

# Power Synchronous Control for Weak Grid Using DFIG

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**ABSTRACT:** In this paper, the application of a recently invented, Power-synchronization control is proposed for integrating a doubly fed induction generator (DFIG)-based offshore wind farm to a weak ac grid through a voltage-source converter (VSC)-based High-voltage dc link. The control strategy, along with the anti windup Techniques and the bump less transfer between two Different control modes, is elaborately discussed. Two different Fault cases, namely, onshore and offshore faults are considered and carried over through the fault-ride techniques are presented. Foran offshore fault, a coordinated fault-ride through Scheme is proposed when the offshore HVDC converter and the wind farm is in voltage-control modes. The entire study is carried out in mat lab simulation software.

## I. INTRODUCTION

We have been harnessing the wind's energy for hundreds of years. From old Holland to farms in the United States, windmills have been used for pumping water or grinding grain. Today, the windmill's modern equivalent - a wind turbine - can use the wind's energy to generate electricity. Wind turbines, like windmills, are mounted on a tower to capture the most energy. At 100 feet (30 meters) or more aboveground, they can take advantage of the faster and less turbulent wind. Turbines catch the wind's energy with their propeller-like blades. Usually, two or three blades are mounted on a shaft to form a rotor.

A blade acts much like an airplane wing. When the wind blows, a pocket of low-pressure air forms on the downwind side of the blade. The low-pressure air pocket then pulls the blade toward it, causing the rotor to turn. This is called lift. The force of the lift is actually much stronger than the wind's force against the front side of the blade, which is called drag. The combination of lift and drag causes the rotor to spin like a propeller, and the turning shaft spins a generator to make electricity. Wind turbines can be used as stand-alone applications, or they can be connected to a utility power grid or even combined with a photovoltaic (solar cell) system. For utility-scale sources of wind energy, a large number of wind turbines are usually built close together to form a wind plant. Several electricity providers today use wind plants to supply power to their customers.

Stand-alone wind turbines are typically used for water pumping or communications. However, homeowners, farmers, and ranchers in windy areas can also use wind turbines as a way to cut their electric bills. Small wind systems also have potential as distributed energy resources. Distributed energy resources refer to a variety of small, modular power-generating technologies that can be combined to improve the operation of the electricity delivery system.

The contributions of this paper are twofold. First, it is shown that by using power synchronization control, an offshore wind farm can successfully be connected to a weak mainland grid. Stable operation is verified through simulation studies in a real time digital simulator (RTDS). For clarity and tutorial purposes, a thorough review of power synchronization control in wind farm applications is given. Second, it is shown that the ride through of a solid three-phase fault at the onshore station can be performed without a chopper (i.e., braking resistor) in the offshore HVDC station; the crowbar protection in the wind turbines is solely relied upon. This is a practically important aspect, since space is at a premium on offshore platforms. The ride through strategy is independent of the control strategy of the onshore station, and can thus be used also with strong mainland grids and the standard current-control-based method

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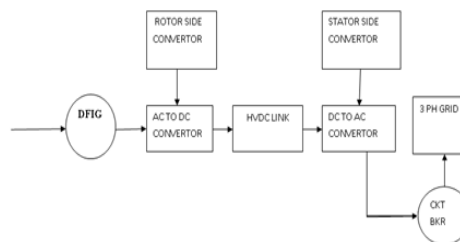
## II. NEED OFFSHORE WIND ENERGY

There are several factors which suggest the development of an offshore wind energy industry. The resource is extremely large, the energy costs, although initially higher than for onshore, are cheaper than other renewable technologies and the risks are low, as several demonstration projects elsewhere have shown. Greater distance will reduce visual impact from land.

Water may be deeper Weather and the sea state may be rougher Economics may dictate larger turbines with limited proven performance Installation will be more difficult and costly

## III. BLOCK DIAGRAM AND DESCRIPTION

The power generation of the wind energy is generated by the DFIG in AC supply is converted to the DC through the rectifier side converter on the offshore side to the power transmitted through HVDC link. The power in HVDC as converted to the AC. The generated power on offshore has been connected to Grid through the circuit breaker.

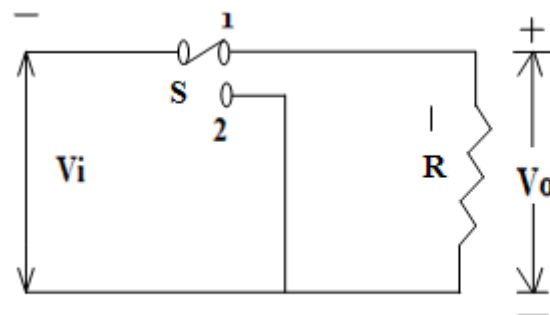


Block diagram of power synchronous control for weak grid

The DC to AC converter is simply called as inverter this has been done DFIG stator converter side because of for long transmission AC power has become higher losses to avoid this losses we are using converters both grid side and rotor side. For source side rotor side converter will takes place and the grid side stator side converter will take place. Finally the output power has been connected grid via, Circuit breaker. The circuit breaker is used for switching and handling of three phase power.

