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A Novel Approach in Offshore Wind Generation Scheme and Implementation of MEPT and MMPT Methods

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Abstract

A new offshore wind generation scheme is proposed in this paper. This scheme implements a wind generation scheme in offshore with a Hybrid generator and the generated power is transmitted to the onshore substation using a hybrid transformer. The proposed HG uses two rotor field excitations. Maximum Power Point tracking techniques are implemented as Maximum mechanical power tracker and maximum electric power tracker in wind energy conversion system. The MEPT and MMPT methods has greater MPPT efficiency. By using hybrid transformer in transmission system the losses in the system is reduced. Voltage control is provided by the DC-DC converter By using this method efficiency is increased and system losses is reduced.

Keywords: Hybrid generator, HVDC hybrid transformer, MEPT, MMPT, Offshore, DC-DC Converter,

INTRODUCTION

An offshore wind generation scheme has attracted the recent research and industrial attention in the past decade[1]. Operating the renewable energy systems in their maximum power point is very important in order to increase the effectiveness. The wind energy system is considered as a renewable energy sources which is clean and efficient, they can be functioned with a constant or variable wind speed[2].The variable speed operation increases the efficiency and reduces generated power fluctuations[3].The use of a maximum power point tracking (MPPT) algorithm is necessary to extract as much of power as possible from the wind when its speed changes[4]. The wind energy conversion system consist of a wind turbine and an generator, WECS connect to DC load requires a three phase rectifier, MPPT controller[5]. Wind turbine is one of the key device which converts wind energy into mechanical energy. By using the Hybrid generator the mechanical power is converted into the electrical energy. At a certain wind speed there is an optimum turbine speed at which the turbine output mechanical power reaches its maximum [6]. The MPPT controller tracks the optimum turbine speed and regulates the turbine speed to optimum speed. There are different MPPT methods reported in the literature[7] that are explained in detail as follows, Tip speed ratio (TSR) control is a well known technique. Power signal feedback (PSF) method tracks the maximum power by reading the current power output to determine the control mechanism. Hill-climbing search (HCS) is also called as Perturb and Observe(P&O) is an algorithm used for photovoltaic system[8]. In this method the MEPT method is introduced, the MEPT extracts maximum output electrical from wind energy conversion system. Very simple structure, low-cost, and very good response to sudden variations in wind speed are the other benefits of the two trackers[9]. The generated power is then transmitted by the HVDC hybrid transformer. The HVDC transformer is located within the each wind turbine, the turbines themselves are connected in parallel directly to a HVDC collection grid. The HVDC transformer substation is not required so that the system redundancy is improved [10]. While the solid state DC-DC transformer have been used to implement the potential magnetic transformer design. This paper proposes and evaluates three single phase hybrid HVDC transformer, to minimize the switching losses and overcome the design limitations[11]. A variable speed wind energy conversion system consists of a permanent magnet synchronous generator that offers a constant speed, such as maximum power point tracking capability and reduced acoustic noise at lower wind speeds[12]. This method does not use any type of sensors. The Generator used in this power generation scheme is Hybrid generator which is a combination of permanent magnet and squirrel cage rotor. FIG 1, Illustrates the commercial offshore wind farm generation, this scheme AC output from the wind generator is converted in to DC and it is inverted in to AC using two controlled back-to-back voltage source converter (VSC)[13]. A typical system representing this scheme is installed in Walney wind farm in UK where each turbine is 3.6MW Siemens turbine model SWT-3.6-107[14].

