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ENHANCEMENT OF WIND POWER INTEGRATION IN TO AC MICROGRIDS USING SUPERCAPACITOR ENERGY STORAGE

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ABSTRACT
The inclusion of renewable energy sources such as wind power in power system is steadily increasing around the world. Due to the nature of wind, the output power gets fluctuated according to the wind speed variations. Technologies have been developed to match the generated frequency with grid frequency. In this paper, a supercapacitor have been developed to regulate the output power of wind farms to improve power system reliability and power quality. It considers the integration of the short term energy storage in a DFIG in order to smooth the power variations. This storage device can also be used to reinforce the DC bus during transient, thereby enhancing its low voltage ride through capability. This paper also proposes an operation scheme of wind farm to alleviate power fluctuation by choosing an appropriate control mode and co-ordinating multiple wind turbines in consideration of grid conditions. This paper deals with three main aspects of WPG are 1) Voltage control, 2) Frequency control and 3) Mitigation of output power variation. Simulation studies are carried out in MATLAB to verify the effectiveness of this proposed system.

KEYWORDS Supercapacitor(SC), Distribution generation(DG), Microgrid(MG), Voltage control(VC), Frequency control(FC), Wind power generation(WPG).

INTRODUCTION
WIND POWER generation is considered as the most economic viable alternative within the portfolio of renewable energy resources. While wind energy continues to grow worldwide, the industry will need to confront the challenges associated with higher levels of penetration. Grid connection of WPG is becoming an important form of DG [1].

With the increasing penetration of wind power, the fluctuating output of wind farms will considerably affect the operation of the interconnected grids. This situation can leads to severe problem that affect the PQ such as violations of voltage limit, system frequency, oscillations etc.., This condition causes low inertia in MG and requires an available enough fast spinning reserve.

For new wind farms, the types of interconnection studies that are required at the distribution level can be summarized interms of power quality and voltage impacts (short term and longterm). For bulk systems, the typical concerns are more related to the impact on stability, voltage support, and ability to balance the intermittency using complementary generation, typically by allocating sufficient spinning reserves. Various studies have been completed in these areas, [2],[3]; however, further work is still required in order to provide a generalized methodology, as existing methods are either not yet sufficient, or have not been made public

ENERGY STORAGE DEVICES SUPERMAGNETIC ENERGY STORAGE DEVICES
Superconducting magnetic energy storage (SMES) system, a device that stores energy in the magnetic field can instantly release stored energy and are considered ideal for shorter duration energy storage applications. It has been developed to smooth out the

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fluctuations in power generation. It improves power quality for critical loads and provides carryover energy during momentary voltage sags and power outages.The higher cost of superconductors is the primary barrier to commercial use of SMES as energy storage. The main drawback of the SMES technology is the need of a large amount of power to keep the coil at low temperatures.

FLYWHEEL

Flywheel stores energy in rotating mass. It stores kinetic energy in a high speed rotating drum which forms the rotor of a device. When surplus electrical energy is available it is used to speed up the drum. when the energy is needed the drum provides it by driving the generator. It can be maximally charged and have energy efficiency upto 90%.Flywheels have low specific energy. There are safety concerns associated with flywheel due to the high speed rotor and the possibility of it breaking loose and releasing all of its energy in an uncontrolled manner.

SUPERCAPACITORS

Supercapacitors stores power as static electricity. Like conventional capacitors , supercapacitors does not contain any dielectric material to separate the electrode. Instead they have activated carbon that when an electric charge is applied to a material a double electric field is generated acts like a dielectric. The main advantage of this is it can be operated over wide temperature and voltage range, it has longer life time, high storage efficiency.

PROPOSED CONTROL SCHEME

Fig.1 summarizes the proposed control scheme in detailed model. This model consists of the Power conditioning system, super capacitor, control block, filters and protective circuits.

