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Low-Frequency Ac Transmission for Offshore Wind Power

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Abstract: *Presently days the measure of power created from wind has developed quickly. Offshore wind cultivate is right now observed as a promising answer for fulfill the developing interest for sustainable power source. The principle purposes behind the fast advancement of offshore wind farms incorporates much better wind assets and littler ecological impact. Be that as it may, the present condition of the offshore wind farms presents monetary difficulties altogether more prominent than inland. The reconciliation of offshore wind farms with the fundamental power framework is a noteworthy issue. The conceivable answers for transmitting power from wind farms are HVAC, Line commutated HVDC and voltage source based HVDC (VSCHVDC). In this paper Low Frequency AC (LFAC) transmission framework is utilized for interconnecting the offshore wind farms for enhancing the transmission ability and furthermore the dc gathering framework with arrangement associated wind turbines are utilized at the offshore to diminish the cabling necessity. Plan of framework parts and their control procedures are examined. Reenactments are performed utilizing MATLAB/SIMULINK to show the framework's execution.*

Keywords: High voltage AC (HVAC), high voltage DC (HVDC), permanent magnet synchronous generator (PMSG), thyristor converters, underwater power cables, wind farms.

I.INTRODUCTION

The expanding interest and progressive need of utilizing sustainable assets, for example, wind, sun powered and hydro vitality, have achieved solid requests for financial and specialized advancement and improvement. Particularly offshore wind farms are relied upon to speak to a critical segment without bounds electric age choice because of bigger space accessibility and better wind vitality potential in offshore areas. Specifically, both the interconnection and transmission of sustainable assets into synchronous framework frameworks have turned out to be promising themes to power engineers. For vigorous and solid transmission and interconnection of sustainable power source into focal framework exchanging frameworks have been utilized, Since exchanging frameworks can without much of a stretch allow magnificent controllability of electrical flags, for example, changing voltage and frequency levels, and power factors.

At present, high-voltage ac (HVAC) and high-voltage dc (HVDC) are notable advancements for transmission [1-3]. HVAC transmission is profitable on the grounds that it is to some degree easy to outline the insurance framework and to change voltage levels utilizing transformers. Be that as it may, the considerable charging current because of the high capacitance of submarine ac power cables lessens the active power transmission capacity and limits the transmission remove. Along these lines HVAC is embraced for moderately short underwater transmission separations. HVAC is connected for separations under 60km for offshore wind power transmission. Two classes of HVDC frameworks exist, contingent upon the sorts of power-electronic gadgets utilized: 1) line-commutated converter HVDC (LCC-HVDC) utilizing thyristors and 2) voltage-source converter HVDC (VSC-HVDC) utilizing selfcommutated gadgets, for instance, protected entryway bipolar transistors (IGBTs)[4]. The real preferred standpoint of HVDC innovation is that it forces successfully no restriction on transmission remove because of the nonappearance of reactive current in the transmission line. LCC-HVDC frameworks can transmit power up to 1GW with high unwavering quality [1]. LCCs expend reactive

power from the ac matrix and present low-arrange sounds, which brings about the necessity for assistant gear, for example, ac channels, static synchronous compensators and capacitor banks. Interestingly, VSCHVDC frameworks can freely direct active and reactive power traded with the coastal network and the offshore ac accumulation lattice [7]. The decreased effectiveness and cost of the converters are the drawbacks of VSCHVDC frameworks. Power levels and unwavering quality are lower than those of LCC-HVDC. HVDC is connected for separations more noteworthy than 100 km for offshore wind power transmission. Furthermore HVAC and HVDC, high-voltage low frequency ac (LFAC) transmission has been as of late proposed[8-9]. In LFAC frameworks, a middle of the road frequency level 16.66 or 20Hz is utilized, which is made by utilizing a cycloconverter, that lowers the lattice frequency to a littler esteem, typically to 33% its esteem. By and large, the primary favorable position of the LFAC innovation is the expansion of power capacity and transmission separate for a given submarine link contrasted with 50-Hz or 60-Hz HVAC.

