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論　文　要　旨
Thesis Abstract

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※報告番号	甲 第　２０８号	氏　名 (Name)	NGUYEN DUY DINH

主論文題名　（Title）

Modulation and Control of Solid-State-Transformer

内容の要旨　（Abstract）

Together with the high penetration of renewable energy into the utility, Solid-State-Transformers (SSTs) have gained more and more attraction in recent years. The exponential demand of electric energy also contributes to the promotion of SSTs in such applications to interconnect grids within a nation or inter-nations to form super-grids. It has also been applied for automotive applications as a substitution for the hybrid energy storage system. As a transformer, SST is an isolation device which can transform the voltage from one level to other levels. Furthermore, SSTs have a lot of distinguished advantages which are not available in the conventional passive transformer such as: improving voltage regulation, load/short-circuit protection, power quality improvement, etc. Especially, the communication capability makes SSTs intelligent devices enabling the concept of the Energy Internet.

However, there are two major issues that restrict the popularity of SSTs: price and efficiency. As for the first issue, it can be solved gradually by mass production and/or by applying cutting edge innovations in the material technology. Nowadays, although SSTs are still costly, their price will be more competitive in the near future.

Let us see from another aspect. Instead of making SSTs cheaper, they can be made worthier with the high price by equipping with advanced functionalities. Functions such as voltage regulation, protection, power management, power quality enhancement, etc. can be accomplished by a correspondent control system.

The efficiency of a SST is not as high as a passive transformer in the same circumstance because it contains a lot of switching devices. Those devices consume power when operating that restricting the overall system performance. However, this issue can also be resolved by improving the modulation strategy. The power dissipation in a SST can be identified and modelized. With an appropriate algorithm, the loss can be significantly reduced. The stress on switching devices is suppressed allowing the usage of lower-rating devices in heavy-duty

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applications. Besides, the noise caused by the commutation operation is weaken and presents less effects on other electronic equipments. As a consequence, the whole system will become more reliable.

Motivated by the aforementioned reasons, this dissertation is reserved to deal with modulation and dynamic control of SSTs:

Firstly, a new strategy is proposed to modulate Dual-Active-Bridge (DAB) converters, the core technology of all SST types. The DAB converter is analyzed in the time domain. After that, a closed-form modulation function is derived. The function is then modified to operate when the frequency is restricted. The target is not only to achieve soft-switching in the wide operation range, but also to minimize reactive power in the system.
%The experiment validation is conducted in the comparison with other methods also based on frequency variation.

Secondly, a new observer-based dynamic control system is proposed to improve the voltage regulation as well as the power management capabilities of the converter. The converter is modelized in the frequency domain with high accuracy. Thanks to the decoupled control system, the active and reactive powers can be separated from each other and are individually manageable. Furthermore, by controlling the quadrature component of transferred current to adhere an appropriate reference, reactive power can be handled intentionally. The soft-switching area is expanded to the whole power range. Experiment results confirm that dynamic performance of the converter is much improved.

Finally, all of the above approaches are applied for a Triple-Active-Bridge converter, which is another configuration of SSTs derived from the Dual-Active-Bridge topology, intentionally used for electric vehicle applications. The frequency domain analysis is carried out once again. Each operation modes of the converter will be considered to develop its corresponding soft-switching modulation strategy. The control system is then constructed for only one mode, but the same designed procedures can be applied for other modes.

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