

Analysis of reactive power support on performance of grid integrated wind energy conversion system

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ABSTRACT

In an attempt to reduce the stress on conventional energy sources and to obtain energy in an environmental friendly manner much attention is focused on Wind Energy Conversion Systems (WECS). But, the intermittency of wind introduces enormous challenges in the operation of wind integrated power system which is associated with cost of operation, power loss and voltage security. In this work the improvement of voltage security aspect has been addressed. In this regards, the impact of reactive power (Q) support facility into the system at different capacity and in different operating scenario is demonstrated. The variation and analysis of system parameters wrt the Q change both during normal operating condition and during faulty situation has been demonstrated. A grid integrated WECS model has been developed in MATLAB/SIMULINK environment to demonstrate the effect of Q support on wind turbine generators (WTG) and grid at various wind profiles.

Index Terms—Reactive power, Wind turbine generator, Wind farm.

I.INTRODUCTION

THE fast expansion of wind power generation brings new requirements for wind energy integration into the network. One of the new challenging issues[1,2] is that a wind farm has to provide fault ride through capability and remain connected during network faults. Over the last few years, doubly fed induction generator (DFIG)-based wind turbines have been the preferred alternative for high-capacity wind farms. This is due to their ability to control electrical torque (hence active power) and reactive power exchange with the network [3]. Thus they provide variable speed operation and also superior performance in system stability during large disturbances. Moreover, variable speed operation leads to a higher energy yield given the same wind regime, reduces the dynamic loads on the tower and the gearbox. As the penetration of the wind [4] farms into the power system increases, ancillary services, such as voltage control provided by the wind turbines, become more significant.

In this paper three wind farms of different capacities are connected to grid through point of common coupling (PCC). Under different operating conditions their effect on systems real power (P), reactive power (Q), voltage and current are observed. From the results, an attempt is made to predict about the optimum

operating strategy during which the above operating parameters will not show major swing. Along with this the use of Q support in restoring the system back into normal operating condition has been demonstrated.

II.SYSTEM UNDER CONSIDERATION

A number of identical wind turbines are connected together to form three wind farm (WF) of capacity 2 MW, 3 MW and 4MW capacities. It is shown in the Figure 1. In implementing a wind farm connected to a grid through a PCC requires a separate step-up transformer at the PCC which is finally connected to the grid via Pi section T-Line. The difference between a single wind Turbine connected to a grid & a wind farm connected to grid can be seen by an additional transformers & individual transmission line connected to PCC.

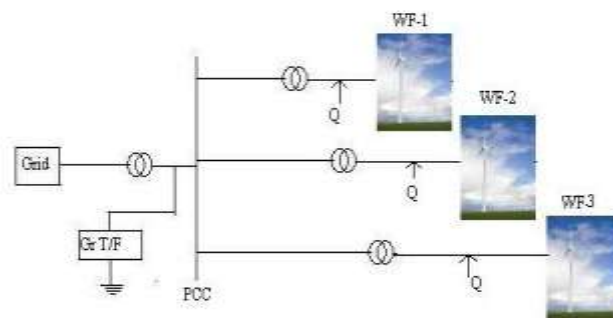


Fig.1. System under consideration

WF-1,WF-2 and WF-3 are assisted with reactive power support from three separate arrangements of shunt capacitors having a rated capacity of 300 kvar, 600 kvar and 1000kvar. The provision of Q support is arranged due to the fact that the exact prediction of future wind speed cannot be done accurately. This intermittent nature introduces two types of uncertainties [6,7].Those are under estimation and over estimation.

In this work attention is focused on analyzing the under estimation aspect.

When the scheduled power is found to be less than the capacity of actual wind power available, the scenario is known as *under estimation*. During underestimation, there will be a surplus amount of available wind power. From the system operation point of view, the ISO should maximize the utilization of available wind power. If the actual available real power output from the wind turbine generator increases, the reactive power profile deteriorates. This in turn affects the system voltage. To prevent the degradation of system voltage profile [8], it becomes necessary to give the system the necessary Q support so that system may be run in a voltage secure manner.