This prompts generous cost investment funds because of the diminishment in cabling necessities (i.e. less lines in parallel for a required power level) and the utilization of ordinary ac breakers for assurance. In this paper, a novel LFAC transmission topology is dissected. The proposed framework varies from past work. Here the wind turbines are thought to be interconnected with a medium-voltage (MV) dc framework, conversely with current practice, where the utilization of MV ac accumulation lattices is standard[9]. DC gathering is turning into an achievable option with the improvement of financially savvy and dependable dc circuit breakers, and studies have demonstrated that it may be invaluable regarding ac accumulation as far as effectiveness and diminished generation costs[11]. The required dc voltage level can be worked by utilizing the arrangement association of wind turbines [12]. For instance, multi MW permanent-magnet synchronous generator (PMSG) with completely appraised power converters (Type-4 turbines) are generally utilized as a part of offshore wind plants[10]. By disposing of framework side inverters, a medium-voltage dc gathering framework can be shaped by interconnecting the redressed yield of the generators. The fundamental explanation behind utilizing a dc gathering framework with LFAC transmission is that the wind turbines would not should be upgraded to yield low-frequency ac power, which would prompt bigger, heavier, and costlier magnetic segments, for example, advance up transformers and generators. The proposed LFAC framework could be worked with financially accessible power framework parts, for example, the less than desirable end transformers and submarine ac cables intended for general power frequency. The stage move transformer utilized at the sending end could be a 60-Hz transformer de appraised by a factor of three, with the same evaluated current however just a single third of the first appraised voltage. Another favorable position of the proposed LFAC plot is its plausibility for multi terminal transmission, since the plan of multi terminal HVDC is confounded, yet the investigation of such an application isn't attempted in this. In outline, LFAC transmission could be an attractive specialized answer for medium-remove transmission i.e., 50 to 160km.

II. POWER SYSTEM DETAILS

The framework under examination comprises of a wind homestead of 50 wind turbines with each turbine's MVA-rating of 3.6MV A. The wind cultivate MVA-rating is in this way 180MV A. Turbines are furnished with enlistment generators and a back to-back full range voltage source converters (VSC) for variable speed operation. A few preferences of variable speed wind turbines with back-to-back full range voltage source converters (VSC) are: (a) Power streamlining, e.g. increasing more power yield at different wind paces and (b) Reducing mechanical loads due to slower turn and after that less cost on support. With this turbine structure of acceptance generator and back-to back full-extend converters, it is additionally conceivable to have autonomous variable speed for each wind turbines in the wind cultivate

contingent on the accessible wind at that specific wind turbine. For an extensive wind cultivate, the circulation of wind isn't uniform for all the wind turbines. A design of the wind turbine segments is introduced in figure 1 and talked about in detail in customary wind cultivate format is considered, where all turbines are associated with an AC authority organize at 33kV.