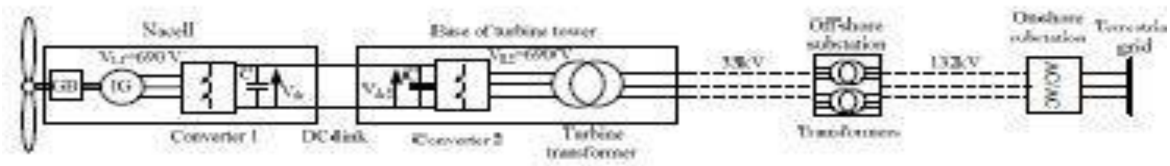


Figure 1(a) Wind generation in Walney wind farm in UK with HVAC

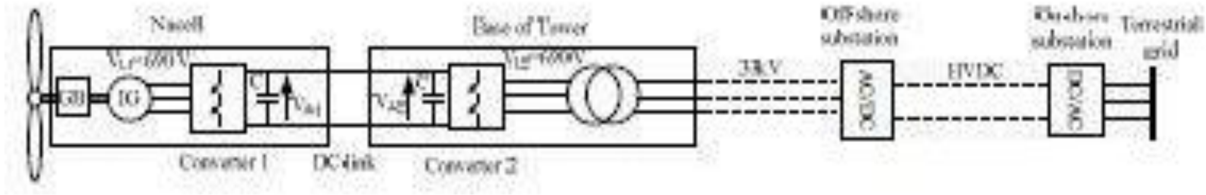


Figure 1(b) Wind generation scheme with HVDC

Fig 1(a) represents, In this system the generated voltage from the Induction generator is 690v. It is stepped to 33 KV by the tower transformer and then it is transmitted to the offshore substation. At the offshore substation the generated power from all the turbines are stepped up to 132 KV and it is transmitted to the onshore substation using HVAC cables. Fig (b) represents the wind generation scheme employing the HVDC transmission. By using HVDC transmission the losses are reduced and it is efficient way of transmitting the generated power.

This paper deals with the technique that the MEPT controller are used to obtain the maximum power from the generator and the maximum mechanical power is obtained from the MMPT controller. Both the power from the MEPT and MMPT controller are transmitted to the DC-DC converter and then it is transmitted to the grid through the hybrid transformer.

WALNEY EXTENSION GENERATION SYSTEM

In this section a commercial wind farm is taken for the comparison. The wind farm is Walney extension wind farm. The 660MW Walney Extension offshore wind farm is located in Irish sea, Off the coast of cumbria in the UK neighboring to the 367.2 MW Walney offshore wind farm. The power obtain from the turbine is transmitted to the two offshore substation where it is stepped up to 34kv to 220kv voltage level. An interlink between the two offshore substation provides partial redundancy reducing risks to operational availability. The power is transmitted from the offshore substation to the onshore substation through the two 220kv offshore and onshore export cables. The onshore substation is connected to the National grid at Middleton near Heysham. The wind turbines used in the Walney extension offshore wind farm is MHI Vestas V164-8.0MW and Siemens SWT-7.0-154-7MW. It employs 87 turbines of which 40 MHI Vestas V164-8.0MW and 47 Siemens SWT-7.0-154-7MW.

This section deals with the schematic diagram of the Walney extension wind farm. It also includes the characteristic of the turbine MHI Vestas V164-8.0MW and Siemens SWT-7.0-154-7MW used in the wind farm

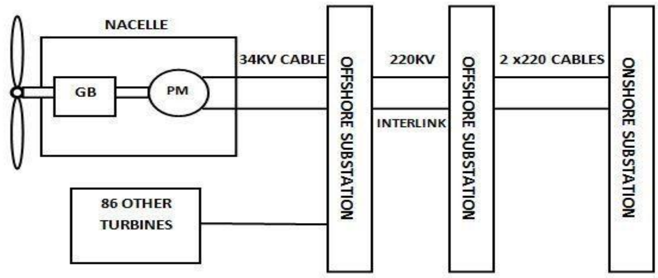


Figure 2: Walney Extension wind farm in UK

Table I. Details of Walney Extension Offshore Wind Farm

ITEM	WALNEY EXTENSION
Wind Turbine type	MHI Vestas V164-8.0MW, Siemens SWT-7.0-154- 7MW
Number of turbines	87
Output Power(MW)	660
Transmission type	HVAC
Operating voltage level	34/220
Offshore substation (MVA)	2 x 220
Approximate total area (km)	145
Approximate water depth	21-37m LAT
Length of the export cable	Offshore-80Km, interlink-23Km, onshore-4Km