III.SIMULATION, RESULTS AND DISCUSSION

In this work, performance of the wind integrated power system analysis is carried in two different scenarios. Those are

(i) Pre-disturbance system analysis without Q support. (Case1)

(ii) Post-disturbance system analysis with Q support. (Case2)

For post disturbance analysis, first of all a 3-phase to ground fault is intentionally introduced in the system, so that its impact on system parameters and operation of nearby wind farm can be demonstrated.

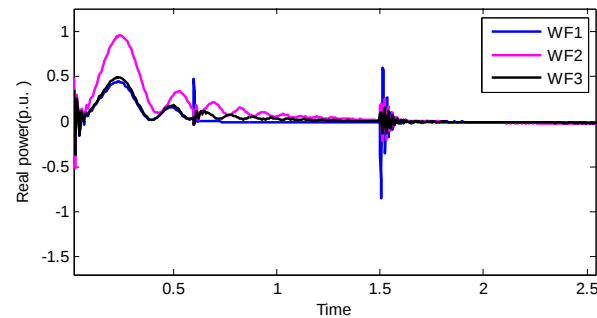


Fig.2. P variation during Case1

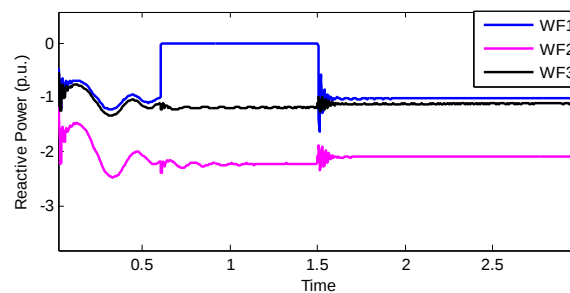


Fig.3. Q variation during Case1

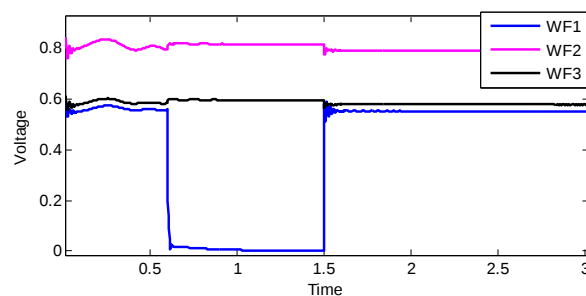


Fig.4. V variation during Case1

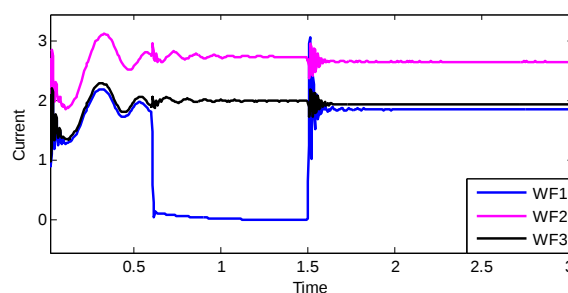


Fig.5. I variation during Case1

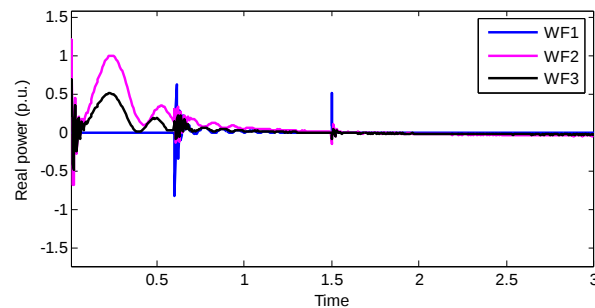


Fig.6. P variation during Case2.

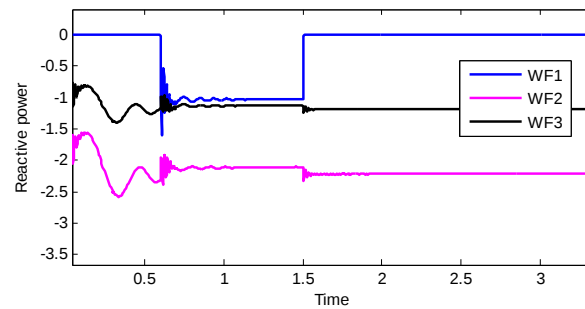


Fig.7. Q variation during Case2.