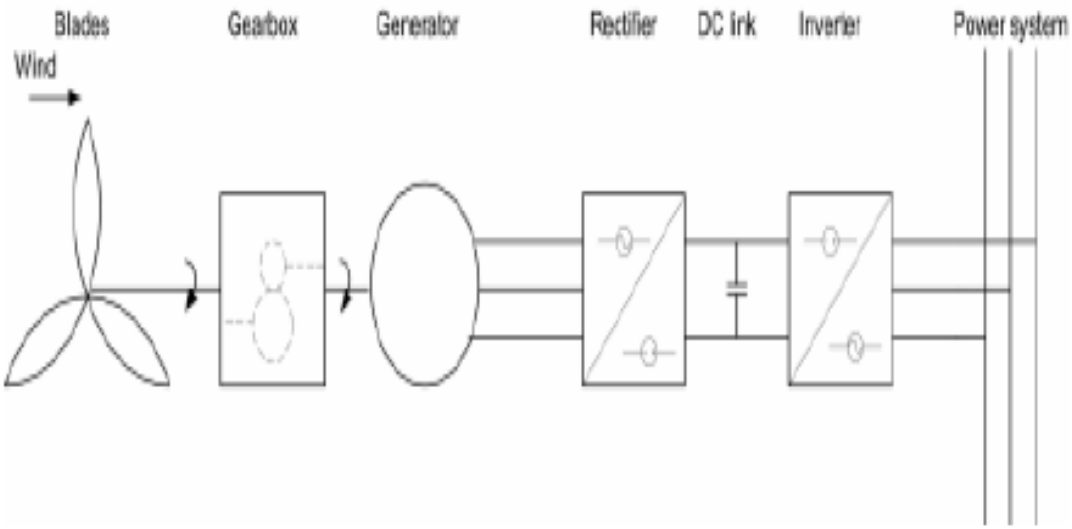

Fig. 1. Wind turbine components layout.

At the offshore stage, the gatherer arrange voltage is ventured up to 100kV with a recreation center transformer. The accumulation arrange cables are displayed utilizing a lumped comparable Π demonstrate. The transmission of power from the wind homestead to the ashore AC lattice/pcc is done by means of a HVDC interface, with the goal that a rectifier VSC is available at offshore stage and an inverter VSC exhibit ashore associates the wind ranch to the ashore transmission framework. The multilevel voltage source converters at each end are controlled in a way so all the power from the wind cultivate is transmitted to the lattice under ordinary working conditions. The subtle elements of the control methodology will follow in the coming areas. A 100km DC bipolar transmission is considered with two shafts at ±100kV. The schematic chart of the framework is introduced in figure 2.

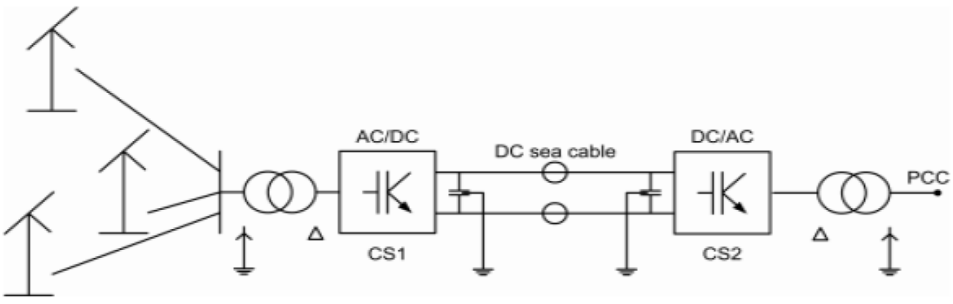

Fig. 2. Schematic connection of wind farm to the on land grid.

