THE IMPORTANCE OF INTEGRATING SYNCHRONOUS COMPENSATOR STATCOM IN WIND POWER PLANT CONNECTED INTO THE MEDIUM VOLTAGE GRID

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Abstract - Integration of wind power plant in medium voltage grid is comply with the same regulations as conventional plants. To realize in the point of common coupling grid, reactive power levels as close to zero is necessary to use reactive power compensators and ensuring the compensation. Static compensators STATCOM shunt satisfy this requirement very well, by absorption / injection of reactive power from / to grid based on the voltage amplitude the point of common coupling at grid. The article presents the behavior of wind power plant, which is connected to the compensator STATCOM, on medium voltage fault and the importance using it in the wind power plant

Keywords: Wind energy, system protection, medium voltage.

1. INTRODUCTION

In "Romania's energy strategy for the period 2007 - 2020", one of the priorities of development of the Romanian sector is to promote energy production based on renewable resources, so the share of these resources in the total gross consumption of electricity to be 33% - 2010 35% - 2015 and 38% - 2020. It is noted that these percentages are not an upper limit, but only a minimal that the Romanian Government was committed to touch. [8]

Connecting wind farms to electricity grids requires solving a large number of technical problems to achieve safe operation of these sources in the electricity system and maintaining the system into operation in their presence. [7]

1.1.Wind turbine configurations

The most used configurations for wind turbines are classified ability to control speed and power adjustment by the method used by the respective turbine. If one considers the method of speed control as classification criterion, may present four turbines of the most used. These configurations can however classify by control mode after power supplied.

Power groups used in wind turbines are of two categories, depending on the speed control: fixed speed and variable speed.

- Type A fixed speed turbine,
- Type B: variable speed limited turbine
- Type C: variable speed turbine and inverter power lower than the nominal power

Type: variable speed turbine and inverter power equal to nominal power

<u>*Type A fixed speed turbine*</u> - This configuration is known as the "Danish concept" that uses a squirrel cage induction generator to convert mechanical energy into electricity. The difference in speed turbine rotor and asynchronous generator speed is necessary to use a multiplier (gearbox) which performs the necessary harmony between these two speeds. Sliding asynchronous generator varies little as generated power increases without remains substantially constant. Since the electric machine speed variations are below 1%, this type of turbine is considered to operate at a constant speed or fixed speed. [9,10]

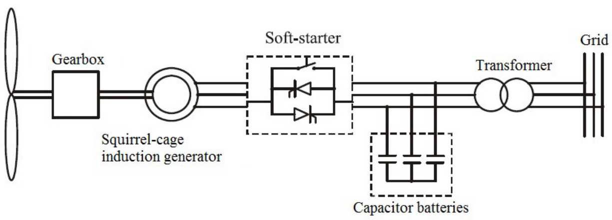

Fig.1. Wind turbine type A - fixed speed (the Danish concept).

Fixed speed turbine is currently under active aerodynamic braking systems (stall control) even though they were designed turbine systems with fixed speed and adjusting the angle of attack. Squirrel cage induction generator rotor is connected to the grid by a transformer. Due to changes in voltage, asynchronous generator absorbs reactive power from the grid. For this reason, the configuration shown uses a capacitor battery with the role of compensating the reactive power. Connecting to the grid is performed through a soft starter with the role to prevent shocks if the current conditions in parallel coupling of the two power sources (asynchronous generator and grid) are not met. [10]

Whichever method to control power generated, it should be noted that fluctuations in wind speed is transformed into mechanical power fluctuations and therefore fluctuations in electrical power. If a small grid, these fluctuations in electrical power give rise to variations in the voltage at the point of connection to the network. [10,3]

Technical codes of the transport or distribution of electricity contain requirements that apply to all power plants in the point of common coupling (PCC) of their power system, including wind farms. [3,4]

The main requirements for wind power in the PCC refers to:

- The provision of reactive power;
- The possibility of crossing over fault (foul ride-through) produced electrical power system grid;
- Voltage control;
- Control of power quality (voltage fluctuations, harmonics, voltage dips, overvoltage industrial frequency);
- Frequency control.