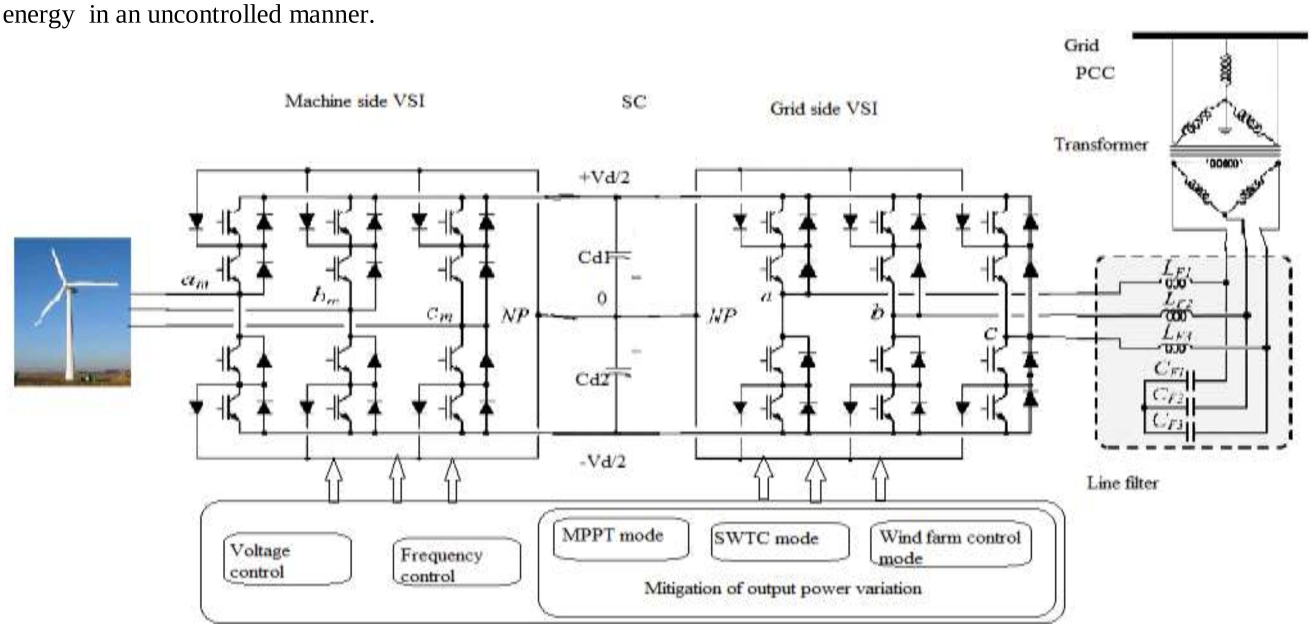

Fig.1 The proposed control scheme

POWER CONDITIONING SYSTEM

The PCS provides a power electronic interface between the electrical MG and wind plant to achieving two goals: one is to convert the electrical power with variable amplitude and frequency to the fixed amplitude and frequency, and the other is to charge/discharge efficiently the SC. A PCS is intended to improve the quality of the power that is delivered to electrical grid.

The PCS proposed in this paper is composed of a back-to-back ac/dc/ac converter that allows meeting all the specific MG code requirements of power quality, flexibility, efficiency and reliability demanded to modern DG systems. Two voltage source inverters (VSI) compose the core of the back-to-back converter, i.e., a machine-side inverter and a grid-side one. The grid-side VSI is shunt-connected to the distribution network by means of a step-up coupling transformer and the corresponding line sinusoidal filter, as described in Fig. 1 (right side). This grid-side inverter corresponds to a dc/ac static converter using high-power fast isolated gate bipolar transistors (IGBTs). In addition, the output voltage control of the VSI is

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achieved through sinusoidal pulse width modulation (SPWM) techniques [9].

The middle and internal levels have practically the same functions as the middle and internal control levels of the grid-side VSI, respectively. The main difference with the grid-side VSI control is that the synchronism angle to make the coordinate transformation is not computed via a PLL. In this case, the angle is obtained by measuring the position angle of the machine and multiplying by the number of pairs of poles

The external level is responsible for determining the active and reactive power exchange between the grid-side VSI and the utility system. The external level control is designed for performing the active power control and the voltage control.. The middle level control allows the expected output to dynamically track the reference values set by the external level. This block has two main parts, the current regulator and the dc voltage regulator. For the current regulator, the control is performed with the synchronous dq rotating reference frame with conventional PI controllers.

