Review of Low Voltage Ride through Methods in PMSG

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ABSTRACT

In this paper discussed about low voltage ride through (LVRT) scheme for permanent magnet synchronous generator (PMSG) and wind energy conversion system. Wind generation system has potential application for the grid support. The voltage of the direct driven permanent magnet wind generators (PMSG) is variable due to the intermittent nature of the wind energy. With increasing penetration of wind turbine (WTs) in the grid. Grid connection codes in most countries require that WTs should remain connected to the grid to maintain the reliability during and after a short-term fault. The controllers for grid-side converters are coordinated to provide fault ride-through capability. The generator side is forced by space vector modulation and grid implemented field oriented control (FOC).

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I. INTRODUCTION

The attention soars towards the sustainable energy sources, in particular the wind energy. This one is considered as the most important and most promising renewable energy sources in terms of development. In terms of wind power generation technology as a result of numerous technical benefits (higher energy yield, reducing power fluctuations and improving var supply) the modern MW-size wind turbines always use variable speed operation which is achieved by electrical converters. Nowadays variable speed wind turbine is most popular viz. is Doubly Fed Induction Generator (DFIG) or Permanent Magnet Synchronous Generator (PMSG). PMSG have advantages over DFIG such as higher efficiency and energy yield, for the magnet field excitation no additional power supply etc.

In transient operation, low voltage ride-through (LVRT) requirement demands wind power plants to remain connected when a grid dip occurs, contributing to keep network voltage and frequency stable by delivering active and reactive power to the grid with a specific profile depending on the grid voltage dip depth. Generally, these requirements cover many topics such as, voltage operating range, power factor regulation, frequency operating range, grid support capability, and low fault ride-through capability. The grid codes require the LVRT ability of the wind turbine system. Low-Voltage Ride-Through (LVRT) capability is considered to be the biggest challenge in wind turbines design.

Synchronous generators are the majority source of commercial electrical energy. In a permanent magnet generator, the magnetic field of the rotor is produced by permanent magnets. Other types of generator use electromagnets to produce a magnetic field in a rotor winding. The direct current in the rotor field winding is fed through a slip-ring assembly or provided by a brushless exciter on the same shaft.

II. LOW VOLTAGE RIDE THROUGH

LVRT is short for Low Voltage Ride-Through and describes the requirement that generating plants must continue to operate through short periods of low grid voltage and not disconnect from the grid.

When voltage drop occurs turbines are required to remain connected for specific time duration before being allowed to disconnect. This requirement is to ensure that there is no generation loss for normally cleared faults. Disconnecting a wind generator too quickly could have a negative impact on the grid, particularly with large wind farms.

Grid codes invariably require that large wind farms must withstand voltage sags down to a certain percentage of the nominal voltage and for a specified duration. Such constraints are known as LVRT requirements. They are described by a voltage versus time characteristic, denoting the minimum required immunity of the wind power station to the system voltage sags.

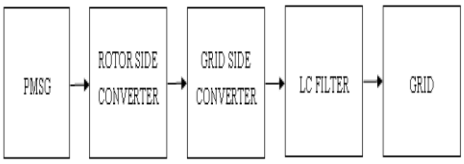


Fig.1 Block Diagram of grid connected PMSG

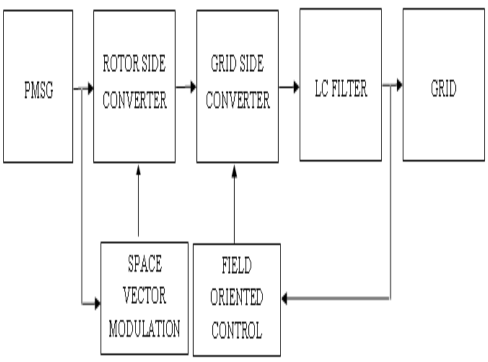


Fig.2 Control structure of grid connected PMSG

The LVRT characteristic for wind turbines has recently been suggested resulting from potential impact of wind on power systems due to the growth of the industry and the size of present installations. The basis behind this new requirement from utilities is that the wind installation should remain in operation for most normally cleared faults. This is particularly important in case of weak systems where the wind generator should help to provide voltage support and contribute to the load at the end of the line. However, in some cases, this translates to a ride through requirement of 0.5 s for a voltage of less than 0.5 pu, which can translate to significant additional costs for the generator system.