Modern solutions control quickly and automatically voltage fluctuations and power electronic systems used to control reactive power flow.

Systems FACTS (Flexible Alternating Current Transmission System) built based on power electronic circuits, ensure state control of electrical quantities to achieve the necessary transfer of power in electric networks. [3.4]

FACTS devices can control parameters quickly and sizes of condition of power lines, such as line impedance, voltages and phase angles of the voltages at both ends of the line. Their use can lead to improvements in the operation of power systems by increasing transport capacity of power lines, power lines according to circulation, improving static and transient stability reserves, power oscillation amortization. [3]

FACTS main type structures are used today to control voltage and power fluctuations and power grid enhancers or being developed are [4]:

- FACTS devices for voltage and reactive power control:
  - SVC (Static VAR Compensator)
  - STATCOM (Static Syncronous Compensator)
- FACTS devices for longitudinal control of the electrical reactance:
  - TCSC (Thyristor Controlled Series Compensator)
- FACTS devices for controlling the angle of dephasing:
  - SSSC (Static Synchronous Series Compensator)
- FACTS devices to control power and voltage fluctuations
  - UPFC (Unified Power Flow Controller)

1.2.Static synchronous compensator shunt (STATCOM)

It is a device that uses power electronics with forced commutation (eg GTO - Gate turn-off thyristor, IGBT - insulated gate bipolar transistors) to control voltage and power flow, and improving the transient stability into electricity grids.

STATCOM uses a voltage source converter to absorb or inject in nodes grid is connected amount of reactive power to control voltage in node connection or flow control reactive on power line connection at the power system [1, 2].

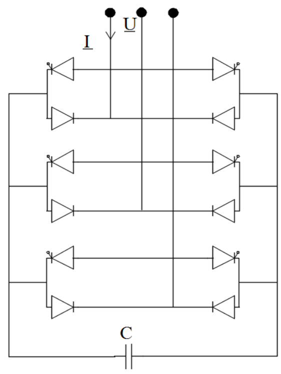

Fig.2. Three-phase scheme of STATCOM

STATCOM is the most efficient synchronous compensator shunt, his answer is the same as the synchronous compensators (rotating) and, moreover, has no mechanical inertia. The three-phase schematic diagram is shown in Fig. 2.

A STATCOM can be used in two ways

a) *The voltage control mode connection.*

STATCOM regulates voltage into the mains connection point by controlling the reactive power absorbed or injected into the power grid through a converter VSC. Reactive power absorbed or injected into the grid by this device depends on the voltage amplitude in the connection point. When the voltage amplitude into the connection point is higher than the reference value (Uref), STATCOM absorbs reactive power from the grid and thus reduce the tension in the connecting node (comparison inductive STATCOM). When the voltage amplitude into their grid connection point is lower than the reference value (Uref), STATCOM inject reactive power into the power grid and thus there is an increase in tension in the node grid connection (comparison capacitive STATCOM)

b) *Reactive power control mode in the connection node*

In this mode of operation is controlled STATCOM reactive power output, independent of other parameters of grid.

1.3.The effect on the quality of electrical energy in electric grid

Depending on the technology used to convert wind energy to electricity grid connecting wind farms may create certain problems which, if not resolved, may reduce power quality supplied to consumers. This might result in some damage to users, and penalties for grid operator. [19].

Mainly it is necessary to consider the following issues that occur when connecting wind power plants (units) in electrical power grid:

- Voltage variations in electricity network;
- Voltage dips and overvoltage temporary to connection and disconnection of wind turbines;
- Voltage fluctuations/ flicker;
- Emission of harmonics and interharmonics;
- Unbalance;
- Disruption of centralized remote systems.