Supercapacitors are also known variously as electric double layer capacitors, ultracapacitors, and Electrochemical Double Layer Capacitors (EDLC). They have a very high energy density and are governed by the same equations as all capacitors. The value of capacitance is given by (1).

$$C = A/d \qquad (1)$$

Supercapacitors use a porous carbon-based electrode and the surface area of this porous material is around 2,000,000 m2/kg. The charge separation distance (less than 10 angstroms) is much smaller than what can bebaccomplished using conventional dielectric materials. These properties give the supercapacitors their extremely high capacitance in accordance with (1), with values reaching 5000 F. The equivalent series resistance, Resr , limits the charge/discharge current of the device and contributes to internal heating.The parallel resistance, Repr, simulates the energy loss due to self-discharge.

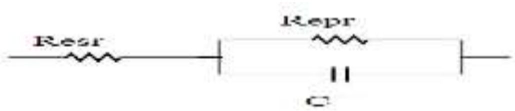

Fig.2.Super capacitor equivalent circuit

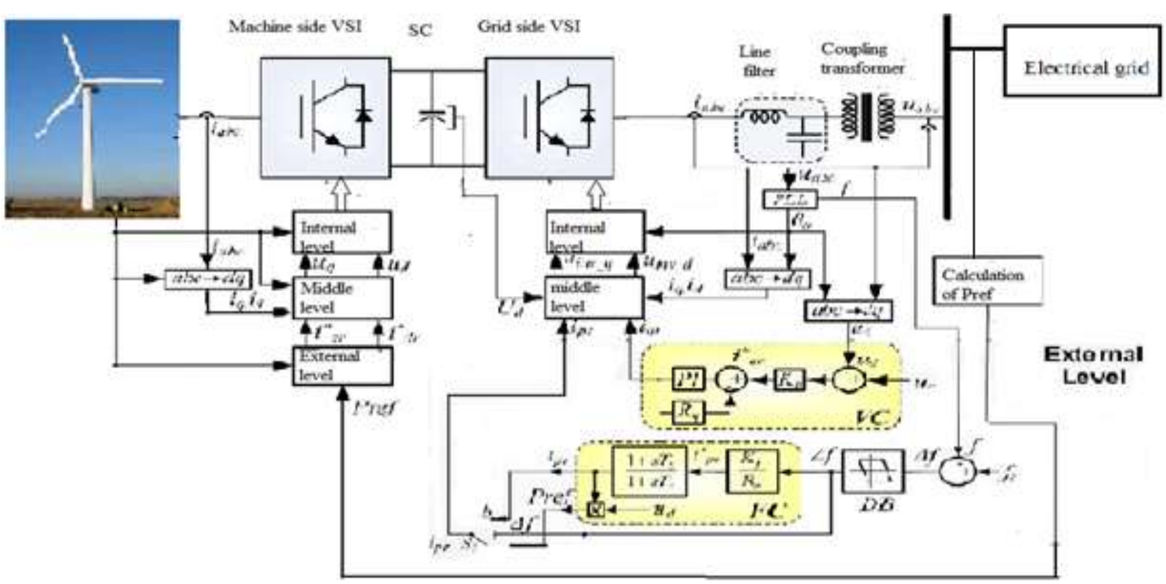

Fig.3.Structure of the multi control in wind mill

CONTROL STRATEGIES

VOLTAGE CONTROL

The VC consists in controlling the voltage at the PCC (point of common coupling) of the device through the modulation of the reactive component of the output current. To this aim, the instantaneous voltage at the PCC(Ud) is computed by using a synchronous-rotating orthogonal reference frame and is then compared with a reference voltage(Ur). A voltage regulation droop (or slope) Rq is included in order to allow the terminal voltage of the device to vary in proportion with the compensating reactive current.