The consequence of LVRT is an increased cost for the wind turbine itself since this usually implies additional equipment or a modification of the control strategies in order to facilitate ride through capability. As well the effect will be different depending on the wind generator technology. Following a description of the ride through characteristic the technical requirements and methods for ride through realization as well as rough cost estimates are given for the different topologies.

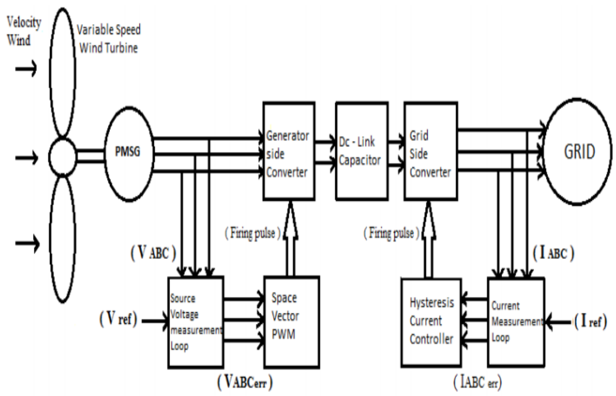
III. LVRT CHARACTERISTICS

The characteristic of LVRT is more or less defined by a minimum voltage throughout the duration of the fault followed by a ramping up to nominal level as the voltage recovers. The width of this minimum is dictated by the length of time to normally clear a transmission level fault (10 to 20 cycles) which then ramps up to the normal operating range with a minimum are dictated by the protection technologies and the location and type of fault, the slope of the recovery likely depends on the strength of the interconnection and reactive power support, whereby and thus minimize the ride-though requirements of the generators.

The functional operation of LVRT is based on the comparison of the characteristic with that of the terminal voltage. Essentially once the voltage dips outside of the normal operating range the control system then compares the recovery of the fault with that o the minimum voltage level as given by the LVRT characteristic. In the case in which the voltage falls below that of the LVRT characteristic, the generator may trip, however, anywhere above the minimum, the generator must remain connected and support the grid.

IV. POWER QUALITY IMPROVEMENT FOR WECS USING PMSG AND HYSTERISIS CONTROLLER

Wind generator has been extensively used both in independent systems for power supplying remote loads and in grid-connected application. The WG power production can be mechanically proscribed by altering the blade pitch angle. This topology is based on the WG optimal power versus the rotating-speed feature, which is frequently stored in a microcontroller memory. The WG turning speed is calculated; the optimal output power is intended and compared to the actual wind generator output power. The ensuing error is used to manage a power boundary. In a similar edition create in the WG output power is calculated and the target rotor speed for optimal power generation is resulting from the WG optimal power versus rotor-speed characteristic.



A. Hysteresis Current Controller

The presentation of the converter system largely depends on the worth of the applied current control strategy. Therefore, current control of PWM converters is one of the most essential subjects of present power electronics. The block diagram of current controller procedure shown in the above figure 3.Whenever the current vector touches the border of the surface, another voltage state is applied to force it back within the square. Similarly, as in the case of the hexagon hysteresis control method, here the square acceptance band moves simultaneously with the reference current such that the current vector points always in the center of the square. For this purpose two hysteresis comparators and components are employed. A simple consideration makes it possible to control the current without any information about the load inner voltage.

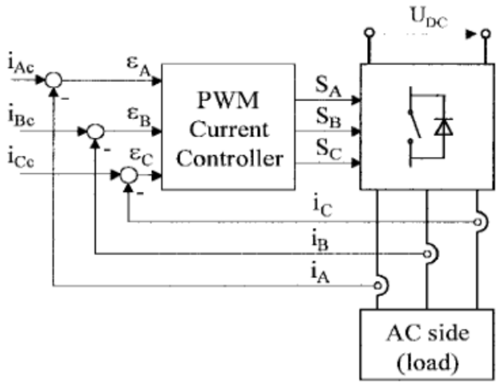


Fig 3 block diagram of cc-pwm converter

B. LVRT using STATCOM

It was observed that STATCOM is effective in eliminating of the quality problems which may occur at the power systems which work by connecting to wind power plant.

If a VSC is connected to the transmission system through a shunt transformer to generate or absorb reactive power from the bus to which it is connected. Such a controller is known as Synchronous Static Compensator or STATCOM and is used for voltage control in transmission systems. If we compare STATCOM with a SVC, The major advantage is its reduced size, sometimes even to less than 50 %, and a potential cost reduction achieved from the elimination of capacitor and reactor banks as well as other passive components required by the SVC.