## IV. BUCK CONVERTERS

As mentioned earlier, step-down converters are used to convert an input voltage to a lower level at the output. Basic principle of a buck topology is shown in figure 2.2 . When the switch is in position one, the output voltage is equal to the input voltage and when the switch is in position two, the output voltage is equal to zero. The resulting average voltage level at the output is a function of the time when the switch is in position one and two respectively. This function is called duty ratio and it is defined by the expression  $D = V_o/V_{in}$ , where  $V_o$  denotes the average output voltage and  $V_{in}$  is the DC voltage generated by the power source.



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The main problem of this basic circuit is the voltage ripple of the output signal of the converter. For this reason a LC-filter is used to decrease the voltage ripple. This modified circuit is shown in figure

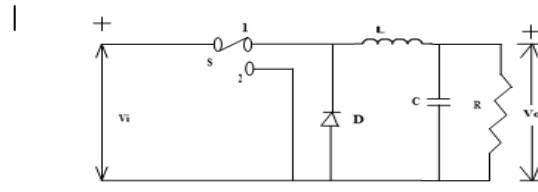
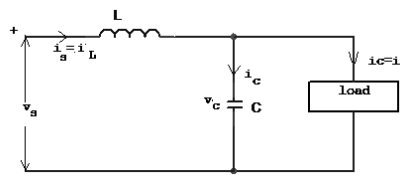


Figure Buck converter

Since the average current through the load resistor  $R$  is approximately the same as the average current of the inductor, the voltage  $V_o$  across the load resistor contains less ripple. A diode is used when the switch is in position two. This allows the capacitor to be charged in both switching positions. When the switch is in position one the energy is transferred from the power source to the capacitor and when the switch is in position two the capacitor is charged with the energy stored in the inductor. This type of operation results in high power efficiency for buck converters.

### Mode 1:

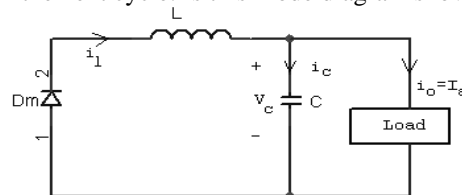
In this mode when MOSFET  $M_1$  is switched on at  $t=0$ . The input current, which rises, flows through filter inductor  $L$ , filter capacitor  $c$ , and load resistor  $R$ . In this mode diagram shown in figure 3.4a.



mode 1 operation of Buck converter

### Mode 2:

In this mode when MOSFET  $M_1$  is switched off at  $t=t_1$ . The freewheeling diode  $D_m$  conducts due to energy stored in inductor and the inductor current continues to flow through  $L$ ,  $C$ , load and diode  $D_m$ . The inductor current falls until transistor  $Q_1$  is switched on again in the next cycle. Is this mode diagram shown in figure



mode 2 operation of Buck converter

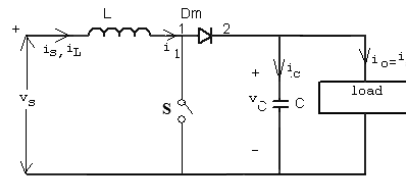
## BOOST CONVERTERS

A boost converter topology is obtained by rearranging the components of a buck converter according to figure 3.5. During the time the switch is closed energy is transferred to the inductor while the diode is preventing the capacitor to discharge through the switch. When the switch opens current through the inductor continues to flow in the same direction as during the previous cycle. This forward-biases the diode and both the input voltage source and the inductor are transferring energy to the load. Hence, a voltage boost occurs across the load, which causes the output voltage to be higher than the input voltage. The capacitor must be large enough to keep the output voltage approximately constant

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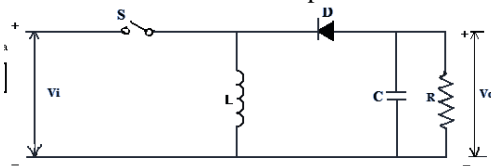
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Boost topology.