Table II. Details of Siemens SWT-7.0-154-7MW

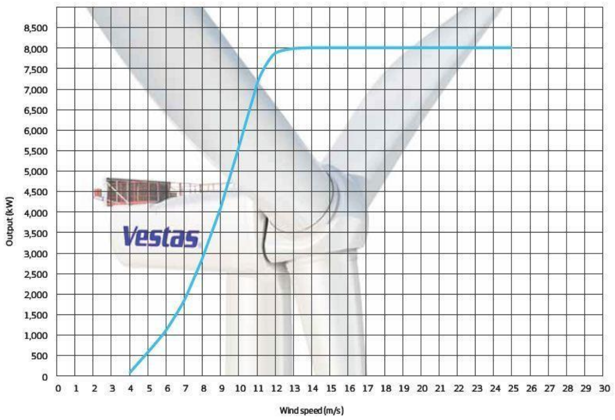
OPERATING DATA	
Cut in wind speed(m/s)	3-5
Rated wind speed(m/s)	13-15
Cut-out wind speed(m/s)	25
GENERATOR, CONVERTER AND TRANSFORMER	
Generator Type	Synchronous, PMG, direct drive
Generator Rated power(MW)	7
Generator rated voltage(V)	1500
Generator number of poles	4
Frequency(Hz)	50
Generator rated speed(Rpm)	1500
Power electronic converter	Full scale converter
Turbine Transformer location	Tower base

ROTOR	
Rotor Diameter(m)	154
Blade length	75m (B75)
Rotor Type	3 Bladed Horizontal axis
Rotor position	Upwind
Hub Height	Site specific
Swept area(m2)	18,600
Brake type	Hydraulic disc brake

Table III. Details of Siemens SWT-7.0-154-7MW

Operating data	
Cut in wind speed(m/s)	4
Rated wind speed(m/s)	13
Cut-out wind speed(m/s)	25
Generator, Gear box	
Generator type	Permanent Magnet
Number of Generator	1
Generator voltage(V)	33-35 and 66kv
Generator rated speed(rpm)	1500
Frequency(Hz)	50
Gear Box type	Planetary
Rotor, Blade, Converter	
Rotor Diameter(m)	164
Swept Area(m2)	21,124
Rotor speed	12.1U/min
Tip speed(m/s)	104
Hub height	Site specific
Blade length(m)	80
Converter type	Full scale converter
Brake type	Hydraulic disc brake

POWER SPEED CHARACTERISTICS OF MHI Vestas V164-8.0MW WIND TURBINE



IMPLEMENTATION OF THE PROPOSED MEPT AND MMPT

The proposed MEPT AND MMPT of the wind energy conversion system is explained as follows