The impact of the disturbance on the power quality depends to a large extent by the short-circuit power at the point where the wind power plant is connected.

A low-power power system is a factor that can dramatically limit the number and power of the wind power that can be connected to that grid. How to connect to the grid can also be a factor. Thus, the computer systems used for network connections allow the limitation or avoidance of voltage fluctuations, but could cause significant disturbances in the form of harmonics.

1.4.Circulation of reactive power and voltage control

Connecting the wind groups can change profile voltage electricity distribution grid due to changes in circulation active and reactive power through line impedances. Generally the point of connection to the grid voltage increases to connect wind farms compared to the where they are lacking.. [5,3] .

Changing the voltage profile in different operating modes depends largely on the short-circuit current of the grid analyzed and reactive power which traverse the grid analyzed.

In normal operation, to ensure safe operation, it is necessary to maintain voltage within the prescribed limits. It should be noted that the presence of wind power into the power grid can improve the voltage profile along the line. Increased voltage on medium voltage lines must be linked to control transformers MV / LV for not cause dangerous increases in blood level of LV [3,4].

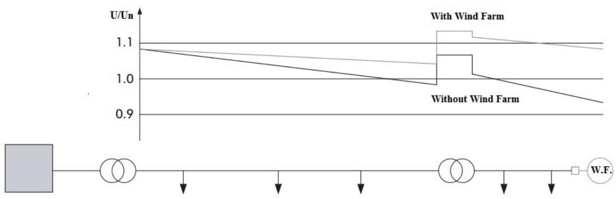

Fig.3. The influence of wind groups on the profile voltage in an electrical distribution grid

In Fig.3. [6,3] is shown, for example, the influence of voltage control by wind turbines into the electricity distribution network.

1.5.Effects of dips and voltage interruptions on wind groups.

The effects of voltage dips and short interruptions on wind generators depends largely on the type of generator.

If squirrel cage induction generator stator is connected directly to the network and has a practically constant speed. The occurrence of a voltage dip or short interruptions, the rotational speed of the generator can greatly increase and it may lose stability. The existence of a drive machine shaft can limit the effects of short duration and therefore the risk of disconnection due to wind turbine overspeed admitted.

If a short circuit which causes a voltage dip, squirrel cage asynchronous machine may charge an electric current inductively 2-3 times higher than the rated current. When connecting the machine may appear large variations in electric current due to absorption of reactive power necessary for its magnetization of the magnetic circuit.

1.6.Limiting the effects of dips and of short duration interruptions

Modern control power flow can ensure limitation disturbances due to voltage dips and of short duration interruptions using FACTS systems (Flexible Alternating Current Transmission Systems) built on the power electronic circuits. They are used in particular DSTATCOM static compensator (distribution static compensator), dynamic voltage compensator DVR and power quality conditioner UPQC (Unified Power Quality conditioner). These devices use energy storage system to provide the required reactive power compensation to reduce voltage.

DSTATCOM type circuits are used to control voltage and reactive power at the point of connection for power factor correction (harmonics and reactive power). Depending on the strategy type DSTATCOM control circuits can be used to limit the voltage fluctuations, harmonics or voltage dips.

The possibility of limiting the voltage dips depends on the capacity of energy storage capacitors, semiconductor nominal current of the inverter and the nominal power transformer coupling.

2. SIMULATION AND DISCUSSION

To simulate the behavior of a wind farm will start from the calculation of wind turbine power output up protections and simulation of defects having STATCOM device connected or disconnected.

For a wind group we have:

$\rho = 1.23 kg / m^2$ air density

A= rotor area

v=12 m/s – wind speed

$c_p = 0.4$ - power factor taken into account

r=l=34 m – length of a wind turbine blade related

$$A = \pi \bullet r^2 = 3.14 \bullet 34^2 = 3630 m^2$$

$$P = \frac{1}{2} \bullet \rho \bullet A \bullet c_p \bullet v^3 =$$

$$= \frac{1}{2} \bullet 1.23 \bullet 3630 \bullet 0.4 \bullet 12^3 = 1.543 MW$$

$$P_{T-wind/farm} = 6 * 1.543 \approx 9 MW$$

Plant will be composed of a six groups of 1.5 MW per plant resulting in a total power of approximately 9 MW.