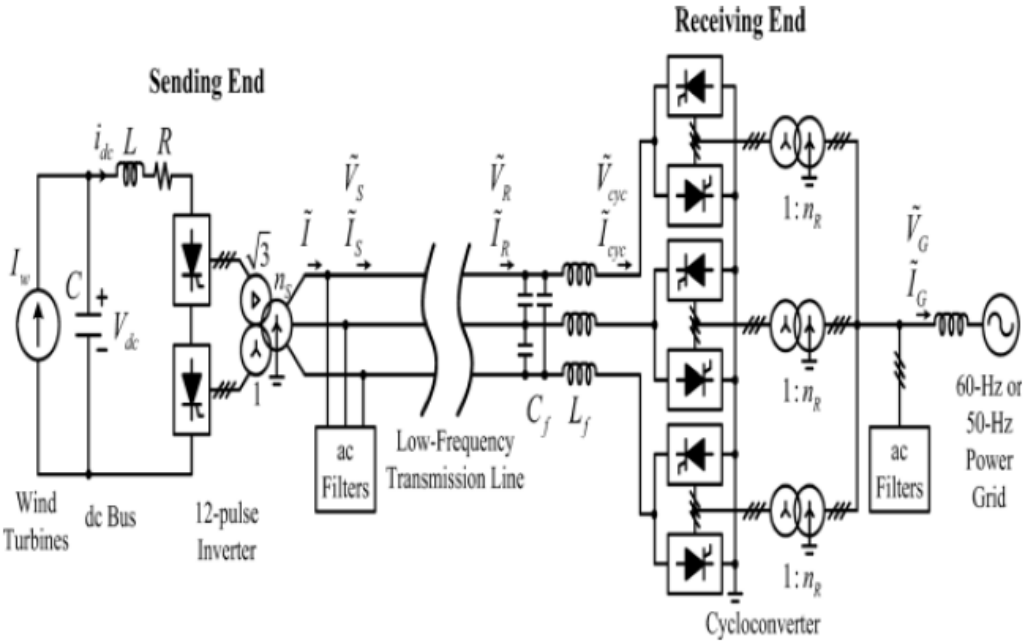

Fig 3: Configuration of the proposed LFAC transmission system.

SYSTEM CONFIGURATION

The proposed LFAC transmission framework is appeared in Fig. 3, expecting a 60-Hz fundamental lattice. At the sending end, a medium-voltage dc accumulation transport is framed by amending the ac yield power of arrangement associated wind turbines. A dc current source speaks to the aggregate power conveyed from the wind turbines. A dc/ac 12-beat thyristor-based inverter is utilized to change over dc power to low-frequency (20-Hz) ac power. It is associated with a three-winding transformer that raises the voltage to a higher level for transmission. AC channels are utilized to smother the eleventh, thirteenth, and higher-arrange current music, and to supply reactive power to the converter. A smoothing reactor is associated at the dc terminals of the inverter. At the less than desirable end, a three-stage connect (6-beat) cycloconverter is utilized to produce 20-Hz voltage. A channel is associated at the low-frequency side. At the network side, ac channels are utilized to stifle odd current sounds, and to supply reactive power to the cycloconverter. Basically, the operation of the LFAC transmission framework can be comprehended to continue as follows. To start with, the cycloconverter at the less than desirable end is activated, and the submarine power cables are stimulated by a 20-Hz voltage. Meanwhile, the dc accumulation transport at the sending end is charged utilizing power from the wind turbines. After the 20-Hz voltage and the dc transport voltage are set up, the 12-beat inverter at the sending end can synchronize with the 20-Hz voltage, and begins the transmission of power. As a general rule, more complex plans for framework startup would need to be concocted, construct by and by in light of this working standard.

A. Sending-End Control

The control structure for the sending-end inverter is appeared in Fig. 2. The controller manages the dc transport voltage by altering the voltage at the inverter terminals. The cosine wave crossing technique is connected to decide the terminating edge