FREQUENCY CONTROL

The frequency control block is responsible for determining the active power exchange with the electrical system when it is necessary to recover the system frequency after eventual faults of some system components. A simple structure of the frequency control is shown in Fig. 3

This control is in charge of minimizing the magnitude and duration of system disturbances by damping power oscillations. The purpose of this is to keep the system frequency above the acceptable minimum level during the transient dynamics. Power oscillations can be damped by themodulation of the active component of the output current. The FC mode is only activated when significant frequency deviations arise. To do this, S1and S2 are switched from position to when the frequency deviation exceeds the dead-band value. S1 manages the active power reference for the FES and S2 manages the active current reference of the grid-side VSI.

According to the FC mode, the FES device must be partially charged at a specific rating to allow power to be absorbed or injected from or into the grid at any time. This permits to counteract positive and negative power changes in the utility system. The level of charge of the FES is controlled by the APS mode that it is in charge ofmaking a suitablemanagement of the stored energy so as to prevent the FES become overloaded or run out of charge.

MITIGATION OF OUTPUT POWER VARIATION BLOCK

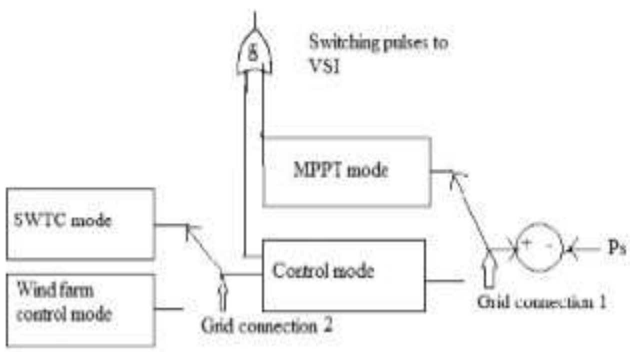

Fig.4. Control of output power variation

This block consists of three modes of operation such as maximum power point tracking (MPPT) mode, single wind turbine control mode and wind farm control mode to control the output power of wind turbines as well as overall wind farms.

MPPT MODE

Every wind turbines are basically operated in MPPT mode. If wind speed changes, the MPPT block automatically calculate the optimal rotor speed reference or optimal tip speed ratio. The rotor side converter in DFIG controls the rotor speed to follow this reference so that the efficiency of wind turbine is maximized.

SINGLE WIND TURBINE CONTROL MODE

To achieve this operation, basically we use the method of hysteresis control. The purpose of hysteresis control is to reduce the power fluctuation duriong small wind speed changes. In this control mode, the final output reference of wind turbine is Pd*. Therefore, the continuous mismatch between Pmech of the mechanical input and Pd* of the electrical demand output can cause the rotor speed variation. For this reason, when the rotor speed exceeds a certain limit, the overall reference power set point should be moved by using the rotor speed limit algorithm in Fig. 4. If the rotor speed exceeds 25% of its nominal value, then pitch control is activated first to reduce rotor speed and the reference power set point is increased. If the rotor speed is below 25% of its nominal value, only the reference value is decreased. These actions will make the rotor speed remain in the boundary.

The wind farm control mode is to regulate the net active power of a wind farm. The wind farm control mode also uses hysteresis loop, a rate limiter and a rotor speed limit algorithm. In the first step, it calculates the expected maximum value of total active power in the wind farm from the wind speed of each wind turbine. This value passes through a low pass filter to reduce frequency variation of the output power before hysteresis control. In the next step, the Pmech

