The performance improvement of modular multi-level inverter using deer hunting optimization algorithm and three-dimensional SVPWM technique

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A modular multi-level inverter (MMI) is a popular topology in medium- and high-power industrial applications because it is modular, scalable, and has better power quality. Nevertheless, practical implementations are still faced with problems like circulating current suppression and capacitor voltage balancing. The present study suggests a superior control method based on the deer hunting optimization (DHO) algorithm to tune the fractional order proportional-integral-derivative (FOPID) controller optimally to minimise the circulating current. Also, a three-dimensional space vector pulse width modulation (3D-SVPWM) method with capacitor voltage sorting is applied to provide a uniform distribution of capacitor voltages and improved control of the output current. Simulation experiments in MATLAB/R2022a indicate that the proposed control scheme can provide an output voltage of 305 V and a total harmonic distortion (THD) of 3.78%, and an output current of 3.5 A and 4.2% THD with a 7-level MMI. The circulating current is reduced to 0.3 A with a ripple of 1.12 per cent and settling time of 0.102 s. Similar results are obtained by experimental validation with a 0.5 kW hardware prototype, which proves the robustness and practical feasibility of the proposed method. The capacitor voltage is kept at 110 V +/- 5% with better performance in voltage balancing. These findings affirm that the combined DHO-FOPID and 3D-SVPWM approach is very effective in improving the dynamic and steady-state behaviour of the MMI.

Keywords: 3D-SVPWM, capacitor voltage balancing, circulating current minimisation, deer hunting optimization, MMI.

transmission lines and power quality improvement. It is also used in real reactive power management in wind energy conversion systems installed offshore[1]. Further, the study explains in detail the pioneer work carried out on MMI and its pulse width modulation (PWM) techniques to balance the capacitor voltage and minimise the circulating current. Liu *et al.*[2] proposed a generalised model of a modular multi-level inverter (MLI) for enhancing the performance under steady-state conditions. Haq *et al.*[3] found that the fundamental component got affected more by injecting a circular current than by keeping the constant voltage in conventional methods. Basu *et al.*[1] used the separate PV cells for an individual unit of a modular multi-level converter (MMC) without connecting a separate direct current-direct current (DC-DC) converter. In which the maximum power point tracking (MPPT) controller is designed for each string of photovoltaic (PV) panels to yield optimum power under normal and partial shading conditions[4]. Thereby, the power imbalance problem had been resolved using the zero-sequence voltage injection method. A novel MMC topology in the static synchronous compensator (STATCOM) in the power transmission line to improve the power transmission efficiency of the line. The social ski driver technique is implemented in the MMC to reduce error voltage[5]. It could perform well during line-to-line (L-L) and three-line fault conditions.

Sharojini *et al.*[6] proposed a novel emulated inertia control for MMC fed from a solar PV system. The energy stored in the capacitance of submodules was well utilised to improve the inertial response. Kaliannan *et al.*[7] introduced a novel pulse width modulation technique known as the pseudo-random multi-carrier technique. The power quality of this MMC improved significantly compared to the H-bridge inverter over the wide range of modulation index. The prototype was implemented to show the efficacy of the proposed scheme. Kumar *et al.*[8] used a modified