$$\alpha_S = \arccos\left(\frac{V^*}{V_P}\right) \qquad (1)$$

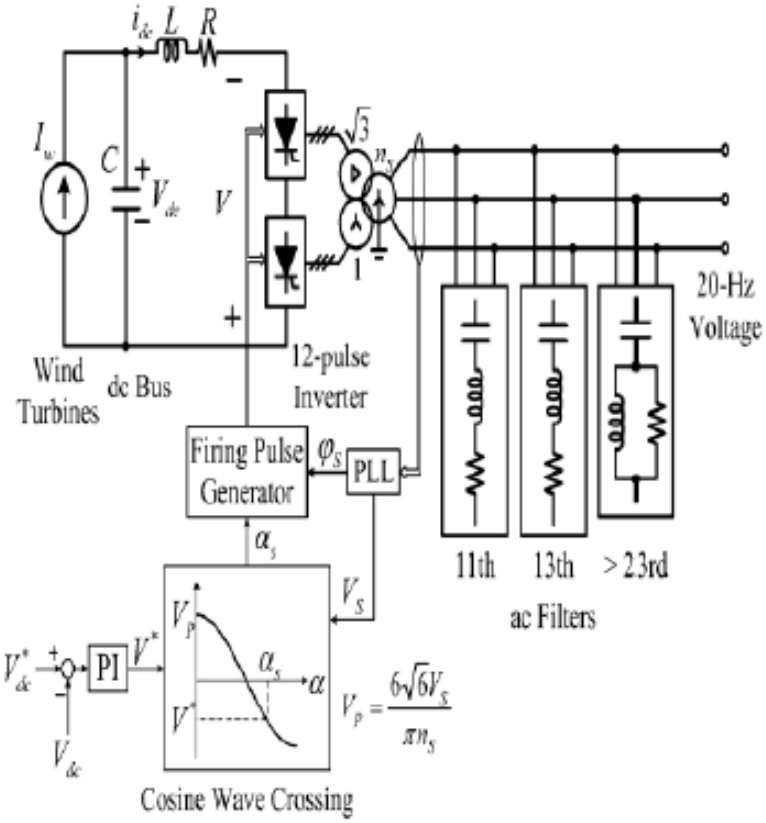

Fig. 4. Sending-end inverter control.

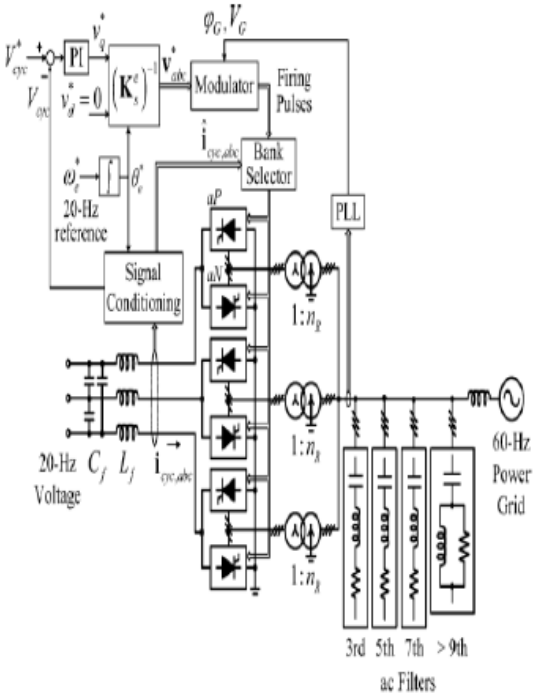

Fig. 5. Accepting end cycloconverter control. (The reference outline change grid is characterized in , and changes factors from the stationary to the synchronous reference outline.)

B. Receiving-End Control

The structure of the cycloconverter controller at the less than desirable end is outlined in Fig. 3. The control objective is to give a steady 20-Hz voltage1 of a given rms esteem (line-to-impartial). The central part of the cycloconverter voltage is acquired with the flag molding rationale portrayed in Fig. 4.The terminating edges are resolved with the cosine wave crossing strategy, as appeared in Fig. 5, which utilizes stage for instance. The terminating points of the stage positive and negative converters (indicated as "aP" and "aN" in Fig. 3) are and , separately. For the positive converter, the transmission distanceis160km. the normal voltage at the 20-Hz terminals is given by

$$V_{aP} = \frac{3\sqrt{6}V_G}{\pi n_R}\cos(\alpha_{aP}) \qquad (3)$$

III. SIMULATION RESULTS

To show the legitimacy of the proposed LFAC framework, reproductions have been done utilizing Matlab/Simulink and the Piecewise Linear Electrical Circuit Simulation (PLECS) tool stash. The wind power plant is appraised at 180 MW, and

