Abstract

Permanent magnet (PM) machines have been widely employed for many applications due to high torque density and high efficiency. Most successful commercial examples for EV and wind power applications include PM machines used in Toyota Prius hybrid and Nissan Leaf electric vehicles, as well as Siemens wind power generation.

However, relatively high cost and potential supply issue of rare-earth magnets are currently major concerns. Less or no rare-earth magnet machines are being seriously considered and investigated; including PM assisted synchronous reluctance machines with reduced NdFeB magnets or employing ferrite magnets. Conventional electrical machines, such as induction, switched reluctance, synchronous reluctance, wound field synchronous machines, are being re-examined. Two recent successful commercial examples are probably ABB's synchronous reluctance machines for industrial drives and Tesla motors' induction machines.New and novel machines, such as stator wound field synchronous (SWFS) machines, are being developed, as will be overviewed in this keynote.

Conventional rotor wound field synchronous (RWFS) machines are actually very mature technology and commonly used in very high power hydro-electric generators. They offer the advantages of low idle loss, no use of rare-earth magnet, no potential irreversible demagnetization issue of the magnet, and easy to control etc. They are currently extensively exploited for other applications and have been re-emerged in various applications. They are commercially employed in the Enercon's direct-drive wind power generators and Continental's electric and hybrid electric vehicles (EVs/HEVs) machines. However, it is well known that RWFS machines have lower torque density and lower efficiency than the PM machines although when the power is higher, they may become more competitive. Further, in these conventional RWFS machines, slip-rings/brushes are usually required in order to supply the DC power to the rotor, which have restricted their potential wider applications since slip-rings/brushes require regular maintenance.

Stator wound field synchronous (SWFS) machines have a set of DC field excitation windings placed on the stator together with AC armature windings and a salient pole rotor without any coils or magnets. Therefore, they do not need slip-rings/brushes, as required in the conventional RWFS machines. Thus, the rotor robustness and reliability of SWFS machines have potential to be better and their maintenance cost has potential to be low. Moreover, compared with RWFS machines, better thermal management can be achieved in SWFS machines since all excitation sources are mounted on the stator.

This keynote willsystematically overview novel electrical machines with/without NdFeB magnets for electric vehicles and wind power generation, with particular reference to recent development in novel SWFS machines,including numerous new SWFS machine topologies with different stator slot and rotor pole combinations, overlapping and non-overlapping stator windings, segmented and integral rotors, etc., together with recent developments in SWFS machines - partitioned stator wound field machines. It will describe their operation principles and compare their relative merits and demerits, electromagnetic performance, with particular reference to their torque capabilities.