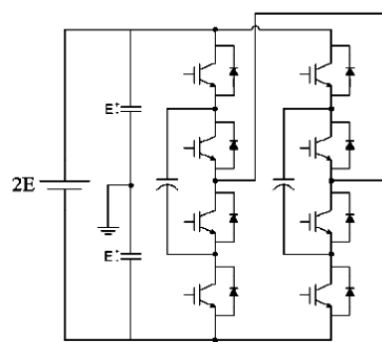
## BUCK-BOOST CONVERTERS

Certain applications require voltage levels to be both higher and lower than the source voltage. A solution to this is a buck-boost converter. A simple buck-boost converter is shown in figure



Next, the switch is open and the inductor maintains the current direction. This forward-biases the diode. During this period the inductor is transferring energy to the capacitor. In other words, the capacitor is being charged as the inductor is being discharged, and the output voltage is rising. Previous discussion implies, that by adjusting the on time of the switch compared to the time of one switching period, the output voltage  $V_o$  can be set to either lower or higher levels than the input voltage  $V_s$ . If the ratio of the on time of the switch and the switching period approaches zero than the output voltage also approaches zero. If the ratio approaches one, than the output voltage level theoretically has no upper limit.

## V. CAPACITOR CLAMPED MULTILEVEL CONVERTERS



capacitor clamped multilevel converters

Figure shows a scheme of a single phase Capacitor clamped multilevel converter. Assuming the DC bus voltage of the converter is  $2E$ , it can be easily found that there are five levels in the output waveform, according to (1), obtains:

$$V_o = (S - 2).E$$

Where  $E$  is the minimum voltage level,  $S=0, 1, 2, 3, 4$ . For  $S$  select  $0, 1, 2, 3, 4$ , five different values of the output voltage can be achieved, i.e.  $(0, \pm E, \pm 2E)$  accordingly.

## VI. POWER SYNCHRONOUS CONTROL

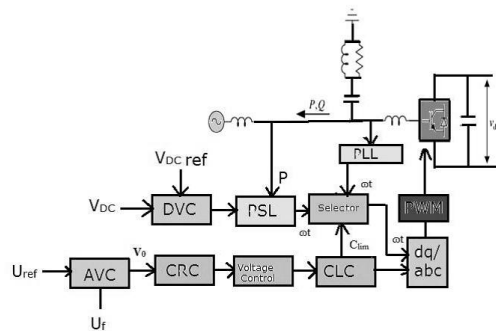
The basic principle of power-synchronization control is similar to the operation of a synchronous machine. In an ac system the synchronous machines maintain synchronism by transient power transfer. This power transfer involves a current which is unknown and is determined by the interconnecting network. Here the

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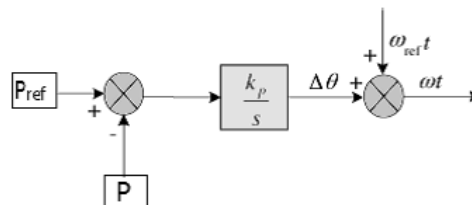
Here  $\Delta$  directly provides synchronization for the VSC. During normal operation an additional PLL is not necessary. The dynamic process of a VSC using power synchronization control is very similar to that of interconnected synchronous machine. The transmitted power is increased or decreased by shifting the output voltage phasors of the VSC forwards or backwards. A simplified schematic diagram of the GSVSC control using power synchronization control system is shown.



The schematic diagram of the GSVSC control using power synchronization control

## Power Synchronization Control Loop (PSL)

PSL maintains synchronism between the VSC and the ac system. It is the active power control loop. The control law is given by equation 5. The power control error is converted to a frequency deviation, which is then integrated to an angle increment. The output of the PSL is used to transform the voltage reference from the converter dq frame to the stationary frame. The block



Power Synchronization Control Loop

## VII. DIRECT VOLTAGE CONTROL (DVC)

GSVSC has to keep the DC voltage constant to keep the balanced active power flow between the two sides. The control law is given as synchronization control is shown below. The DC voltage is set at 1 p.u and the active power is set at 0.8 p.u.

the wind farm can be dispatched to the dc side of the offshore HVDC station. Therefore, a frequency-control loop is added to the controller of the offshore station to generate the power deviation to the reference power from the wind farm.

### DFIG:

Doubly fed electric machines are that have windings on both stationary and rotating parts, where both windings transfer significant power between shaft and electrical system. Usually the stator winding is directly connected to the three-phase grid and the three-phase rotor winding is fed from the grid through a rotating or static frequency converter.

Doubly fed machines are typically used in applications that require varying speed of the machine's shaft in a limited range around the synchronous speed, for example  $\pm 30\%$ , because the power rating of the frequency converter is reduced similarly. Today doubly fed drives are the most common variable speed wind turbine concept

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The doubly fed machine has its origins in wound rotor induction motors with multiphase winding sets on the rotor and stator, respectively, with the rotor winding set connected to resistors via slip rings for starting. However, the slip power was lost in the resistors. Thus means to increase the efficiency in variable speed operation by recovering the slip power were developed. In Krämer (or Kraemer) drives the rotor was connected to an AC and DC machine set that fed a DC machine connected to the shaft of the slip ring machine. Thus the slip power was returned as mechanical power and the drive could be controlled by the excitation currents of the DC machines. The drawback of the Krämer drive is that the machines need to be over dimensioned in order to cope with the extra circulating power. This drawback was corrected in the Scherbius drive where the slip power is fed back to the AC grid by motor generator sets.

