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Internal electrical protection of wind turbine with doubly fed induction generator

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ABSTRACT

Internal protection system of Doubly Fed Induction Generator (DFIG) wind turbine (WT) is one of the most challenging issues in the operation of distributed generation systems especially when penetration level and capacity of them are increasing. Due to a tendency to increase the capacity of wind turbine up to 10 MW with penetration of more than 20% of total power generation in the close future, some standardization and revision should be inspected in this area. The most important reason is that the protection of wind turbines has been considered mainly by manufacturers without significant considerations and requirements from grid system.

This paper deals with the internal protection of DFIG-WTs and shows overall view of internal protection functions of them; and three new scheme: differential protection for inter-turn fault protection, new startup and synchronization method and protection coordination of over current protection with FRT requirements have been proposed.

Contents

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1. Introduction

Nowadays, there has been created a significantly attention to Renewable Energy Sources (RES) and power conversion methods due to increasing demand of energy, political issues, environmental problems and economic competitions. Among these methods the trend has been toward the wind energy conversion systems (WECSs) for those places with plenty of wind [1–3]. The WECSs have more reasonable price especially and have a good availability more than 98% capacity factor of 35–40%, in comparison to other type of Energy Conversion Systems (ECSs). It is estimated that the power produced from this sector will increase from 10% in present to 20% in the next ten years. The wind power cost will be reduced lower than 6€¢/kWh, which is comparable with conventional power plants without considering the maintenance cost. The maintenance cost of WECSs is significantly lower than the other types [4].

There are two main types of WECS – fixed and variable speed. The fixed speed mostly employs induction generators directly connected to network while the variable speed type uses an interface system to fix the frequency of power produced. The power produced and penetration level of the fixed speed type is lower than the variable speed type whilst the power quality of second type can be much higher than the first type [5,6].

Variable Speed Wind Turbine (VSWT) with Doubly Fed Induction Generator (DFIG) is dominant type in WECSs. Growing DFIG-WTs in quantity and capacity causes to playing vital role in the power grids therefore their more reliable protections are critical [1,7,8]. The main advantage of this type is that it can produce electrical power from variable speeds of wind. This capability is obtained with controlling the frequency of the rotor windings via two back to back connected converters [1,2]. The power rating of theses converters is about 30% of generator capacity which is another economic advantage of this type. These converters can be used for achieving more power quantity, quality and higher capacity but its protection system is a challenging issue when a reliable system in different faulty conditions is need [9,10].

The main aim of protection system is to limit the electrical and mechanical variables during normal and emergency condition such as faults to suppress the system damage. As the maintenance cost and failure rate are high in the wind turbines because of their harsh installation conditions, a good and efficient internal protection system is critical for them [9]. It is possible to add some main protection functions to the controller of system to reduce the cost especially in low capacity turbines. But to improve the turbine reliability, security and overall performance, the protection and controller should have different duties although there may still some overlaps between them. In this state, the system down time cost will be reduced [11].

There are a few researches on protection scheme of DFIG and most of them are about connection of wind turbine to the grid and its requirements. Also there has not been proposed a comprehensive protection system yet, considering all turbine parts with especial specifications in coordination to each other [12,11].

Looking into the mentioned facts, this paper considers a deep investigation on internal protection system of a DFIG based WECSs. Then the existent standards and the protection instructions for power plant, DGs, RES and similar cases are evaluated for compatibility with DFIG based WECSs' protection [13]. At the first, a review on protection requirements is presented.

2. Protection requirements

Protection is one of the most important issues in the power systems. Protection knowledge has had long background in the electrical history and has progressed equal to other parts. Duty of protection system is continuously monitoring the power system to ensure maximum continuity of electrical supply with minimum damage equipments and properties [14–17]. Protection system must have specifications like selectivity, speed, stability, and sensitivity. Also a reliable protection system have dependability (disconnect in fault detection) and security (no operation in on faulty condition) that they must be settable by users [14–17].

A protection system consist of three parts: measuring unit, process unit and disconnection unit base on basic protection definition. Therefore, it is unallowable using same sensor and measuring units (CT & PT) for control and protection propose [14–17]. Also the processing unit must not be same for control and protection system. A protection system must have different outputs like alarms, trips and acknowledges base on different setting and conditions [14–17].

There are many considerations for insisting of independency of protection parts from other systems. For example, measuring units of protection system must measure high value of currents and voltages in faulty condition with moderate accuracy but measuring unit in control system must have high accuracy in nominal (rated) scale. For this reason CT must measure current until ten times of rated value for protection class [18]. Accuracy need for protection system is 5% but 0.5% is need for control system [14–17].

Also, if protection system is independent implementation of fundamental duties of protection system design like protection, periodic, preventive tests and maintenances are possible. But they are not achievable in case of built in protection system by manufacturers in the controller system [19].

As reliability has cost and protection systems must have more reliability than controls system, combination of control and protection system reach to low reliability or high cost for both system. Grid automation, data exchange, SCADA and all operation issues are another benefits of independent protection system [20]. Therefore SCADA and dispatching schemes need to independent protection system [21] as emphasized in this paper. Also, if different parts of protection system be separate from other system parts, there will be some freedom degrees for designers and owners that combination of control and protection will never have them [19].

Facing this problem, recently IEC/TC95 is talking about combination of protection schemes and control systems include in one system. But it is seemed that some existing standards will be renewed and some new standards must be developed [22,23].

Also a protection zone must be definable for a protection system that it operates for the only fault inside this area. As protection philosophy view, the protections zones must have overlap