Wind plant is equipped with squirrel cage induction generators. Within the plant was connected to a device STATCOM reactive power compensation.

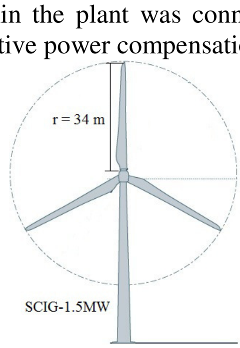

Fig.4. Wind turbine - 1.5 MW equipped with squirrel cage induction generator

Besides this device, within the wind farm, the transformers connected on the low voltage and three batteries capacitors totaling 1.2 MVAr.

Wind plant is connected to a 20 kV line, which are connected four consumers 800 kW - C1, 300 kW - C2, 500 kW - C3 respectively C4-1MW.

Plant injects a 110/20 kV station. Adjustments protections will be chosen in such a way that there is selectivity between protections.

The line for the connection of wind farm:

a) fast overcurrent protection (with sectioning current)

$I_{maxI}=3000A\ t=0,2s$

b) delayed overcurrent protection

$I_{maxII}=360\ A\ t=1,5s$

The line for the connection 3 consumer

a) fast overcurrent protection (with sectioning current)

$I_{maxI}=1000A\ t=0s$

b) delayed overcurrent protection

$I_{maxII}=110\ A\ t=1s$

Like observation, so that supply lines and four consumers as wind power line that debits are fitted with RAR (rapid automatic reclosing)

As protection of the wind farm will include only those that affect the simulation.

Values settings protections will choose from the recommended range of standards.

a) fast overcurrent protection (with sectioning current)

$I_{maxI}=2800A\ t=0s$

b) delayed overcurrent protection

$I_{maxII}=330\ A\ t=1s$

c) the minimum voltage protection

$U_{min}=0,7\cdot U_{ref}=0,7\cdot 21kV=14,7kV\ \ t=0,3s$ – *the phase voltage*

$U_{min}=0,7\cdot U_{ref}=0,7\cdot 12kV=8,4kV\ t=0,3s$ – *the line voltage*

d) protecția de maximă tensiune

$U_{max}=1,1\cdot U_{ref}=1,1\cdot 21kV=23,1kV\ \ t=0,3s$ – *the phase voltage*

$U_{max}=1,1\cdot U_{ref}=1,1\cdot 12kV=13,2kV\ t=0,3s$ –*the line voltage*

e) protection against voltage asymmetry 5% t=10s

f) minimum frequency protection

$f_{min}=47Hz\ t=0,5s$

g) minimum frequency protection

$f_{max}=52Hz\ t=0,5s$

Using Matlab - Simulink we do simulations on the wind farm presented in Fig.6.

