FRT Improvement of FSIG based Wind Farm with Electric Spring

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Abstract: *As world is growing, demand for power is increasing continuously as well there is a need to find new energy resources. It is obvious to get maximum efficiency and utilization from existing energy sources. Now a days due to high cost and more consumption of non-renewable and natural energy resources, researchers have focused on renewable energy sources. This paper presents a one of the renewable energy source wind farm which generates power, and fact device is presented which provides a reactive power in actual generation of wind farm, when disturbance occurs in network. Wind farm contains fixed speed induction generator (FSIG). Concept of PI control logic is applied here which generates a trigger pulses for Statcom to fire and to inject reactive power whenever disturbances or fault occurs. Statcom have a fault ride through (FRT) capability and PI gives immediate response to control signals. LLG fault is simulated here to examine the results with Statcom. But here a recent concept comes as more advanced technique which is Electric spring. Electric spring also helps in LVRT/FRT improvement of FSIG based wind farm when fault occurs.*

Key Words: *fault ride through, fact device, PI logic control, Electric Spring, Statcom*

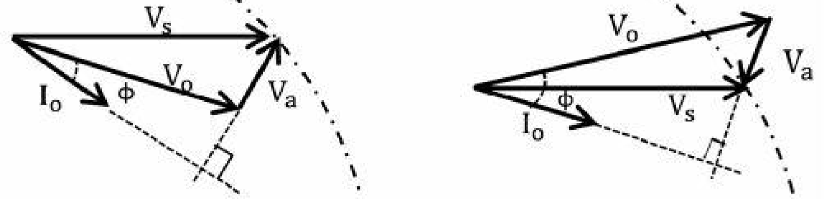
1. INTRODUCTION:

Now a days due to limited number and size of natural resources and because of expansion and growth in electrical utility need occurs to utilize renewable energy sources maximum from available. There may be a disturbance as natural resources are not fixed. Generally easily available natural resources are wind and sun rays. Wind is mechanical input to turbine and power is generated from it, is called wind farm. This wind is not constant throughout the day, year or some particular season. There may be a variation and due to this variation, there may occur variation in power generation capacity. Power may be reduced to some extent which may shutdown device or plant. Some another reason may be a fault in network. And this fault needs to compensate and we need transmission stability and thermal limit. We need to improve quality of power deliver. There is a need of optimum and profitable operation in generation transmission and distribution. We require efficient utilization and control of the existing transmission system infrastructure.

Wind power is Inconsistent, Incoherent with demand. It have about 25% - Utilization factor. Wind farm requires negligible maintenance and recurring cost. India ranks a 4th in wind generating capacity (5,500 MW- India, 59,000 MW- Global). India have a wind power potential of 45,000 MW. Wind speeds in India tend to be significantly lower compared to other major wind power nations of the world. Indian average wind speed can be as low as 1.5 – 2 m/s. Conceptual Design of new wind turbine configuration that enables by-passing the classical theoretical Betz limit of 0.59 for the power coefficient to enable development of low cut-in speed wind turbines. But as it is not possible to cross the bet'z limit till now, still we can try to get maximum power from wind farm either by keeping some good control strategy or by using some fact device to inject reactive power whenever fault occurs.

This paper presents a FSIG based wind farm connected with infinite bus, having capacity of 50MW, 60Hz. Statcom as a fact device is used to inject reactive power, whenever active power decreases due to fault in FSIG based wind farm. Electric Spring is more effective approach to get override through FRT and it is the only device which is connected in series with Load, except all other devices are getting connected in Parallel. Electric spring has capacity to absorb as well inject reactive power and its function is similar to mechanical spring.

2. OPERATING PRINCIPLE:



(a) Capacitive mode (b) Inductive mode
Figure 1. Phase diagram of Electric spring with Resistive-Inductive Load

Consider a phasor diagram as shown above. Vs is source voltage and Vo is load voltage. Va is compensating voltage from Electric spring and Io is load current. Electric spring can be utilized for both active and reactive power compensation. For an ES to be loss less, Voltage from ES should be perpendicular to Io load current. This means for resistive inductive load, Va is leading Io by 90degree and gives capacitive compensation and vice versa for inductive compensation. Total sum of load voltage Vo and ES voltage Va is equal to device voltage Vs. In steady state condition

$Ps = P0 \pm Pa$

$Qs = Q0 \pm Qa$ …… (1)

The ES power, the load power and the power source are expressed below

$\bar{P}a = |Va| \times |I0| \cos(\delta + \phi v)$

$Qa = |Va| \times |I0| \sin(\delta + \phi v)$ …… (2)

$P0 = |V0| \times |I0| \cos\theta$

$Q0 = |V0| \times |I0| \sin\theta$ …… (3)