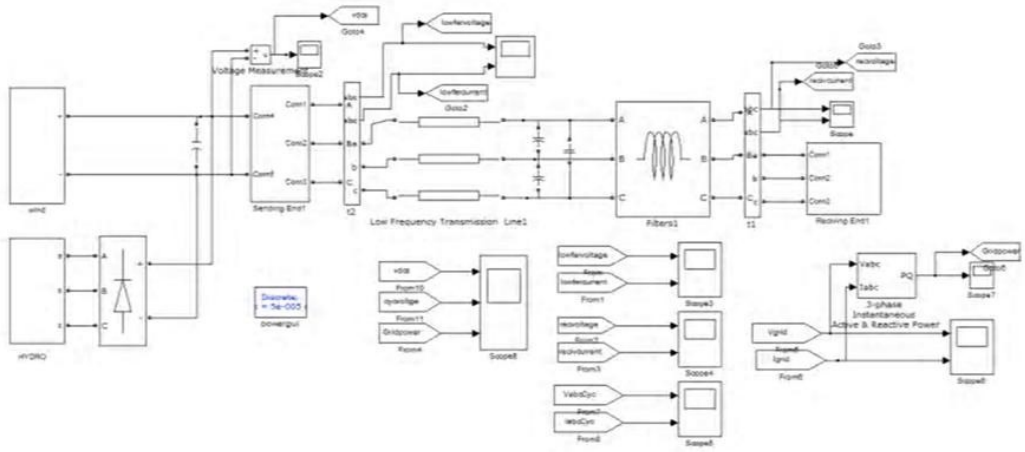

Fig 6:MATLAB/Simulink model of LFAC transmission system

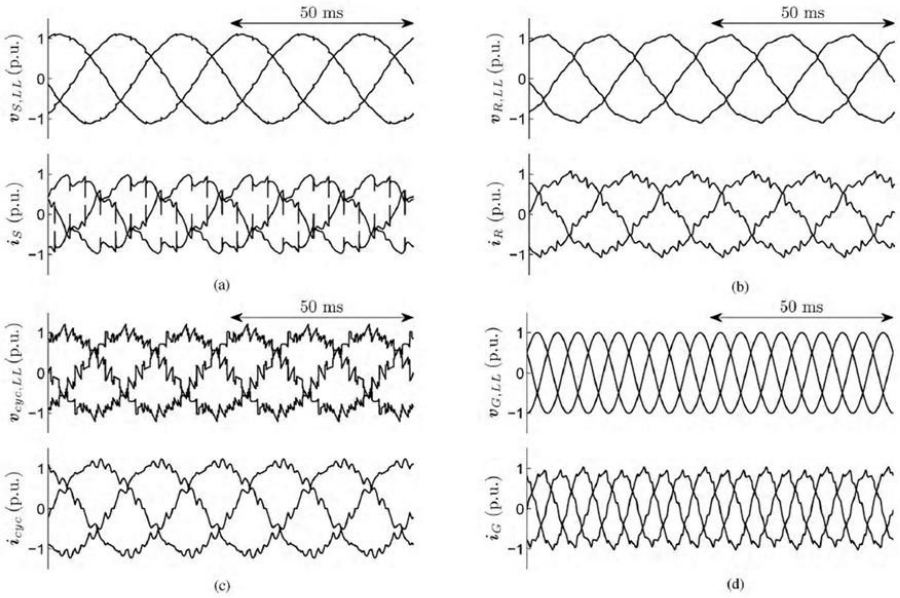

Fig. 13. Mimicked voltage and current waveforms. (It would be ideal if you allude to Fig. 1 for voltage and current checking positions.) (a) Sending end. (b) Receiving end. c) Cycloconverter 20-Hz side. (d) 60-Hz power network side.

VI. CONCLUSION

A low-frequency ac transmission framework for offshore wind power has been proposed. A technique to outline the framework's parts and control systems has been talked about. The utilization of a low frequency can enhance the transmission capacity of submarine power cables because of lower link charging current. The proposed LFAC framework gives off an impression of being an achievable answer for the reconciliation of offshore wind power plants over long separations, and it may be a reasonable option over HVDC frameworks in specific cases. Besides, it may be less demanding to set up an interconnected low-frequency ac system to transmit mass power from numerous plants. The significant preferred standpoint of such a control plan of the wind cultivate side VSC is that the turbines with various generator-converter topologies (e.g. enlistment generators with full range converters and twofold nourished acceptance generators with fractional converters) can be associated with the same VSC stage. The recreation comes about above demonstrate the framework reaction and the power adjust amid and outside the network blame conditions.

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