Electromagnetic Actuators Modeling, Simulation and Optimization

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Abstract

Introduction: Medium voltage reclosers are representing nowadays an important link between transmission power systems and low voltage grids. With a high level of renewable energy penetration, the medium voltage networks are becoming bidirectional. Therefore, the associated switching devices must ensure the protection of newer types of power systems as well as new types of loads. The optimal design of medium voltage reclosers is therefore important in order to enable high level switching capabilities. GriedShield recloser is a well know medium voltage protection device where the single coil actuators are being successfully used. GriedShield recloser has the ability to perform as a recloser, sectionalizer or automated load break switch. Proven design rated for 10.000 full load operations [1]. One pole of such device can be considered as being composed of two main subsystems: power and actuation. The first is represented by the power connections and the key element that ensures the arc extinguish - the vacuum interrupter [2]. The second subsystem can be either mechanical or an electromagnetic-based actuation unit. The electromagnetic solution presents several advantages compared to the mechanical approach, such as fewer components, higher reliability and less maintenance. The dynamic characteristics of electromagnetic actuators are strongly influenced by their shape, material proprieties, electric and mechanical elements. The magnetic, electric and mechanical dynamics are actually mutually dependent, with each affecting the others. Therefore, in order to ensure a fast and efficient design it is important to consider the Finite Element modeling and simulation enabling electromagnetic actuators virtual prototyping. This paper focuses on modeling, simulation and optimization of the electromagnetic actuators integrated in ABB's reclosers. In the next section, this paper gives an overview regarding the operating principle of a single phase recloser. The third part focuses on the set-up of a steady-state 2D finite element simulation including materials non-linearity. The fourth section illustrates the coupling of the 2D model with an optimization software, modeFrontier [3] as well as an optimization case study. The next section introduces the challenges related to the actuator's modeling and simulation in 3D Transient. The final part of this paper presents the contribution of this work as well as the perspectives. Operating Principle: The electromagnetic actuation unit used to drive the recloser is shown in Figure 2. The main subsystems of this unit are: stator, the two armatures (corresponding to the on and off positions), the coil, the permanent magnet, the opening spring and the stator. In the closed position, the magnetic flux generated by the permanent magnets attracts the "on" armature. The open position is reached when the repelling opening spring is discharged. The permanent

magnets will generate magnetic short circuits at the rear side of the stator. During the closing process a coil current will generate an attractive force that overcomes the holding force due to the short circuits on the rear side of the stator and subsequently the repelling spring force. At the end of the closing process, the "on" armature is attracted by the stator pole faces. For the opening operation, a coil current in the inverse direction has to compensate the magnetic force of the "on" armature. Then the repelling spring force becomes greater than the attracting magnetic force and the actuator opening operation is initiated. Both for closing and opening processes, the maximum amplitude of the coil current must be high enough in order to cause movement over the whole stroke length. Depending on the reclosers rating, different stroke lengths are included in the actual products. At the same time, the driving current amplitude and control is adapted accordingly [1]. Therefore, depending on the application, different variants of electronic control units are used. 2D Static Simulations: This section presents the setup of a 2D Static simulation model of the electromagnetic actuation unit presented in Figure 2. The subsystems of this model are the stator, the two armatures, the coil and the permanent magnet. The holding force in close and open position is being evaluated in order to identify the optimal permanent magnet volume. Different permanent magnet materials and different ambient temperatures are considered. This section introduces the coupling of the FE 2D static simulation model with an optimization toolbox (modeFrontier). Afterwards, a case study illustrates the application of this approach for the evaluation of different design parameters of the actuator (e.g. permanent magnet volume). 3D Dynamic Simulations: This section will introduce the challenges of setting up 3D Dynamic Simulation and will present the actual status of the models implementation. Conclusions: This paper presents the set-up of a FE simulation and optimization study platform for medium voltage reclosers analysis. The accuracy of the developed methods has been proved by validation against measurements. Based on the described methodology, the influence of different design parameters is analyzed in order to enable the robust design of switching devices.

Reference

1. ABB Inc, GridShield 15/27/38 kV three-phase vacuum recloser, ABB Catalogue, 2012.
2. ABB AG Calor Emag Medium Voltage Products, Vacuum interrupters and Embedded Poles - Medium voltage, ABB Catalogue, 2012.
3. http://www.esteco.com/home/mode_frontier/ mode_frontier.html, July 2012.

