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Abstract: This thesis deals with addressing various challenges associated with induction motor (IM) drives used for high-power applications like railway traction, industrial fans, pumps and blowers. Squirrel-cage induction motors are generally used in these applications because of their rugged and robust structure. Power rating of these motors varies from few hundreds of kilowatts (~500 kW) to a couple of megawatts (~2-3 MW). Voltage rating of these motors varies in the range of 2-5 kV. Insulated gate bipolar transistor (IGBT) based two-level voltage source inverters (2L-VSI) are most popularly used to drive these medium-voltage, high-power motors. Rotor-flux oriented vector control is generally employed to ensure satisfactory dynamic performance of the drive. Such systems suffer from various challenges. In a 2L-VSI, each IGBT blocks the complete DC-link voltage in off state. Thus, voltage rating of these devices should be rated at 4.5 kV or higher. Semiconductor devices with such high-voltage blocking capabilities exhibit compromised switching characteristics both in terms of switching speed and switching energy losses. Thus, the switching frequency (f_{sw}) of these power converters is generally limited to the range of few hundred Hertz (~500-750 Hz). Limited f_{sw} affects both the harmonic and dynamic performance of the drive under closed-loop control. Synchronous pulse-width modulation (PWM) techniques are generally employed in order to ensure satisfactory harmonic performance. Here, the number of switching pulses in the inverter pole-voltages in one fundamental cycle is kept constant. This is also referred to as the pulse number, P. As the modulation frequency of the drive, f_m, increases with the speed of the motor, P is sequentially reduced in order to maintain f_{sw} under the prescribed limits.

Synchronous sine-triangle (SST) PWM is popular among the other synchronous PWM techniques because of simplicity of implementation. For SST PWM scheme, P can also be defined as the ratio of carrier-frequency, f_c and f_m ($P = \frac{fc}{fm}$), P is restricted to be only odd-triplen integers, e.g. 21,15,9,3 in case of SST PWM. Thus, beyond P=9, the harmonic performance of SST PWM degrades considerably. This thesis proposes a hybrid synchronous PWM technique which is a combination of synchronous sine-triangle (SST) PWM and synchronous optimal (SO) PWM for SCIM drives. For higher values of P (e.g. P=21,15,9), SST PWM scheme is employed. At P=9, the proposed scheme shifts from SST to SO PWM. Odd non-triplen values, such as P=7,5 are also incorporated in the proposed PWM scheme using SO PWM. SO PWM suffers from the drawback of increased burden on the memory allocation of the digital control platform as optimal switching angles are required to be stored in a look-up table as a function of modulation index. This thesis proposes a method to implement the PWM scheme without using any look-up table.

Another challenge faced by these drives, under closed-loop operation, comes due to the transition in pulse-pattern applied by the 2L-VSI to the motor as the value of P changes. Such a transition, if done in an unconstrained manner, can lead to huge transients in the line current and electromagnetic torque developed. This thesis proposes a pulse-pattern transition strategy to ensure minimum transient in the line current. The strategy is based on matching the instantaneous stator-flux trajectory for the outgoing and incoming pulse patterns.

Further, this thesis proposes a modified railway traction drive based on open-end winding induction motor (OWIM) drive which consists of two 2L-VSIs feeding power from both the ends of the stator winding of the IM drive. Railway traction drive consists of two single-phase

active front-end converters (AFEC) where the AC side is connected to the two secondary windings of a three-winding transformer. Thus, two isolated DC sources are formed which makes OWIM drive very suitable for this application. A SST PWM scheme is proposed for this drive which incorporates even triplen (P=6,12..)and odd non-triplen integers (P=5,7..) along with odd triplen integers (P=3,9..)as pulse numbers. With the introduction of intermediate values of pulse numbers, large change in f_c is restricted as the value of P changes. A double-fourier series (DFS) based mathematical framework has been developed to predict the harmonic profile for the proposed PWM scheme. Further analyses, such as stator-flux trajectory based analysis, fourier-series based analysis are also done in order to establish the harmonic performance of the proposed PWM scheme.

Following this, another SST PWM scheme for OWIM drive is proposed in this thesis where dissimilar carrier signals are used for the two VSIs in the OWIM drive. Only triplen values (odd and even) of P are considered in the proposed PWM scheme. The value of P corresponding to the two VSIs, P_1, P_2, may not remain equal unlike in the conventional drive. The effective pulse number of the drive, P, is taken to be the average of P_1 and P_2. When P takes odd-triplen values, P_1 and $P_2$are kept equal. However, a phase-shift is introduced between the two carrier signals. On the other hand, for even triplen values of P, P_1 and P_2 take different values. P_1 is kept as the odd-triplen number higher than P and P_2 is kept lower than P. For example, for P=6, P_1 is kept at 9 and P_2 is kept at 3. Through extensive mathematical analysis based on double fourier series, simulation and experimental validations, it is shown that the proposed PWM scheme exhibits improved harmonic performance than the conventional scheme.

Another challenge faced by high-power IM drives in terms of control techniques is the performance of speed-sensorless control algorithms specially in the low-speed operating region. This thesis considers a multi-induction motor drive system (MMDS) wherein two or more Y-connected SCIMs are coupled together on the same shaft driving a common load. The load under consideration has a specific torque-speed characteristics wherein the torque-demand from the drive increases with increases in speed, like industrial fans, blowers and pumps. For a MMDS driving such a load, at least one of the motor need not produce any torque at low speed. It may just rotate and maintain its rated flux. It is established in this thesis that a PLL designed used the stator-current of the zero torque producing motor gives accurate information about the rotor-speed of the MMDS even at very low speed.

Performance of the proposed PWM techniques and control algorithms has been validated on simulation using MATLAB/Simulink and then verified experimentally on lower power laboratory set-up. Relevant simulation and experimental results establish the improved performance of the propositions over the conventional methods.