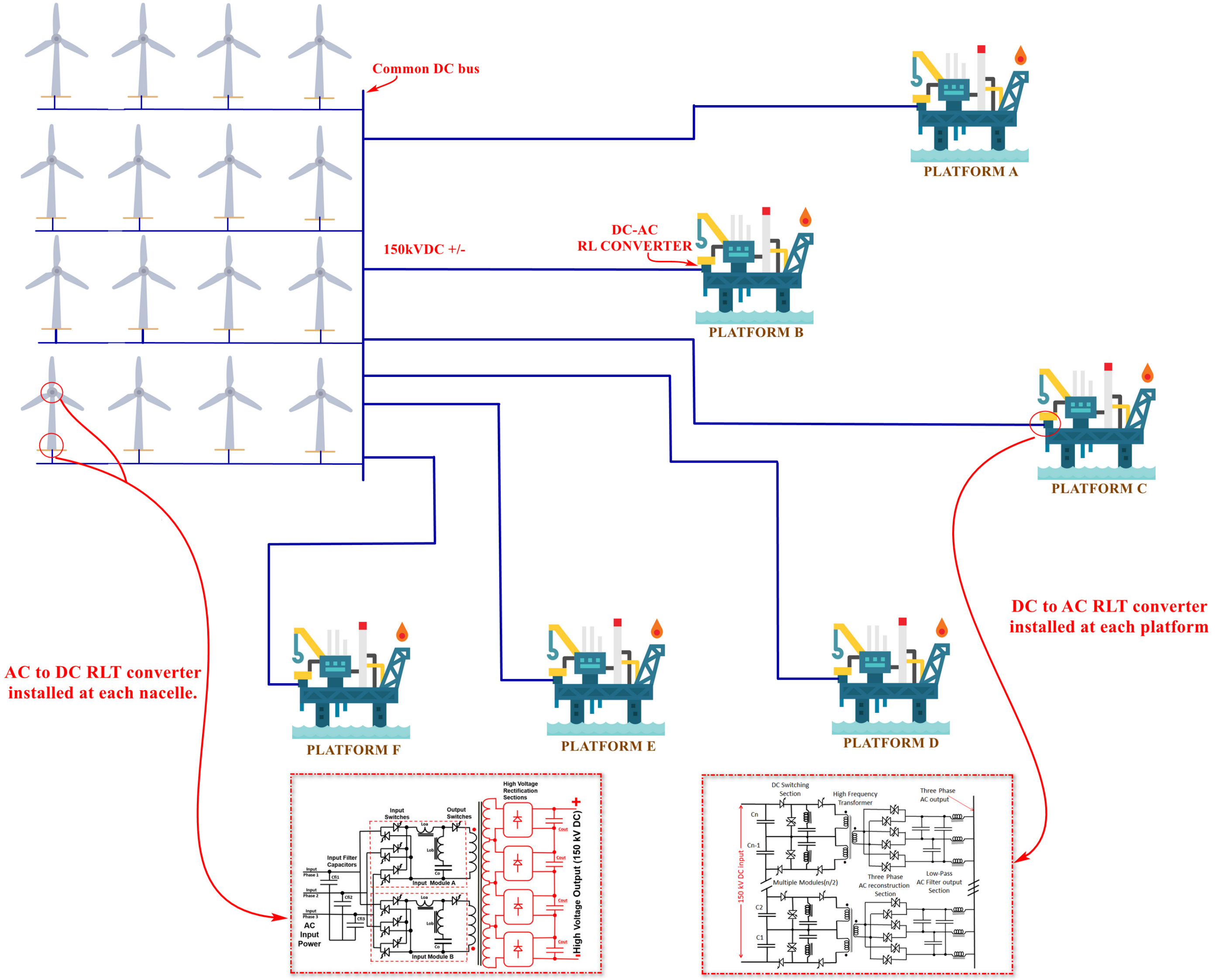


Illustration of a 6-platform oilfield connected to wind farm via 150kVDC direct connections

Basic DC ring main connection from windfarm to platforms

- Each turbine would house the high frequency transformer and rectifier for 150kVDC.
- All HVDC would “gathered” at common point (possibly subsea).
- DC-AC inversion would take place on each platform
- Higher security of supply with HVDC ring main (but perhaps higher cost).