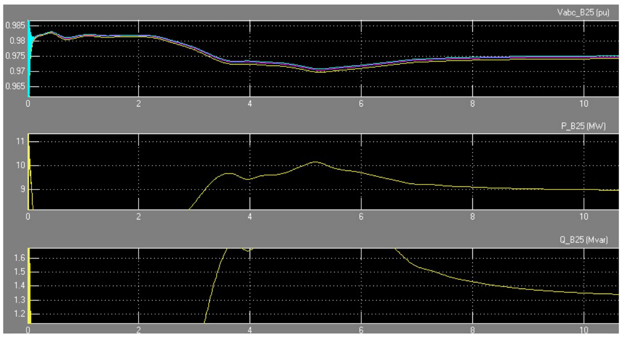

Fig.5. Grid operation with compensator STATCOM connected

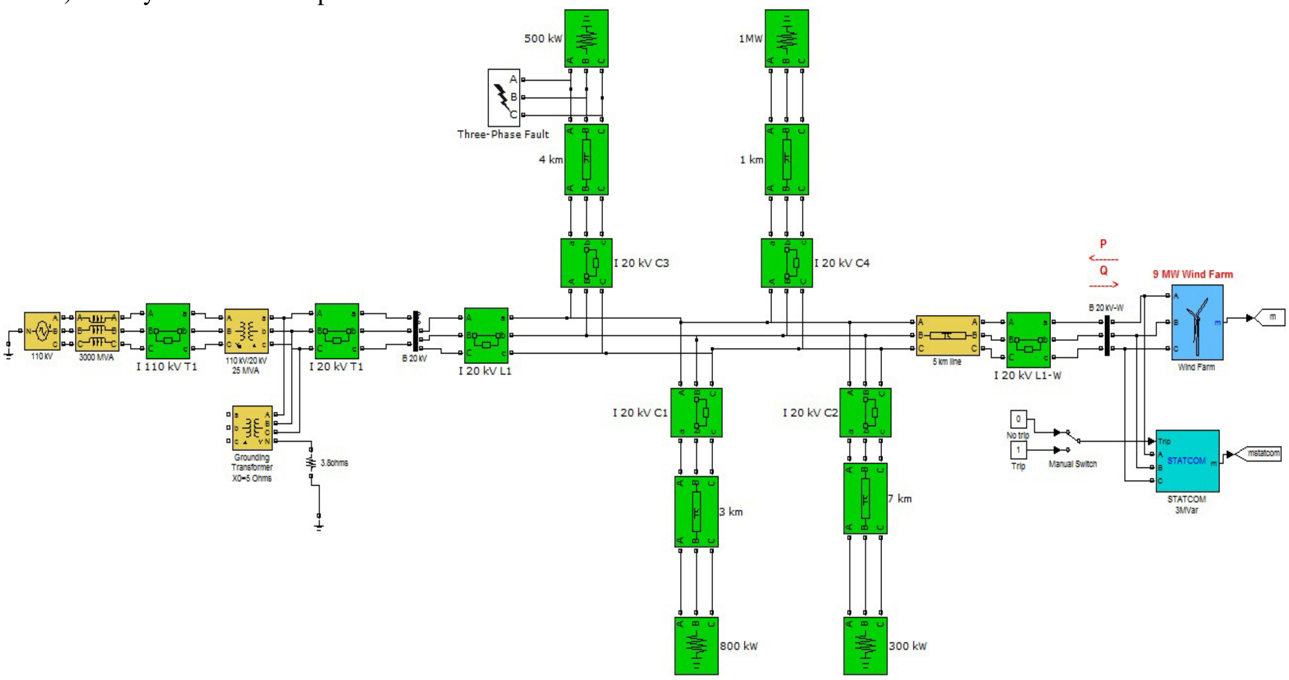

Fig.6. The scheme of the proposed grid simulation

As you can see in Fig.5. using compensator STATCOM connected voltage on medium voltage bar from point of common coupling is maintained at the value of 0.97 p.u. in all three phases. To produce the entire active power of 9 MW, asynchronous squirrel cage generators need a 3 MVAr reactive This power shall be obtained through capacitor (1.2 MVAr) and the rest is taken from static shunt compensator STATCOM (1.8 MVAr). Excess reactive power produced by the device STATCOM (MVAr 1.2) is included in the medium voltage grid and has the effect of maintaining the voltage value of 0.97 p.u.