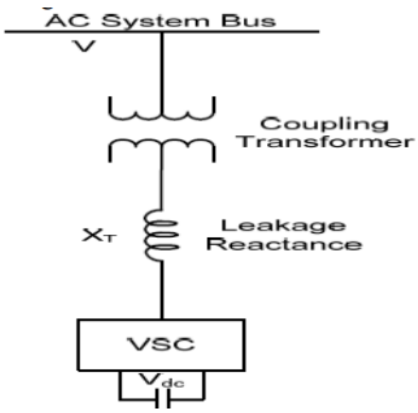


Fig 4 STATCOM

Assuming that no active power is exchanged between STATCOM and the grid (lossless operation) the voltage of the controller is in phase with the grid voltage. In this case, If the compensator voltage magnitude is smaller than the voltage at the connection node current will flow from the grid to STATCOM. Hence the reactive power will be consumed or if the situation is to opposite the reactive power will be delivered to the grid.

C. Back to Back Converter

A line-side converter (LSC) has a conventional cascaded control structure composed of an inner current control loop and an outer DC-link voltage control. For vector control of a PMSG, a cascaded control scheme composed of an inner current control loop and an outer speed control loop is employed. In order to obtain maximum torque at a minimum current, the d-axis reference current component is set to zero and then the q-axis current is proportional to the active power, which is determined by the speed controller.

The MPPT method is applied for turbine power control, which gives the speed reference of the PMSG under normal grid conditions. At a grid voltage sag, however, the MPPT control stops in order to reduce the turbine power extracted from wind. During this operation, the speed reference of the system is set higher than in the case of presag, which means that some portion of the turbine power can be stored in the system inertia

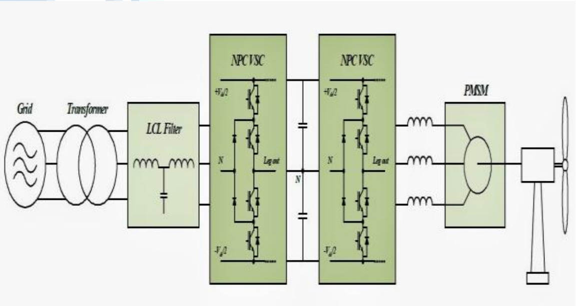


Fig 5 NPC back to back converter

D. Energy Storage System

The ESS consists of a DCDC buck/boost converter and capacitor, which is connected at the DC-link of the back-to-back converters as shown in Fig. 6.

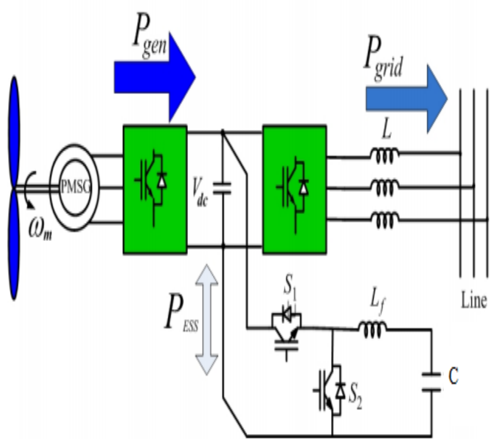


Fig 6 PMSG wind turbine system with ESS

A control strategy for the ESS composed of power and current controllers is suggested, resulting in an improvement in the overall performance for both ride-through and power smoothening.

Control of ESS Under voltage sags, the generator output power may exceed the maximum level which the grid can absorb through the line side converter (LSC) due to decreases in the grid voltage. Therefore, to keep the DC-link voltage constant, the ESS is activated to absorb the differential energy between the generator and grid, which is expressed as:

$$P_{diff} = P_{gen} - P_{grid} \,|_{\text{max possibility}}$$

where P_{diff} is the differential power between the generator and the grid, P_{gen} is the generator power, and P_{gid} is the grid power.

During a voltage sag, the LSC is operated at its rated current. As a result, the generator can deliver as much power to the grid as is possible.

V. CONCLUSION

To overcome the power quality issues various LVRT methods are used. Hysteresis controller is used to improve the WG power, making the generated speed constant and by controlling the pitch angle. Statcom's are used to supply/absorb the reactive power to/from the grid through voltage source converter. NPC back to back converters are also used and LVRT, field oriented control methods are presented. Energy storage system is used to store the rotor energy during low voltage operation. STATCOM methods are widely used because this method does not requires external arrangements. NPC converter requires rotor converter and grid side converter. Energy storage system requires buck/boost converter and capacitor.

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