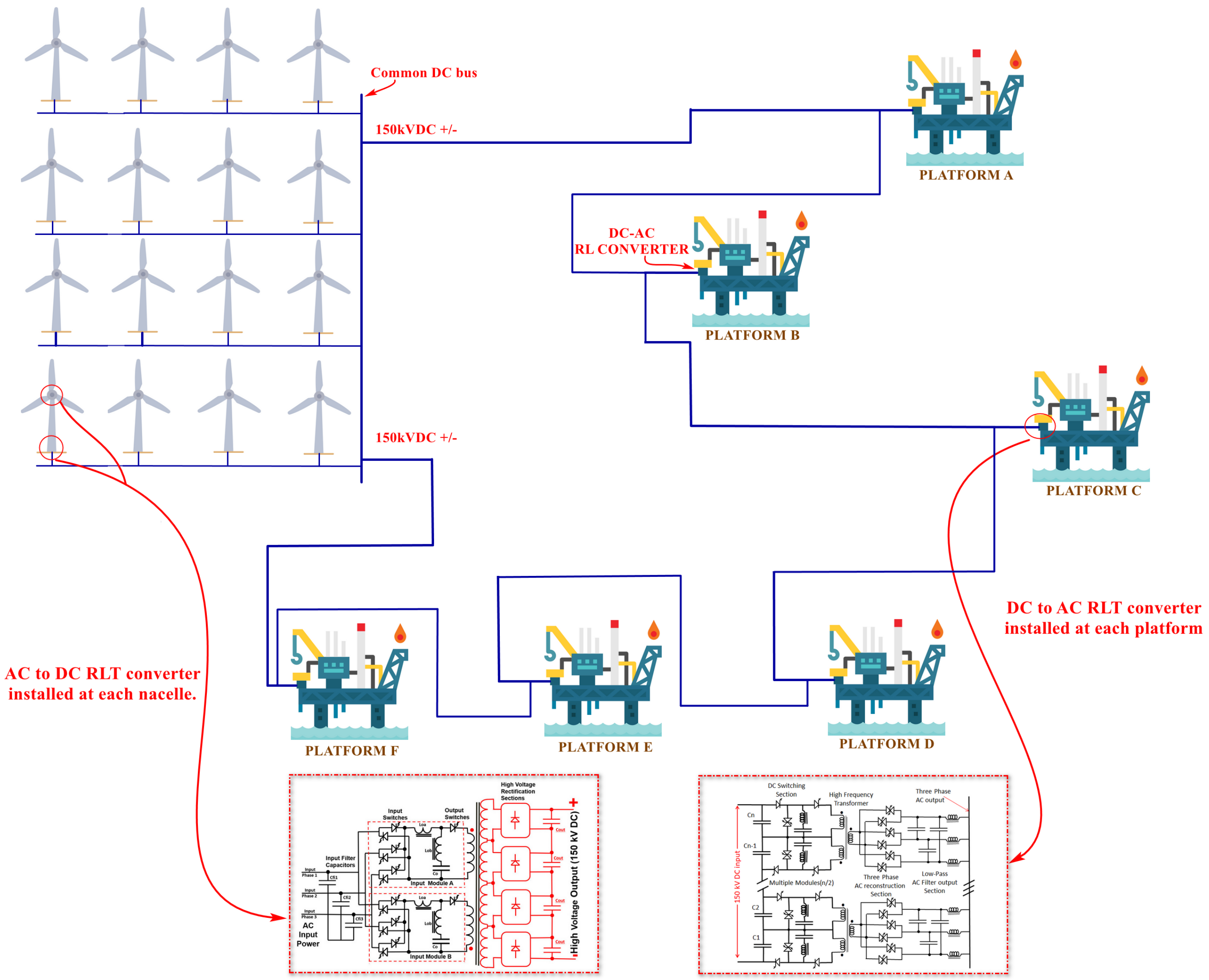
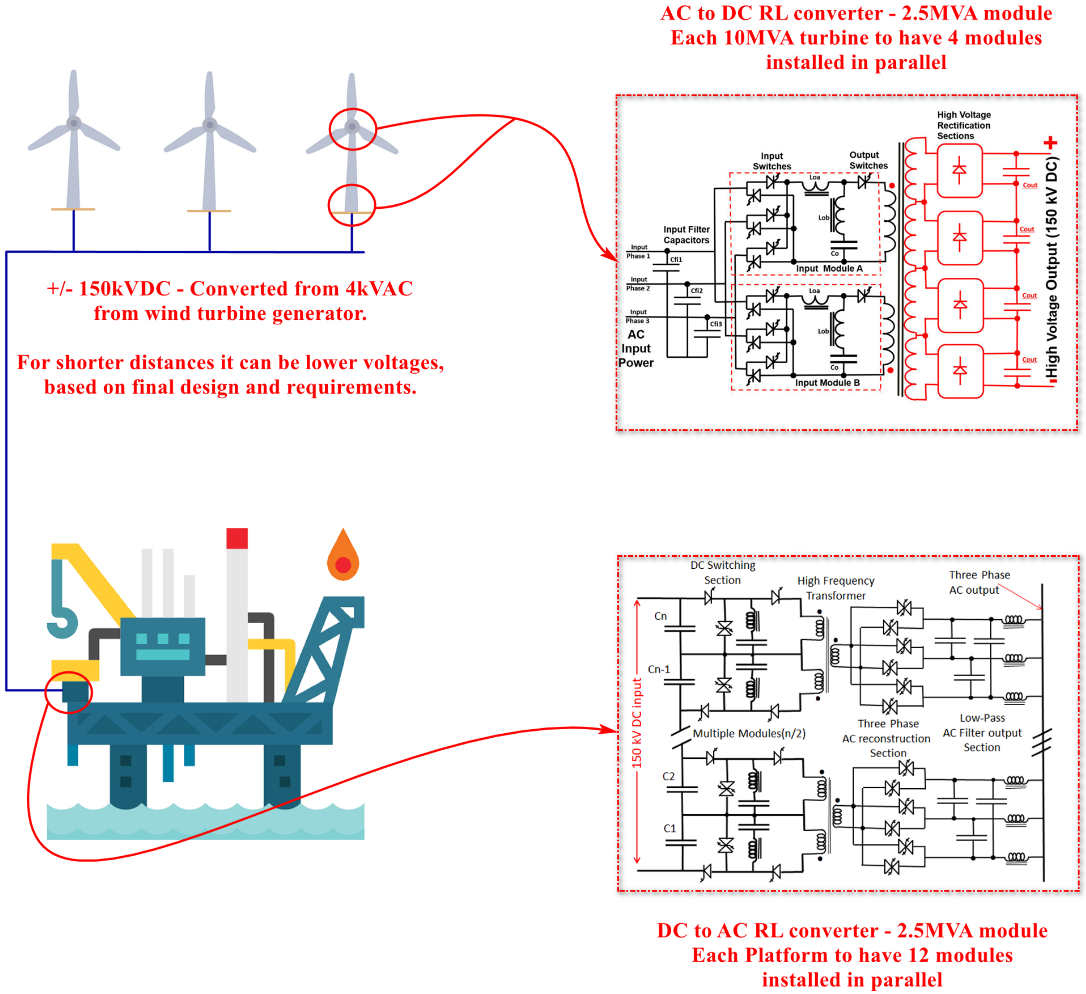