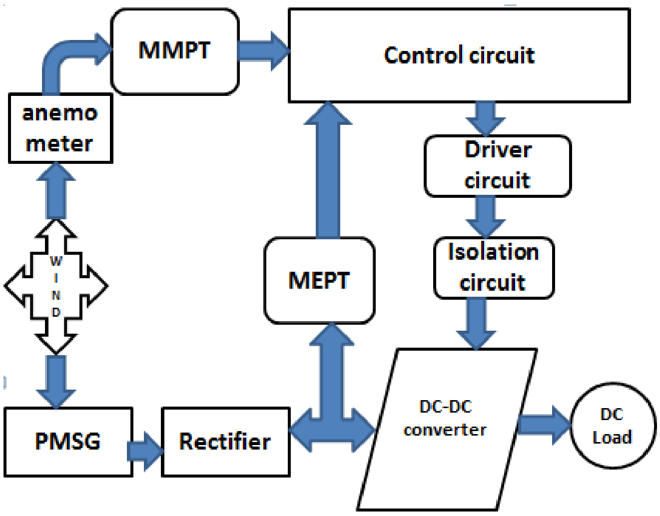


Figure 3. Block diagram of the proposed MEPT and MMPT

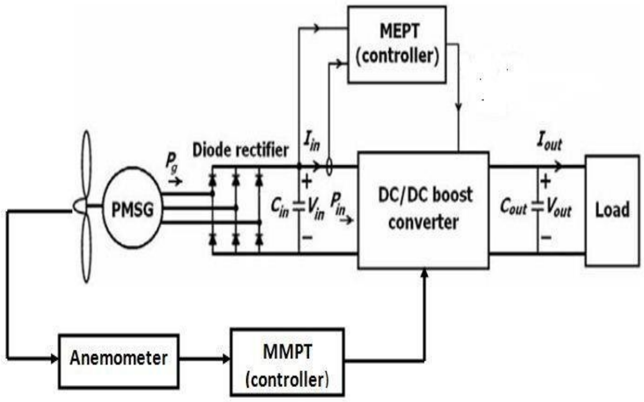


Figure 4. Schematic diagram of the proposed MEPT AND MMPT

Fig 3, represents the basic block diagram of the proposed MEPT and MMPT. And the Fig 4, represents the schematic diagram of the both MEPT and MMPT.

In this method the Permanent magnet synchronous Generator is used. The mechanical energy is converted into electrical energy in the PMSG. And then it is converted from AC to Dc using a diode rectifier. The maximum electrical power is tracked by the MEPT controller. In this method the anemometer is used. It is a instrument used to measure the speed of the wind. Anemometer sense the speed of the wind and send it to the MMPT controller. Both the Electrical and mechanical power from the MEPT and MMPT is fed to the load using a DC-DC boost converter. It is used to step up the voltage from its input to its output(load).

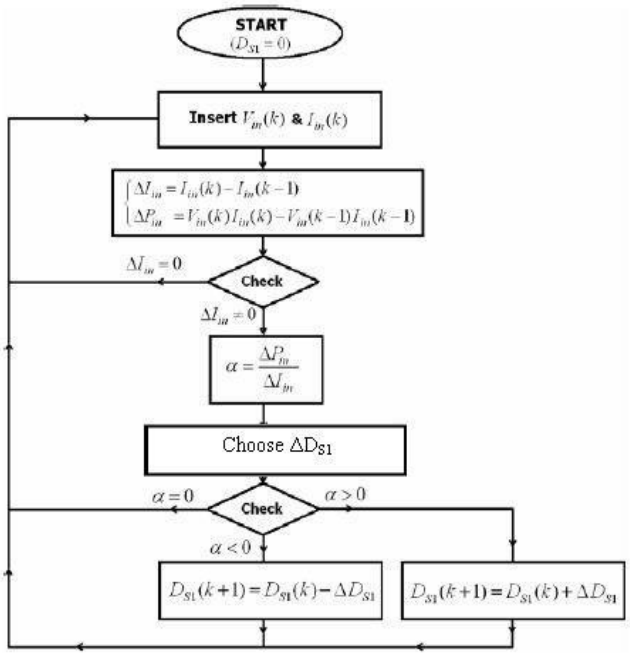


Figure 5. Operational flowchart of MMPT

Fig 5 represents the operational flowchart of the proposed MMPT.