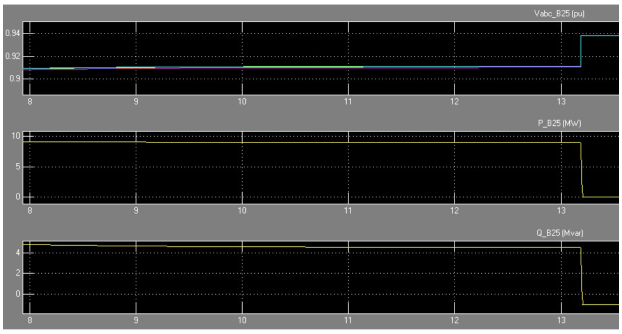

Fig.7. Grid operation with compensator STATCOM disconnected

After disconnecting the device STATCOM (Fig.7.) Voltage value decreases from 0.97 p.u. the value of 0,91p.u and kept constant until t = 13.1 s groups when out of service due to high consumption of reactive power from the grid.

Next was simulated a short three phase line which powered consumer with the device 3 STATCOM connected and disconnected in the wind power plant.

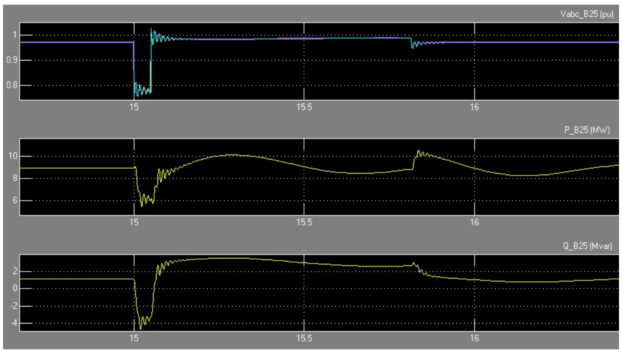

Fig.8. Three-phase fault on line that supplies the consumer 3

When (Fig.8.) t = 15s a three phase defect occurs, current whose value was set at 1500 A. Rapidly overcurrent protection starts and give an impulse of tripping at I 20 kV for the consumer 3. After 0.8 s after the trippind of breaker, RAR automation reconnects breaker and consumer sites is refueled with electricity. As can be seen, measured parameters on medium voltage bar from point of common coupling between 15-16s have disturbed values, and return to normal after t = 17s.

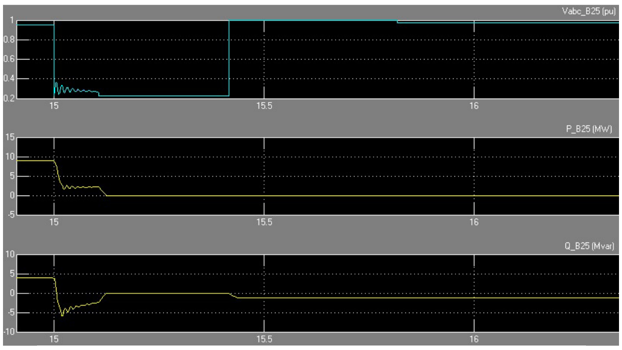

Fig.9. Three-phase fault on line that supplies the consumer 3 - STATCOM disconnected

Have been preserved the values before and was disconnected STATCOM device (Fig.9.). Disconnect the device STATCOM make the necessary reactive power to be consumed on the grid, leading to the decrease voltage on medium voltage bar from point of common coupling, under value adjustment of the protections of minimum voltage related groups wind, and therefore out of operation of groups. After out the operation of groups, medium voltage bar from point of common coupling remains energized from grid.

3. CONCLUSIONS

Using devices for reactive power compensation STATCOM type and elsewhere, is of particular importance for the functioning at the parameters corresponding of wind farms. Inexistence or disconnecting devices for reactive power compensation, results in a very high consumption of reactive power from the grid. This lowers the voltage on medium voltage bar from point of common coupling and wind the output of operation groups. Besides the reactive power compensation, STATCOM devices also contributes to the maintenance voltage of medium voltage bar depending on amplitude of voltage. When the voltage amplitude into point of common coupling decreases below a set value, the device STATCOM injected reactive power into the grid. When the voltage amplitude into point of common coupling increases above a certain value, the device STATCOM absorbs reactive power from the grid.

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