

### Abstract

- High-voltage low-frequency ac (LFAC) transmission has been recently proposed for connection of distant offshore wind farms. In LFAC systems, an intermediate frequency level is used, which is created using a cyclo-converter that lowers the grid frequency to a smaller value, typically to one third its value.
- In general, the main advantage of the LFAC technology is the increase of power capacity and transmission distance for a given submarine cable compared to 50-Hz or 60-Hz HVAC.
- This leads to substantial cost savings due to the reduction in cabling requirements (i.e., less lines in parallel for a desired power level) and the use of normal ac breakers for protection.



Figure 1: SuperGrid Phase 1

### LFAC Fundamentals

$$P_{\max} = \frac{V^2}{X} = \frac{V^2}{2\pi \cdot fL} \quad \Delta V\% = \frac{QX}{V^2} \times 100 = \frac{2\pi \cdot fLQ}{V^2} \times 100$$

X will decrease to 1/3, when frequency is 50/3Hz.

Therefore:  $P_{\max}$  will increase to 3 times

$\Delta V\%$  will decrease to 1/3

Distance (miles)	Capability of Power Transmission (MW)										
	10	30	50	70	90	100	120	140	160	180	200
Transfer Capability (MW) at 60Hz	180.3	82.8	57.54	44.17	36.78	34.31	30.56	27.98	26.19	24.84	23.38
Transfer Capability (MW) at 20Hz	225.3	141.3	106.1	86.28	73.49	68.29	60.19	54.27	49.22	45.21	41.96

Figure 2. Maximum transmission capacity at 76kV

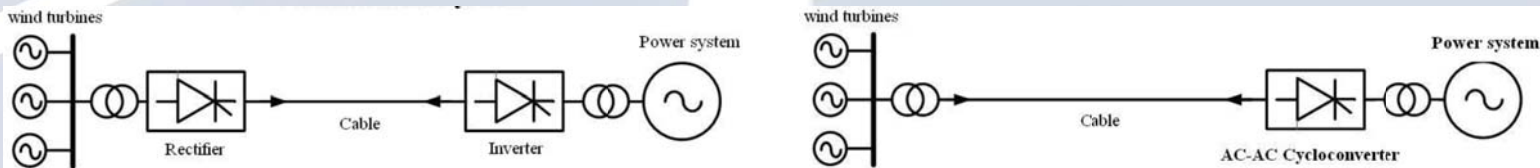


Figure 3. HVDC versus LFAC transmission

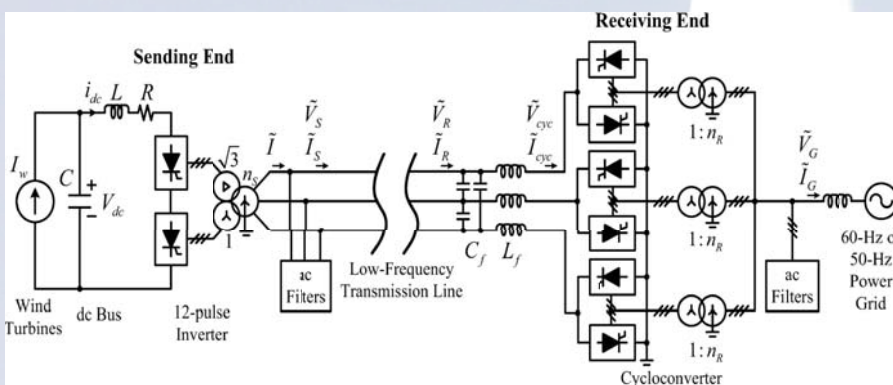


Figure 4. Configuration of LFAC transmission systems and dc electrical collector at the wind farm [1].

### LFAC Advantages:

- The cycloconverter can be used as the centralised control of the wind farm to provide dynamic voltage and frequency support and efficient fault management
- Reduce cost and weight of wind power unit
- Omit offshore converter
- Simplify offshore maintenance task
- Prolong the undersea cable lifespan

### LFAC issues:

- **Reliability of power electronics**
- **Increase in size of components, e.g. transformer**
- **Supply chain issues**

### Conclusions

- LFAC can improve the transmission capability of submarine power cables.
- Supply chain issues must be resolved.
- An informed comparison among HVAC, HVDC and LFAC should include investment and operating costs, and performance under power system transient.
- Is there a challenge for LFAC to form wind farm clusters?

### References

- [1] Chen, H. et al., "Low-frequency AC transmission for offshore wind power" IEEE Transactions on Power Delivery, Vol. 28, No. 24, 2013.
- [2] Carbon Trust, Ecofys Report

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