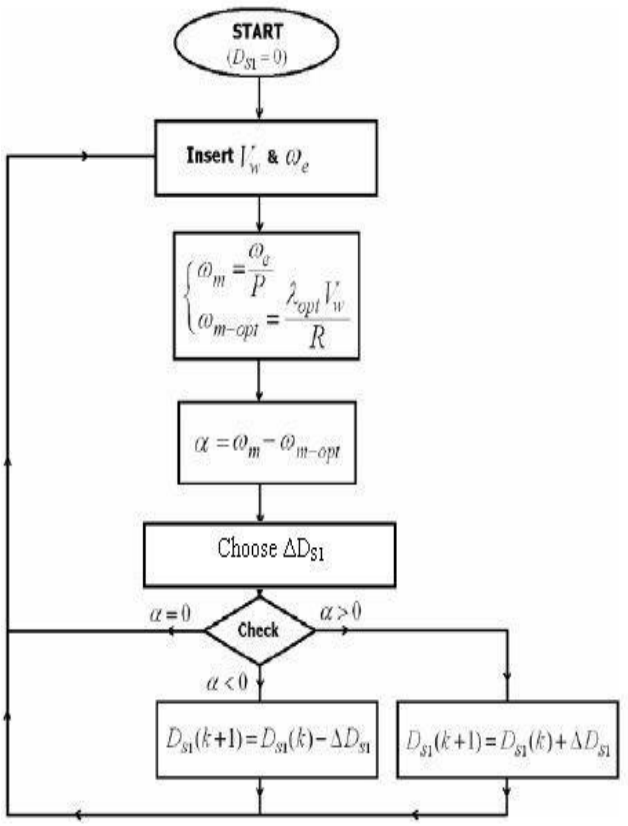


Figure 6. Operational Flowchart of MEPT

For the wind turbine used in the WECS, the tip speed ratio is defined as

$$\lambda = R\,\omega_m / V_w \qquad (1)$$

where V_w is the wind speed, R and ω_m are respectively the radius and angular speed of the wind turbine. At a certain wind speed, the optimum angular speed ω_{m-opt} , at which the maximum output mechanical power of the turbine occurs, can be obtained by (1) as

$$\omega_{m-opt} = \lambda_{opt} V_v / R \qquad (2)$$

T_s is the switching period. $T_s = 1/f_s$ and f_s is the switching frequency. Duty ratio is defined as

$$D_{S1} = t_{on}/f_s \qquad (3)$$

PROPOSED WIND GENERATION SCHEME WITH HYBRID GENERATOR AND TRANSMISSION

The proposed scheme comprises of a hybrid generator, passive rectifier, magnetic transformer, converters and HVDC interconnections. This scheme results in reduced system cost due to the reduced component count due to reduced count and complexity, the HG and passive rectifier replace the existing practice of induction or PM generator, back-to-back VSC's. The HG output rectifiers can be mounted close to the machine assembly. The ABB wind former system uses a PM generator connected to the rectifier without any control to the DC link. By using the hybrid transformer with in the turbine system the requirement of offshore substation is reduced.

HYBRID GENERATOR(HG)

The brief discussion about Hybrid generator is explained in this section. The HG is a multi-phase high voltage generator that consists of two rotor sections namely PM rotor and squirrel cage rotor. Hence the name hybrid refers to the combination of two rotors. The squirrel cage rotor and PM rotor sections exists on a one rotor assembly inside one machine housing. Both the rotors rotate in same speed. The HG combines the output voltage due to a fixed field from the PM rotor and a controlled variable voltage due to the variable field of the Squirrel cage rotor. The total output voltage is the combination of both the squirrel cage rotor and the permanent magnet rotor.