Illustration of a 6-platform oilfield connected via HVDC ring main using Resonant link power converters.

Basic Resonant Link converter connections from three turbines to a single platform

- Each turbine nacelle would house the high frequency transformer and rectifier for 150kVDC.
- All HVDC would “gathered” at common point (possibly onboard platform).
- DC-AC inversion would take place on each platform
- Higher security of supply with HVDC ring main (but perhaps higher cost).
- For short distances, the DC transmission voltage can be reduced based on final design and requirements.



Resonant Link based single platform powered by three wind turbines.

Conclusions - Main benefits for Resonant Link power transmission for floating/fixed wind power for platforms

Very high-power density

All equipment, including high frequency transformers can be installed in the nacelle (AC-DC) and on the platform (DC-AC).

High efficiency

98% across the load range.

No harmonic or EMC filtering required

Direct AC-DC and DC-AC conversion with THDi <1-2%.

Complete fault-immune

Natural fault current limiting (AC and DC). All AC and DC faults are turned off in less than 1ms i.e., 1/20th of a cycle.

Modular system

AC-DC and DC-AC conversions based on parallel 2.5MW-3.0MW power modules (depending on generator voltage) .

Hot swappable

System can continue to operate during of replacement of power modules.

RESONANT LINK TECHNOLOGY

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