This paper proposes a hybrid modulation strategy for asymmetrical cascaded multilevel converters operating under normal and faulty conditions on power cells. The proposed algorithm explores the advantages of both space vector (SV) and carrier-based modulation approaches. An SV is used for higher voltage cells to properly choose their voltage vectors in a way such as to avoid converter saturation, particularly under fault conditions. A generic algorithm to identify the domains of higher voltage vectors in which a reference lies, without the need for separation lines, is proposed. Then, to simplify the implementation of the algorithm, carrier-based modulation is employed for lower voltage cells, which switch with pulsewidth modulation. This suppresses the need for defining multiple switching sequences for different operational conditions, and it avoids converter saturation as much as possible, particularly under fault conditions on power cells. Simulation and experimental results for normal and faulty operational conditions are given, validating the theoretical analysis and demonstrating the good performance of the proposed hybrid modulation approach.