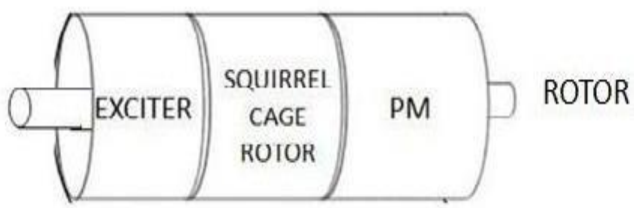


Figure 7 (a) Schematic view of Hybrid Generator

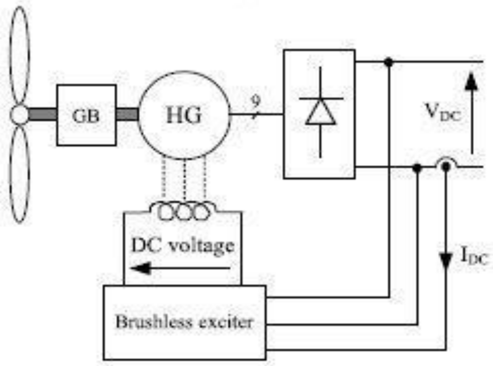


Figure 7(b). HG in a wind turbine

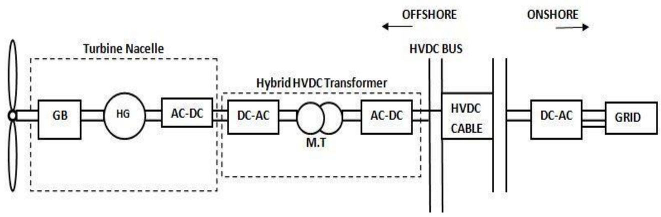
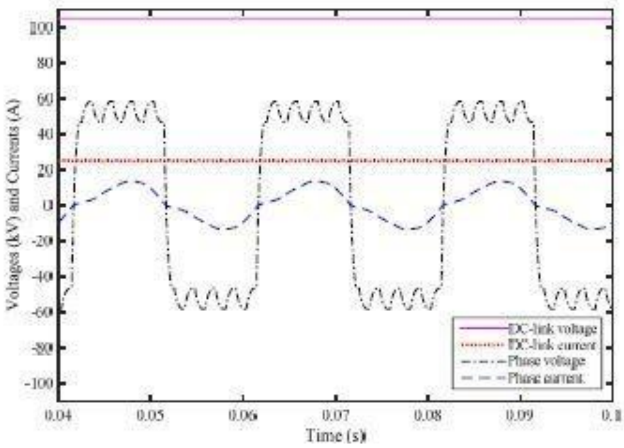


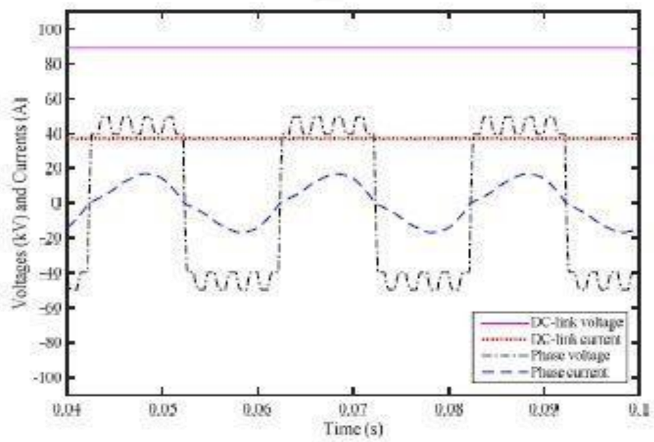
Figure 8. Schematic diagram of proposed system

In this system the Hybrid Generator is used to convert the mechanical energy in to electrical energy. The obtained electric power is converted into DC. Then it is again converted into AC and fed to the Hybrid HVDC transformer system.The transformer used in this system is Magnetic Transformer.The magnetic transformer is used to comply the with the Hybrid HVDC transformer design specifications. Then it is connected to the HVDC bus. Through the HVDC cables the obtained power is transmitted from the offshore to the onshore substation. HVDC transmission is used so that the losses are reduced. For short distance transmission HVAC transmission can be used. From the onshore substation it can be converted into AC and connected in the grid.

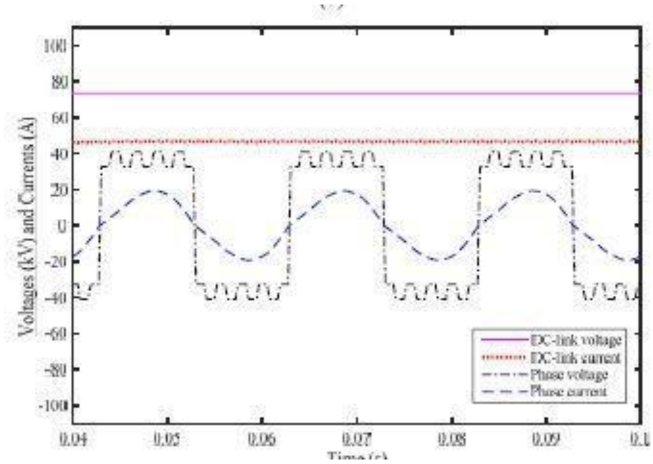
SIMULATION RESULT:



(a)



(b)



(c)

HG output waveforms (a) V_{dc} = 105kv(1.0 p.u)

(b) V_{dc} = 89.25kv (0.85 p.u) (c) V_{dc} = 73.5kv(0.7 p.u)

CONCLUSION

A new wind generation scheme with hybrid generator and transmission through hybrid transformer is proposed in this paper. A new method of MEPT and MMPT having greater MPPT efficiency is also discussed in this paper. It was shown that the MEPT extracts the electrical power and the MMPT extracts the mechanical power from the wind turbine. The MEPT and MMPT not only provides good response in sudden variation in the wind speed but it also very simple and cheaper than the conventional WECs. By using Hybrid transformer in the offshore wind generation the losses are reduced.

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