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A critical review of voltage and reactive power management of wind farms

A.K. Pathak [a,*], M.P Sharma [b], Mahesh Bundele [a]

[a] Poornima University, Jaipur 302021, India
[b] RRVPNL, Jaipur 302021, India

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ABSTRACT

Wind generation is currently the major form of new renewable, generation in the world. The wind power is totally dependent on wind flow, due to randomness and uncertainty of wind flow, the wind power generation is quite fluctuating in nature and large scale wind farms may cause significant impact to the power system safety, quality and stability. The active power mainly depends upon the potential of the wind power produced and wind turbine generator design. The reactive power demand on the other hand depends upon conversion devices and recovered power quality fed to the grid. The wind farms which accesses to power grid cause fluctuations and reactive power redistribution and sometimes lead to voltage collapse. Similarly, the dynamic voltage stability is a major challenge faced by distribution network operators. The easy solution comes into picture is to install reactive power source devices with optimization of the existing assets to deliver enhanced reactive power to the grid. With solution to reliability, voltage regulation, reactive power requirements, grid integration problems, weak grid interconnection, off grid wind power generation and its integration to power grid, wind power penetration in distribution grid, wind power uncertainty, flicker and harmonics etc. The categorization of issue considered the goal of our work is the reactive power management of wind farm in most technical and economical way without compromising quality power system voltage, and considering the wind turbine technology for already commissioned wind farm, and change in WT technology in present scenario. More than 100 research publications on voltage and reactive power control of wind farms, extending from year 2003 to 2013 have been critically examined, classified and listed for quick reference.

Contents

1. Introduction

Wind energy is playing a vital role in world energy markets and wind energy has been focused as a clean and endless energy

* Corresponding author.
E-mail addresses: pathak287@gmail.com (A.K. Pathak), mahavir_sh@rediffmail.com (M. Sharma), maheshbundele@poornima.org (M. Bundele).

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Nomenclature

ANFIS adaptive network – based fuzzy inference system
CUPS custom power device technology
DSTATCOM distributed static synchronous compensators
D-VAR dynamic var
DVC dynamic var compensator
FACT flexible AC transmission system
FES flywheel energy storage system
GTOINV gate turn off thyristor inverter
STATCOM static synchronous compensators
SVC static var compensator
PHIL power hardware – in-loop

sources, its penetration level has been increased throughout the globe. The growth rate of renewable investment increases fast at the end 2013, it is 318 GW. But the unpredictable level of the nature of wind causes fluctuating wind power which gives rise of instability problem to already existing network, along with other associated problem such as voltage regulation, reactive power, fluctuation, harmonics, flickers etc.[1]. Increasing use of wind generation imposes the requirement for a wind farm to be capable of contributing network support and operation on the same way as a conventional power generating system.

The active power supply mainly depends upon the potential of the wind power produced and wind turbine generator design. The reactive power demand on other hand depends upon conversion devices and recovered power quality fed to the grid. The wind farms which accesses to power grid cause fluctuations and reactive power redistribution and sometimes lead to voltage collapse. Voltage variation due to variable wind generation and dynamic voltage stability is a major challenge faced by distribution network operators [2,3].

Reactive power control is important because all wind farm technology do not have the same capability. The wind farm is usually installed in remote areas, therefore reactive power has to be transported over long distances resulting in power loss. The wind farm has to provide reactive power control in response to voltage variation [4–6]. The reactive power control requirement is related to characteristic of grid because the influence of injection of reactive power in various voltage levels depends on network short circuit capacity and impedance. The reactive power compensation become utmost requirements for wind farm operation and contribution to the power grid, uncompensated reactive power cause stress on the hosting grid as well as casting effects. In general reactive power compensation of wind farms have the main purpose to keep the voltage profile of a wind farm at the appropriate level and ensure minimum losses in transferring power to the main grid also comply with connection requirement related to reactive power exchange set by grid code. The basic device for reactive power compensation is Under Load Tap Changer (ULTC) of the station transformer. If the action of ULTC does not comply grid requirement than other reactive power compensator devices, static capacitors, FACTS devices such as Static Var Compensators (SVC), Unified Power Flow Controller (UPFC), Unified Power Quality Conditioner (UPQC) and Distributed Static Synchronous Compensators (DSTATCOM) aimed at regulating reactive power requirements. A decision on the application VAR compensation technique depends upon the feasibility study taking into account technical requirements and economical consideration. These devices are now suggesting for control of reactive power requirements of wind generators, studies also shows their acceptability in voltage stabilization control [7–11]. This increases the acceptability of wind power penetration even in distribution network world-wide.

Among number of control strategies of reactive power one of the strategy is to utilize inherent reactive power capability of power electronic based wind generators. If the different induction generators are analyzed it is observed that reactive power management depends on WTG used in the wind farm. For wind power generation by use of the squirrel cage induction generator SCIG, it demands reactive power, the rotor of this machine runs at constant speed. Usually reactive power is provided through mains or in the capacitor bank. So wind farm active (reactive) power injected (demanded) into the power grid leading to variation in the wind farm terminal voltage. On other hand DFIG and FCWG has inherent characteristic of reactive power capability which can be utilize to enhance voltage and transient stability during grid disturbance. The permanent magnet induction generators PMSG are connected to grid via back to back converters which provide path between stator and power system also these converter decouple system frequency with frequency at stator of synchronous generators [12–14]. One of the most difficult requirement for wind generator is capability to ride through a fault, wind generator were tripped once the voltage at their terminal reduced below 80%, earlier that was accepted as its impact on the grid was less but with increased penetration of wind energy and with revised grid code requirement the fault ride through and power control capability of wind farm is at voltage 15% or low. The wind machine should be capable to withstand LVRT and HVRT [15]. The necessary dynamic reactive power need assessment of wind farm to meet utility interconnection requirement is also important [16].

The major issues from outcome of research papers steam lined. The issues generally comprise of, Voltage and Reactive Power Requirements and reactive power compensations of Wind Farms, Control Algorithm and Primary and Secondary Converters, Wind-Farm Grid Integration Requirements fulfillments, ESS for Weak Grids and MG Integration, SVC /FACT Devices for reactive power management and Grid Stability. All these are required to maintain the power quality fed into grid, apart from the challenges of meeting common grid code requirements, capable of meeting LVRT and HVRT, active power, voltage regulation and frequency requirement.

Comprehensive review on the topic of voltage and reactive power management of wind farm, classification, techniques/methodologies etc. presented in the paper. Over 102 publications [1–102] are critically reviewed and classified into four major categories. The first [1–16] is on general wind power requirements related issue. The second category [17–62] reactive power requirements of wind farms, which is further subdivided, [20–41] use of STATCOM for managing reactive power requirements of wind farms, [42–48] includes application of SVC techniques for resolving the issue of voltage and reactive power requirements, [52–62] application of capacitor banks, DVR, SDBR and other devices. The third category [63–80] is an energy storage system for weak grid and hybrid wind farm for mitigation of reactive power requirements. The fourth category [81–92] is wind farm integration with the grid and use of HVDC for off grid wind farms. The final and fifth category [93–102] specifies reactive power management with other works say use of the control algorithm, primary voltage converter, secondary voltage converter, controllers, etc., however, some publications include more than one category and have been classified based on their dominant field.

This paper is divided into five sections. Starting with an introduction in Section 1. Section 2 describes power quality affected with wind power penetration. Section 3 covers the