This paper presents an investigation on a nonredundant topology for two-leg fault at a back-to-back converter-fed induction motor drives. In the case of faults occurring in any two inverter legs, the six-leg back-to-back converter can be changed to a four-leg back-to-back converter by employing one motor phase connected to the rectifier leg and another phase connected to the dc-link capacitor mid-point for fault-tolerant operation. The four-leg back-to-back converter is very attractive for the merit of not requiring additional power switches for fault-tolerant. However, as the shared-leg connection between inverter and rectifier, the rectifier and the motor drive are deeply coupled. A novel scheme-based model-predictive control is presented to achieve independent control of the grid and motor currents. The voltage limitation for independent control of the rectifier and motor drive is analyzed, and the dc-link voltage utilization is improved by capacitor voltage suppression. With the proposed scheme, the output speed range of the converter is degraded, but other performances, such as output torque capability, unity power factor, and the dynamic response, are maintained after faults occur. Finally, the control concept is verified by a TMS320F28335 DSP-based prototype.