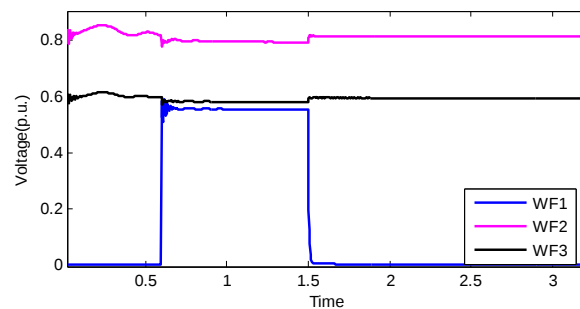


Fig.8. V variation during Case2.

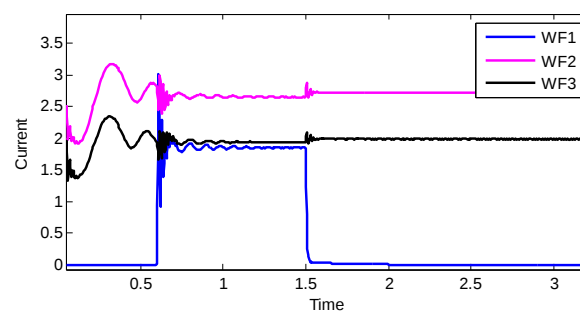


Fig.9. I variation during Case2.

From the above figures, the following remarks may be drawn

- Comparing Fig.2 and Fig.6, it may be seen that during normal operating condition, real power swing was there in the system up to time duration of 1.75 seconds. This may be due to the intermittent nature of wind. But even after creating intentionally a fault in the system, due to the Q support provided by the shunt capacitor bank, these oscillations are considerably damped. The effect of 3Ph-ground fault was seen by 0.65 sec which was cleared by 1.4 sec. But as the fault was created in the transmission link connecting WF1; therefore to clear its effect 0.11sec more was required. But the prominent effect of Q support can be seen in terms of reduction of strength of attenuation of P value at 1.5 sec between Fig.2 and Fig.6.
- Comparison between Fig.2 and Fig.6 illustrates that, in the absence of Q support some major Q variations were there in all the three WFs by a time span of 1.5 seconds. But this aspect is overcome in post disturbance states. The Q support aspect was clearly demonstrated during 0.6 sec to 1.5 sec incase of WF1.
- As WF-2 shows better Q capability profile amongst other WFs, its reflections are observed in the voltage profiles of WFs. This may be visualized by comparing Fig.4 and Fig.8.
- It may also be seen that during Case-1, in the absence of Q support the voltage profile of WF-1 was degraded during 0.6sec to 1.5 sec (Fig.4). But in Case-2, due to the Q support the system voltage profile was considerably improved during the above mentioned time even though the system was under the influence of fault (Fig.8) .
- Considerable improvement in the magnitude of current was also observed in Fig.9 as compared to Fig.5. Also strength of current variation at about 1.5 sec in case-1(Fig.5) is substantially improved in case-2 (Fig-9).
- From Fig.2-Fig.9, it may also be noted that during normal operating condition WF-2 was giving better response as compared to WF-1 and WF-3 though it was not so remarkable. But the characteristics were retained even after occurrence of fault. It suggests that fault in any wind farm is not going to miserably affect the system response of other WECS if proper Q support is being exercised.

IV.CONCLUSION

This work demonstrates the significance and impact of reactive power on the functioning of grid integrated WECS. It may be summarized from the results that effective clearance of fault within shortest span of time and maintaining synchronism with grid may be properly maintained in the presence of reactive power support. Along with fault clearance, the severity of fault may also be reduced significantly if proper Q support arrangements are done. For simplicity of modeling this work has taken the use of shunt capacitors for providing the necessary Q support but besides using this, also shunt FACTS devices like SVC and STATCOM may be considered as a more appropriate option for the above purpose.

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