$\bar{P}s = |Vs| \times |I0| \cos\delta$

$Qs = |Vs| \times |I0| \sin\delta$ …… (4)

Where ϕv is the phase angle between the ES and power supply voltage, δ and θ are the power factor angle of the power supply and load, respectively. From (1)–(4), the load power can be calculated as shown in

$\bar{P}0 = |Vs| \times |I0| \cos\delta - |Va| \times |I0| \cos(\delta + \phi v)$

$Q0 = |Vs| \times |I0| \sin\delta - |Va| \times |I0| \sin(\delta + \phi v).$

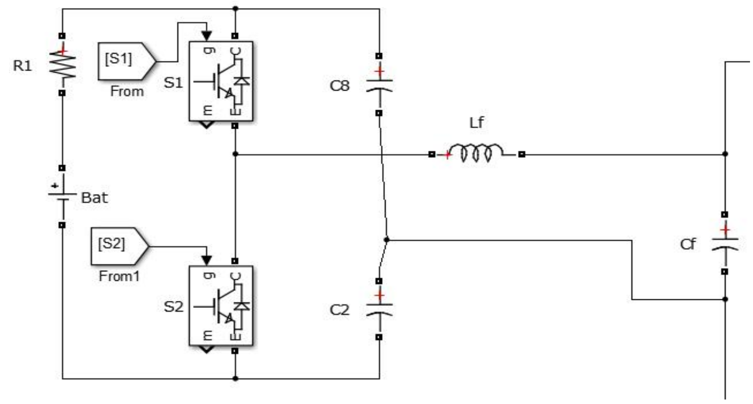


Figure 2: Electric Spring Logic

In Electric spring Battery is used as energy source which has capacity to get charge when over voltage on line and can release power when under voltage is observed on line.

3. SIMULATION:

A schematic of wind farm simulation strategy is shown. Wind farm generates 50MW of power. Main goal to present this simulation and to carry out this research work is to simulate fault at particular period in wind farm and to observe effect of power on transmission line. Statcom approach is presented to stabilize power. And comparative analysis with Electric spring is shown.

This simulation shows 50MW wind farms and fault is created on transmission line as shown in figure. Obviously whenever fault occurs, either voltage sag or swell will observed. Here voltage sag is created for simulation testing purpose.

