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SYMMETRICAL AND UNSYMMETRICAL REGIMES OF CASCADED H-BRIDGE M-LEVEL INVERTER

A single-phase structure of an *m*-level cascaded inverter is illustrated in Figure 1 Each separate dc source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs, $+V_{dc}$, 0, and $-V_{dc}$ by connecting the dc source to the ac output by different combinations of the four switches, S_1, S_2, S_3, and S_4. To obtain $+V_{dc}$, switches S_1 and S_4 are turned on, whereas $-V_{dc}$ can be obtained by turning on switches S_2 and S_3. By turning on S_1 and S_2 or S_3 and S_4, the output voltage is 0. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The number of output phase voltage levels m in a cascade inverter is defined by $m = 2s+1$, where s is the number of separate dc sources.

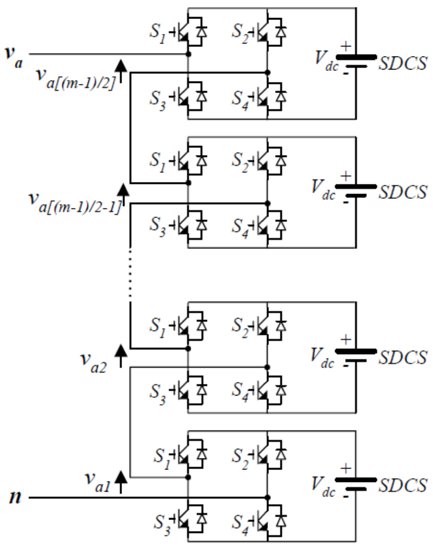

Fig. 1. Single-phase structure of a multilevel cascaded H-bridges inverter

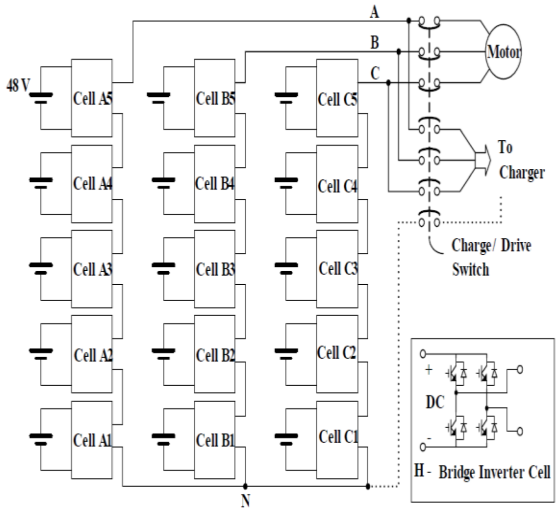

Fig. 2. Three-phase wye-connection structure for electric vehicle motor drive and battery charging

Cascaded inverters have also been proposed for use as the main traction drive in electric vehicles, where several batteries or ultracapacitors are well suited to serve as SDCSs [1]. The cascaded inverter could also serve as a rectifier/charger for the batteries of an electric vehicle while the vehicle was connected to an ac supply as shown in Figure 2. Additionally, the cascade inverter can act as a rectifier in a vehicle that uses regenerative braking.

The main advantages and disadvantages of multilevel cascaded H-bridge converters are as follows [1].

Advantages:

The number of possible output voltage levels is more than twice the number of dc sources *($m = 2s + 1$)*.

The series of H-bridges makes for modularized layout and packaging. This will enable the manufacturing process to be done more quickly and cheaply.

Disadvantages:

Separate dc sources are required for each of the H-bridges. This will limit its application to products that already have SDCSs readily available.

1. FAULTS AND THEIR CONSEQUENCES

Before continuing discussion in this research, it should be noted that the word *fault is* used to refer to a semiconductor power switch used in the MLID that fails to operate when provided gate drive signals and includes faults such as *short circuit or open circuit.* One particular effect on a faulty switch is unbalance output voltage of a MLID. In a balanced MLID system, the three line to neutral output voltages are equal in magnitude and are phase displaced from each other by 120 degree as illustrated in Figure 3 [2-3].

On the other hand, if a fault occurs at a semiconductor power switch in a cell, it will cause an unbalanced output voltage; for instance, the MLID system as shown in Figure 2 has fault (open or short circuit) on cell 5 at phase B, then the magnitude of line to neutral output voltages of phase B (V_{BN}) are not equal with other phases. This causes the line to line output voltages to also be unbalanced as shown in Figure 4 [4].

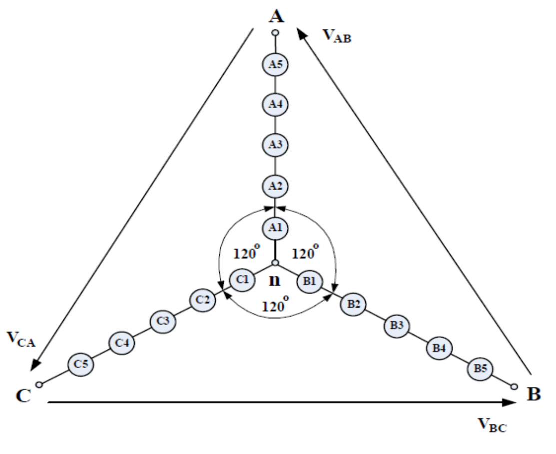

Fig. 3. Balanced output voltage available for 5 cells per phase

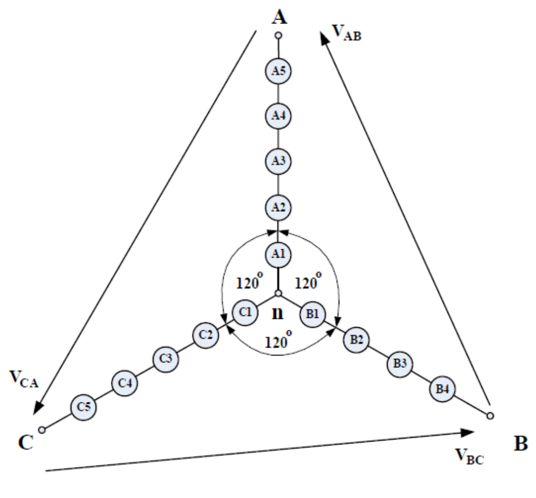

Fig. 4. Unbalanced output voltage on VBC when a faulty cell occurs on phase B

Voltage unbalance also has an impact on a conventional inverter drive system where the front end consists of three-phase rectifier systems. The triplen harmonic line currents which are uncharacteristic to these rectifier systems can exist in these situations leading to unexpected harmonic problems [4].

An excessive level of unbalanced output voltage can have serious impacts on mains connected to an induction motor. The level of an unbalanced current may have several times the level of an unbalanced voltage. The unbalanced current in a line current can lead to disproportionate losses in the rotor and stator of the induction motor. Some induction motors are designed to tolerate a small level of unbalanced voltages and currents; however, they have to be derated if the unbalance is excessive. An induction motor that operates at its nameplate rated capacity without derating even though required load is not at rated capacity because of the unbalance voltages from a MLID will result in the useful lifetime of such an induction motor to be quite short. If the induction motor operates at full load all the time, the stator windings and the rotor may carry more current than that is permitted: this situation can lead to a reduction in induction motor efficiency and can reduce the insulation life caused by overheating. The average expected life of insulation halves for every 10^{o} C of temperature increase as reported in [5]. Moreover, an induction motor operating under unbalanced voltage condition will be noisy in its operation caused by torque and speed pulsation. Obviously, in such situations the effective torque and speed will be less then normal.

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