Figures used in the abstract

Figure 1: ABB 3-Phase GridShield Recloser.

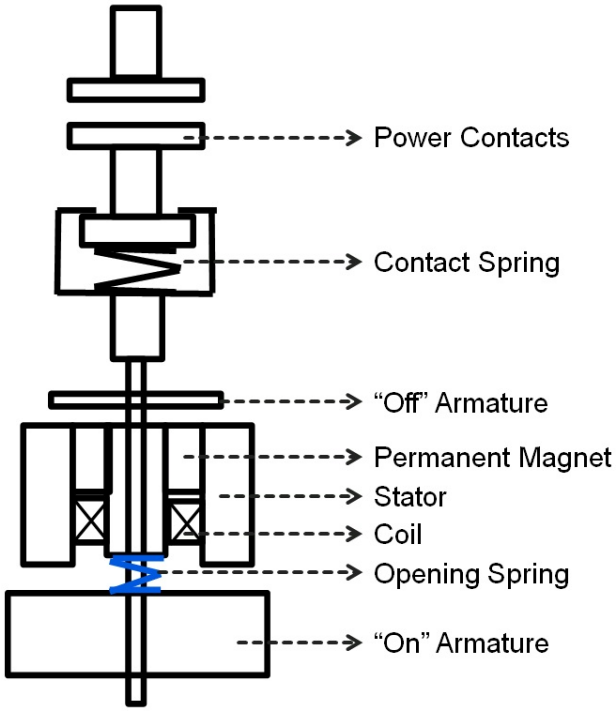

Figure 2: Single Pole Recloser Structure.

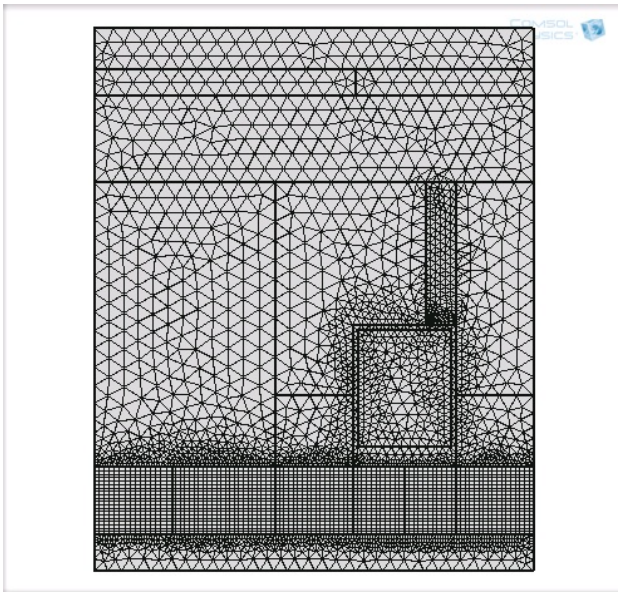

Figure 3: Simplified 2D Static COMSOL Model.

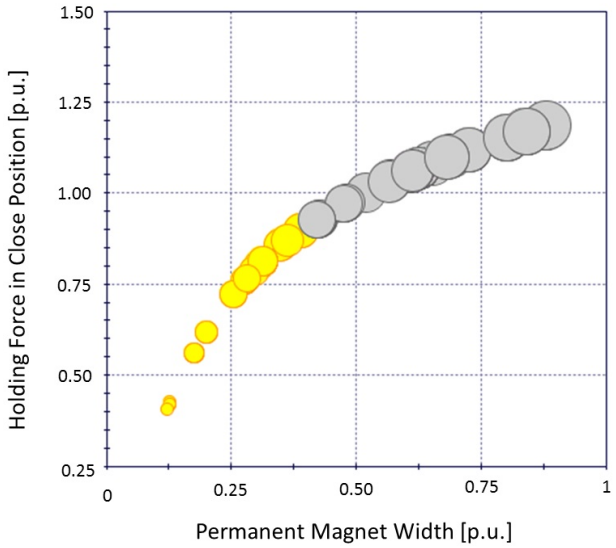

Figure 4: Holding Force as a function of the Permanent Magnet Width.