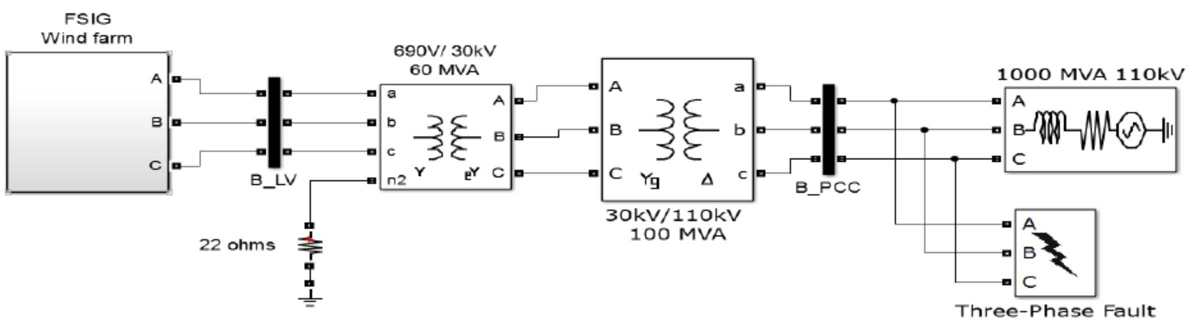


Figure 3: Simulink model without fact device

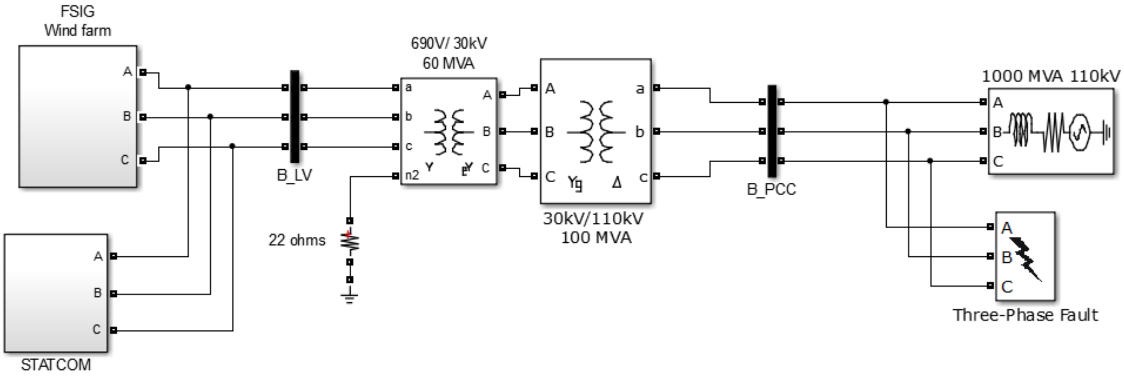


Figure 4: Simulink model with Statcom

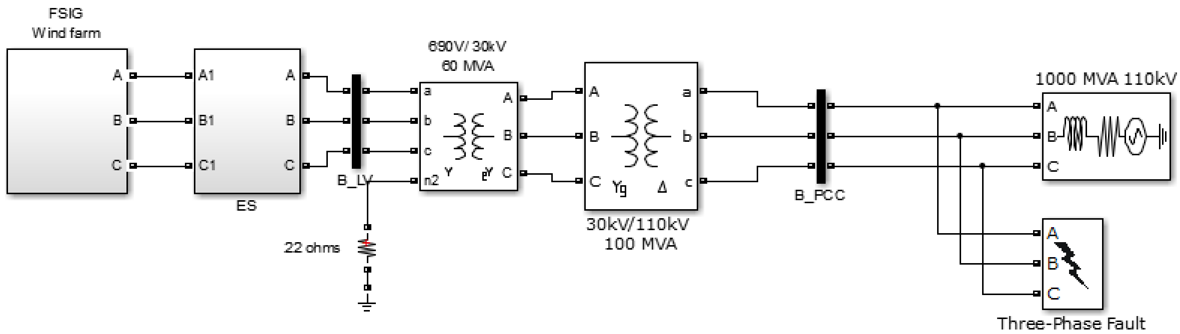


Figure 5: Simulink model with Electric Spring

4. PARAMETERS:

LLLG Fault resistance	0.3Ω
Wind farm	50MW
Reference voltage for p.u	110e3

Electric Spring

DC Battery	1200V
LC filter - L	1.3mH
LC filter - C	10µF

5. RESULT:

As seen is figure 4, when fault occurs, at the same time Statcom activates itself to inject reactive power in line and to maintain stability in transmission line. Waveforms for Statcom based fact device simulation is shown below.

From the result it can be seen that when fault occurs at that time fault is visible in simulation on time axis. But as Statcom control strategy is applied to inject reactive power, it activates itself by using a trigger signal and power quality is maintained whenever fault occurs. And in another simulation Electric spring is connected continuously with transmission line, and it monitors power on transmission line and try to maintain 1p.u of power. When voltage sag or swell gets detected Electric spring activated either to release power or to absorb power.

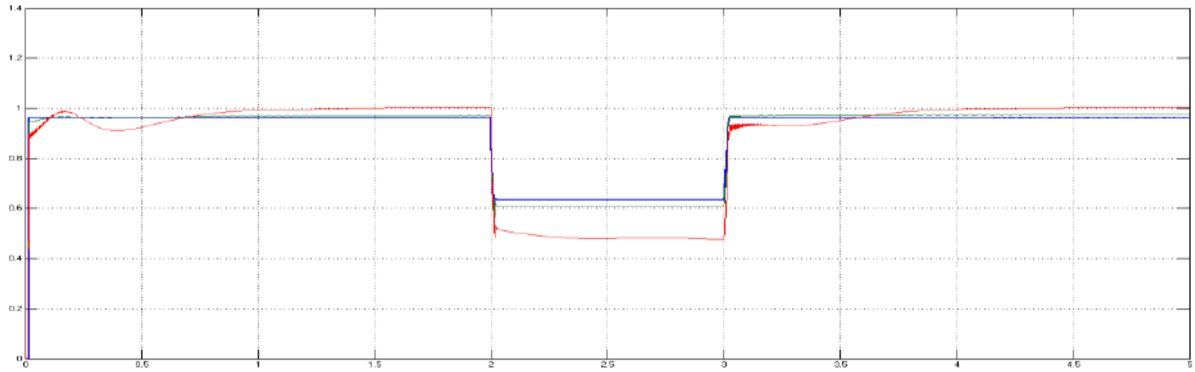


Figure 6: Results, (a) Red - No fact device (b) Blue - Electric Spring (c) Green – Statcom

6. CONCLUSION:

Improved utilization of the existing power system with fault is provided through the application of advanced control technologies. Power electronics based equipment STATCOM, or Flexible AC Transmission Systems (FACTS), provide proven technical solutions to address these new operating challenges being presented today. STATCOM technologies allow for improved transmission system operation with minimal infrastructure investment, environmental impact, and implementation time compared to the construction of new transmission lines.

Here using Electric spring technique for FRT improvement is working very well and provides immediate response to control signal and operation is executed immediately to inject power. Statcom recovers voltage at its nominal value at generator terminal. FSIG is preferred for low cost, and easy operation.

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