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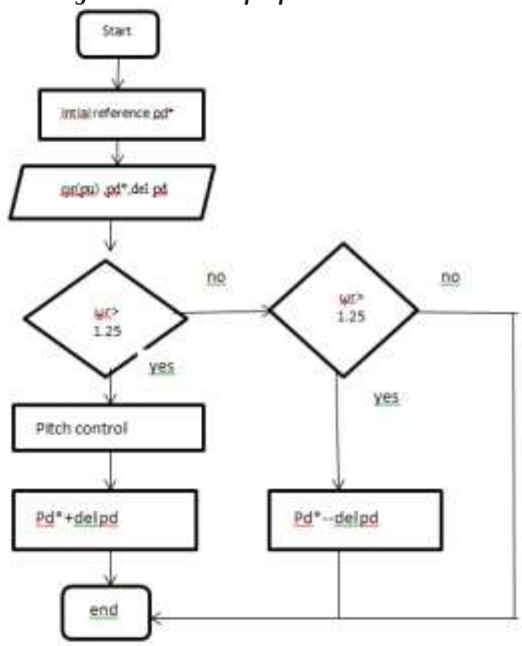
considering real active power of the wind farm by using the reference revision algorithm in algorithm.

Fig. 6. Flowchart of reference revision

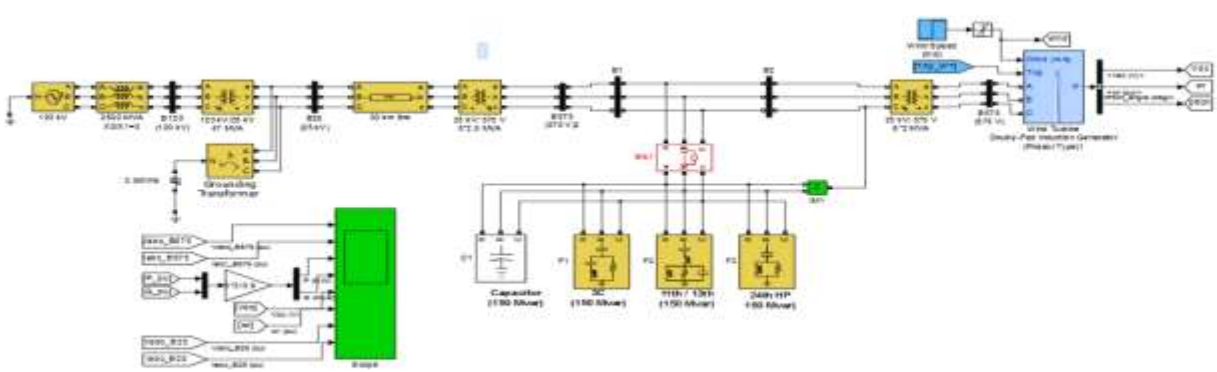


WIND FARM CONTROL MODE

TEST SYSTEM

The simulated power system used to validate the principle, operation and control methodologies of voltage, frequency and power variations to enhance the integrity of wind power system. Also this model is used to evaluate the advanced behavior of super capacitor in the role of charging and discharging in needs.

fig 7. Simulation model of the proposed scheme



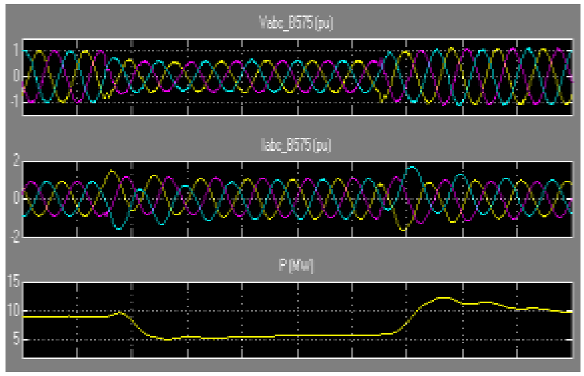


Fig 8. SimulatedOutput

CONCLUSION

This paper presents a control aspects of a wind plant to improve the integration of wind turbines in to grid interactive AC microgrids. A proposal is made for the control algorithm of the devices using three control modes. The first mode is used to maintain the constant voltage at the point of common coupling.

The second mode is used to contribute to the frequency control when important fault arise in the system. And the third mode is used to mitigate the power variations. With these control modes, the power quality of wind generators is improved and, at the same time, a good use of the energy stored is achieved.

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