Control for Modular Multilevel Converter

CONTEXT

The most conventional control method for MMC uses cascaded structures, where the power transmission and internal energy dynamic (outer loops) are limited by the "frequency separation" constraints since the dynamic choice of the currents (inner loops) must consider the tradeoff between speed of responce and robustness. The work have focused on the development of different control approach focusing on the reduction of algorithmic complexity and ease of implementation. The study scope was on the steady state and transient operation, but no faults have been considered in the study.

TECHNOLOGY DESCRIPTION

Arm-modular control law for MMC.

The proposed control law uses some symmetry properties of the MMC to simplify and distribute the control algorithm. Each arm only includes two control loops: the internal one is in charge of the arm inductor current tracking, while the outer one regulates the equivalent capacitor voltage of the arm (corresponding to its average internal energy). The DC power is controlled explicitly, and the AC power is adjusted such that each arm remains in steady-state conditions, individually. This method reduces the algorithmic complexity, lends itself well for hardware control distribution, and offers cleaner and more predictable dynamics.

Differential flatness based linearizing control law for MMC.

The main interest of the proposed control is the possibility to obtain a very high dynamic performance of the MMC power flow, even under noisy measurements and parametric disturbances. This control law is an improvement of the former. It does not rely on linearity hypothesis and solves the need of cascaded loops. Indeed, as two cascaded loops need to be dynamically "distant", either the inner loop is fast and the noise immunity is reduced, or the outer loop is slow and the tracking performance is degraded. Through the framework of differential flatness theory, a full-order, non-linear controller and its associated trajectory generator are built. This control system takes into account the MMC non-linearity and it is able, through non-linear feedback, to linearize all its internal dynamics, leading to both a fast tracking error convergence rate and a global property of stability. While using a complex mathematical background, this method results in a control scheme which is both easy to implement in real-time and very easy to tune (only two parameters for the whole converter).

APPLICATION DOMAIN

- MMC for HVDC and MVDC
- Advanced control

ADVANTAGES

Reduced algorithmic complexity.

Allows Distributed Control Structure.

Very high dynamic performance.

TRL SCALE

1 2 3 4 5 6 7 8 9

DELIVERABLES

Detailed and average simulation models in MATLAB

PhD thesis chapter

SCIENTIFIC REFERENCE

1. P.B. Steckler, J.-Y. Gauthier, X. Lin-Shi, F. Wallart "Structural Analysis and Modular Control Law for Modular Multilevel Converter (MMC)" in ELECTRIMACS 2019
2. P.B. Steckler, J.-Y. Gauthier, X. Lin-Shi, F. Wallart, "Differential Flatness-Based, Full-Order Nonlinear Control of a Modular Multilevel Converter (MMC)" in IEEE Transactions on Control System Technology.