The rotating machinery used for the rotor supply was heavy and expensive. Improvement in this respect was the static Scherbius drive where the rotor was connected to a rectifier-inverter set constructed first by mercury arc based devices and later on with semiconductor diodes and thyristors. In the schemes using a rectifier the power flow was possible only out of the rotor because of the uncontrolled rectifier. Moreover, only sub-synchronous operation as a motor was possible.

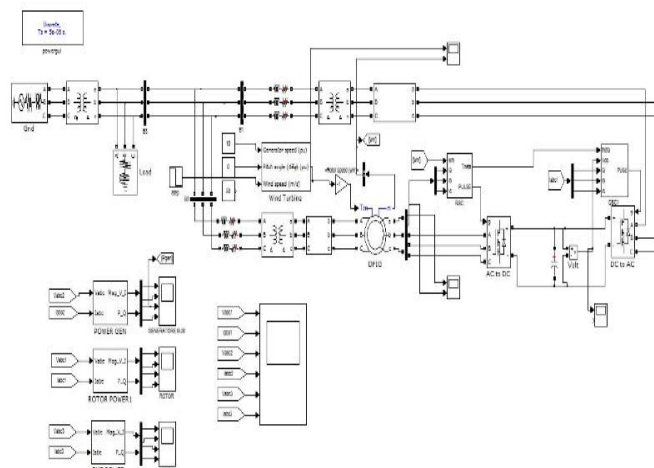
Another concept using static frequency converter had a connected between the rotor and the AC grid. The cyclo converter can feed power in both directions and thus the machine can be run both sub- and over synchronous speeds. Large cycloconverter controlled doubly fed machines have been used to run single phase generators feeding 16 2/3 Hz railway grid in Europe and run the turbines in pumped storage plants.

Today the frequency changer used in applications up to few tens of megawatts consists of two back to back connected inverters. Several brushless concepts have also been developed in order to get rid of the slip rings that require maintenance.

## VIII. SIMULATION

Matlab is an interactive system for numerical computation. Numerical Analyst cleve moler wrote the initial fortuna version of matlab in the late 1970s as a teaching aid. It became popular for both teaching and research and evolved into a commercial software package written in c. For many years now, matlab has been widely used in universities and industries. Matlab has several advantages over more traditional means of numerical computing. Furthermore, matlab is a modern programming language and problem Solving environment: it has sophisticated data structures, contains built-in editing and debugging tools, and supports object oriented programming. These factors make matlab an excellent language for teaching and a powerful tool for research problem solving. Being interpreted, matlab inevitably suffers some loss of efficiency compared with compiled languages, but built-in performance acceleration techniques reduce the in efficiencies and users have the possibility of linking to compiled FORTAN or C code using MEX files.M

## IX. SIMULATION DIAGRAM





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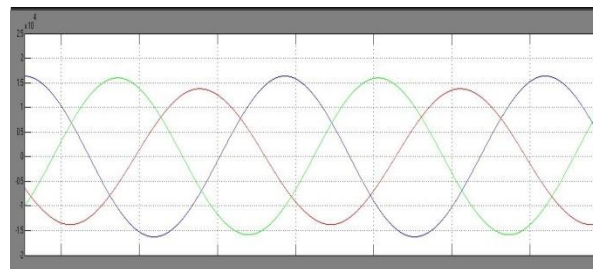
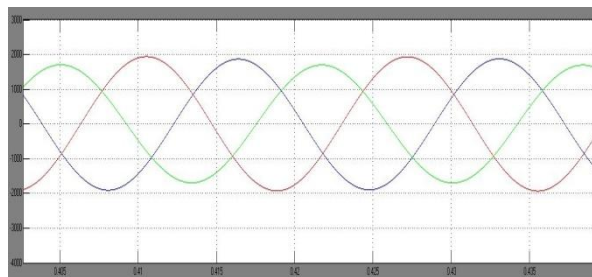
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## STARTING MATLAB

On Windows platforms, start MATLAB by double-clicking the MATLAB shortcut icon on your Windows desktop. On UNIX platforms, start MATLAB by typing matlab at the operating system prompt. You can customize MATLAB startup. For example, you can change the directory in which MATLAB starts or automatically execute MATLAB statements in a script file named startup menu.

## X. SIMULATION RESULT



## XI. CONCLUSION

In this paper, power synchronization control has been applied for a VSC–HVDC link connected to an offshore wind farm from a weak ac grid. It has been demonstrated the power synchronization control is a feasible solution for such applications; the operation is stable during either steady state or contingencies for onshore and offshore faults, the valve current is within the limit, and fault recovery is stable; wind farm applications in case of onshore fault ride through is promising with power synchronization control.

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