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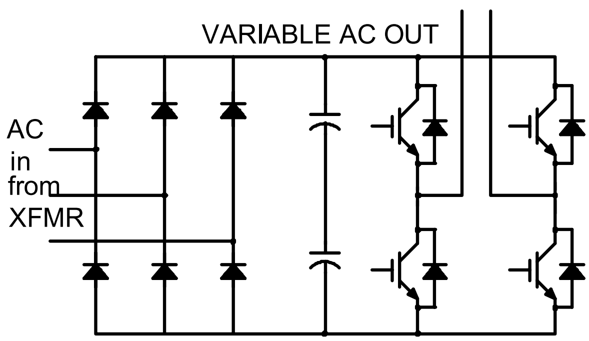
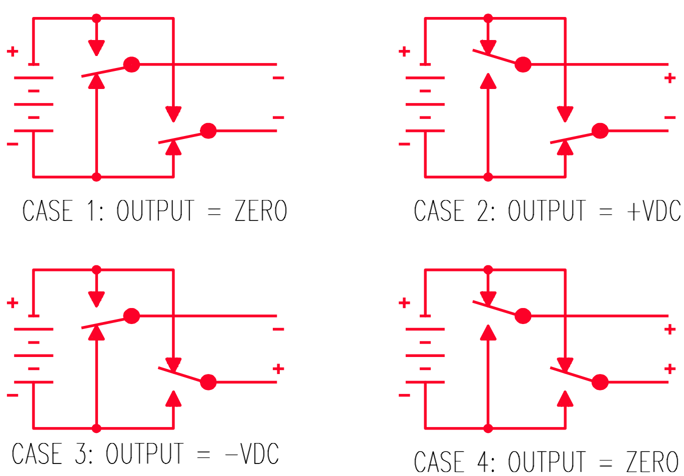
Technical observations on the input/output current of the Perfect Harmony drive

Although it seems counter intuitive, it is possible for the output current of a voltage source drive like the Harmony to be greater than the input current. This is a result of the topology of the circuit and the behavior of the switching devices on the output.

In the Harmony, we have an H-bridge of 4 switches connected between the positive DC link bus and the negative DC link bus. The DC link is just a big capacitor fed from a rectifier bridge, and is an energy reservoir of essentially fixed DC voltage.





There are only four possible combinations of switch states. If you have the upper left and lower right switches on (case 2), then the output voltage of the cell is the DC link voltage in the positive polarity. If the upper right and lower left switches are on (case 3), then the output is the DC link voltage with negative polarity. If both upper switches are on (case 4), or both lower switches (case 1), the output is zero volts.

Now the instantaneous power flow direction is determined by the polarity of the output voltage and the polarity of the output current. If the polarities of current and voltage are the same, e.g., positive voltage and positive current, then energy is flowing from the DC link into the load. If the polarities are different, then energy is flowing from the load back into the DC link. If the output voltage is zero, then there is no energy flow. The current, of any polarity or magnitude, flows into one switch and back out another switch without passing into the DC link.

Now in a pulse-width-modulated control, the amplitude and waveform of the fundamental output is controlled by a judicious sequence of pulses of these four voltage states, which occur for only very short periods of time compared the fundamental period. For lower voltages, the output spends proportionately more time in the zero output state, and near zero output, it spends almost all its time in the zero voltage state.

The result of this behavior is that only the real power delivered to the load is taken from the DC link. So, the DC link input power must always be just the output voltage times the output current times the output power factor.

Conservation of energy requires this, since the switches don’t dissipate significant power. For loads with less than unity power factor, the output current must necessarily be higher than the input fundamental current, which delivers only real power to the DC link.

In the case of non-unity power factor loads, the instantaneous power flow is sometimes positive and sometimes negative. But the DC link reservoir smoothes out that power flow; the capacitor delivers the peak load power when required, and absorbs the returned reactive energy during another portion of the cycle.

So only the net power must be supplied to the link by the rectifier. If you have a zero power factor load, even though the current might be very large, the net charge taken from the link is zero over a cycle, so the rectifier input current will be zero, or only that needed to supply losses.

It is therefore possible to build a drive with a higher output current rating than the input, and drive manufacturers do this all the time because induction motors have less than unity power factor. In the case of the Harmony, the cells have to be rated to handle the maximum output current, so we choose the IGBT’s and rectifiers for a specified current rating, even though the rectifiers almost always have lower current. But the transformer has to deliver only the real power of the load plus drive losses, so it can be rated at lower continuous power.

In the specific case, the 200amp cells can deliver 200 amps continuously at rated voltage. This could be as much as 1.44MW. But the motors cannot produce more than 1000Hp (746kW) continuously, so the drive input transformer need not be much larger than 746kW. So we will use a 1MW transformer. The drive system will have short term overload capacity up to 200 amps which will be limited by the thermal capacity of the motor and transformer.