Group B4 : HVDC and Power Electronics

Question 4:

If there are other practical experience from the new market structure and particular how opportunities and barriers versus HVDC and FACTS have been resolved in other networks, it would be very useful to share this experience at this conference! Secondary, it would be useful if the manufacturers could elaborate on the additional equipment cost and the network benefits which could be obtained by enhancing the performance of existing as well as new HVDC and FACTS equipment.

The thyristor based HVDC technology is nowadays after decades of operating experience a mature, reliable and well proven technology for bulk power transmission. However, there are indeed some potentials unexploited or unused in applications. One representative feature is the black-start capability of conventional HVDC system. For a long time it has been a general opinion that black start capability is a unique feature of voltage sourced converters, while thyristor based converters cannot supply a dead load (black start) due to the absence of a rotating source voltage for commutation. Recent development works performed at Siemens showed that the conventional thyristor converter is able to supply a dead load with a novel control concept.

The power circuit used is identical to standard HVDC systems and no extra equipment is required in this area. It is only the control software that requires moderate modifications to allow a standard HVDC system to supply power to a dead load. Figure 1 shows the circuit diagram of a HVDC connected to a passive load at the inverter

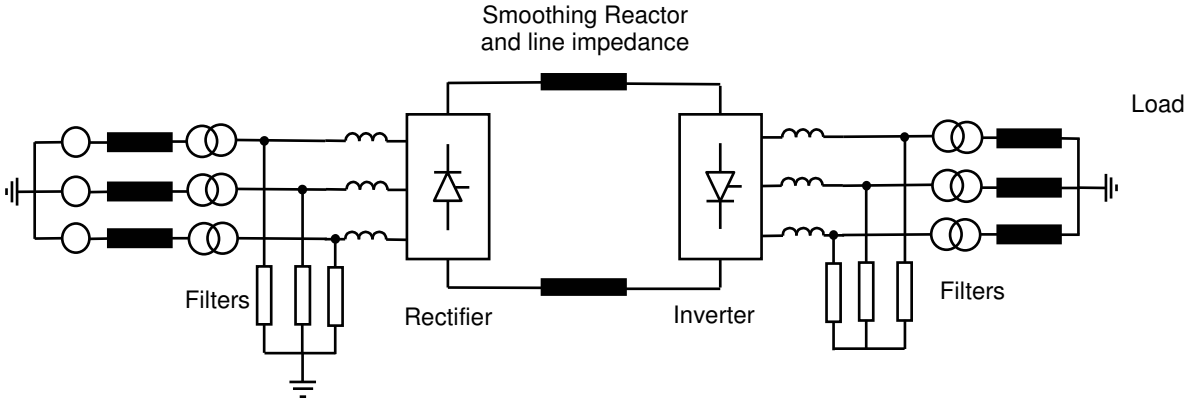

Figure 1. Circuit diagram of a HVDC supplying a dead

side. To be able to supply the dead load, the inverter firing pulses are synchronized to an independent 60Hz (or 50Hz) sinusoidal signal. This is the main difference between the proposed method and the standard HVDC techniques, where the inverter pulses are synchronized to its ac bus voltages. Furthermore, the equivalent impedance on the inverter side shall be capacitive at fundamental frequency to enable a normal commutation. This is normally the case as harmonic filters and shunt capacitors are always present at the inverter ac bus bar. The ac voltage at the inverter will be kept constant at variable loads by controlling the converter dc currents.

Figure 2 shows the start up of the system under no load. During the start up sequence the inverter filters are connected first, the inverter and rectifier are deblocked in sequence. The inverter ac voltage is raised slowly. Under the no load conditions the dc current must be enough to let the inverter absorb all the reactive power generated by the filters (and shunt capacitors if any) at the inverter bus. The dc power under these conditions accounts only for the converter and filter losses. Therefore the dc voltage remains at a very low level and both rectifier and inverter operate at firing angles close to 90 degrees. Therefore the converter equipment shall be designed for continuous 90 degree operation, which can be realized with only moderate investment in the ratings of thyristor valves and harmonic filters.

Figure 3 shows the system response when the load is ramped up from zero to 1pu in 0.1pu steps (resistive) at every 0.5 second. At each step the inverter ac voltage drops initially and then returns back to normal by the proper operation of the controller. DC current and voltage are increased accordingly to keep the inverter ac voltage at the reference level and provide the required power. Increasing the load makes the total impedance

seen by the inverter (i.e. the parallel combination of filters, shunt capacitors and loads) more resistive. Therefore the phase angle between the inverter ac side current and voltage is reduced. This will reduce the extinction angle of the inverter.

It is evident that the conventional HVDC has the same black start capability as a VSC converter and can be used in applications such as supplying power to an island, a remote community or even an oil platform in off shore. Taking other aspects into account such as proven technology, lower losses and equipment costs the conventional thyristor based HVDC system has today still more advantages to offer than the voltage sourced converters. Concerns may be raised about the possible power quality issues for thyristor based HVDC feeding dead load. The harmonic distortions can be well controlled within reasonable limits by the properly designed harmonic filters. The extreme high firing angle operation is only temporary at black start period or during light loads, where the dc current is rather at lower values. At high loads the firing angle is not much different than a conventional HVDC operating at Udio constant control mode or at reduced dc voltage. The voltage step caused by switching of loads or reactive power elements at ac bus terminal is generally governed by the interactions between the passive networks and the converter controls. A coordinated control and dispatch, if necessary assisted by a conventional SVC, can solve the problem.

The HVDC system has also other well-known auxiliary capabilities such as voltage / frequency control by modulation of active and/or reactive power. These features, together with the black start capability, can be made available to participate in the ancillary service of the new structured market. It has to be noted that the HVDC system is normally built for the purpose of active power transmission and the design of the system is also optimized for this purpose. The extra features and functions shall only be considered / specified for a new HVDC system where they are really needed and the increased investment caused by such extra functions is justified. In today's global economical environment the HVDC and FACTS technology will receive more promotions rather by attractive investment costs than some "nice to have" features.

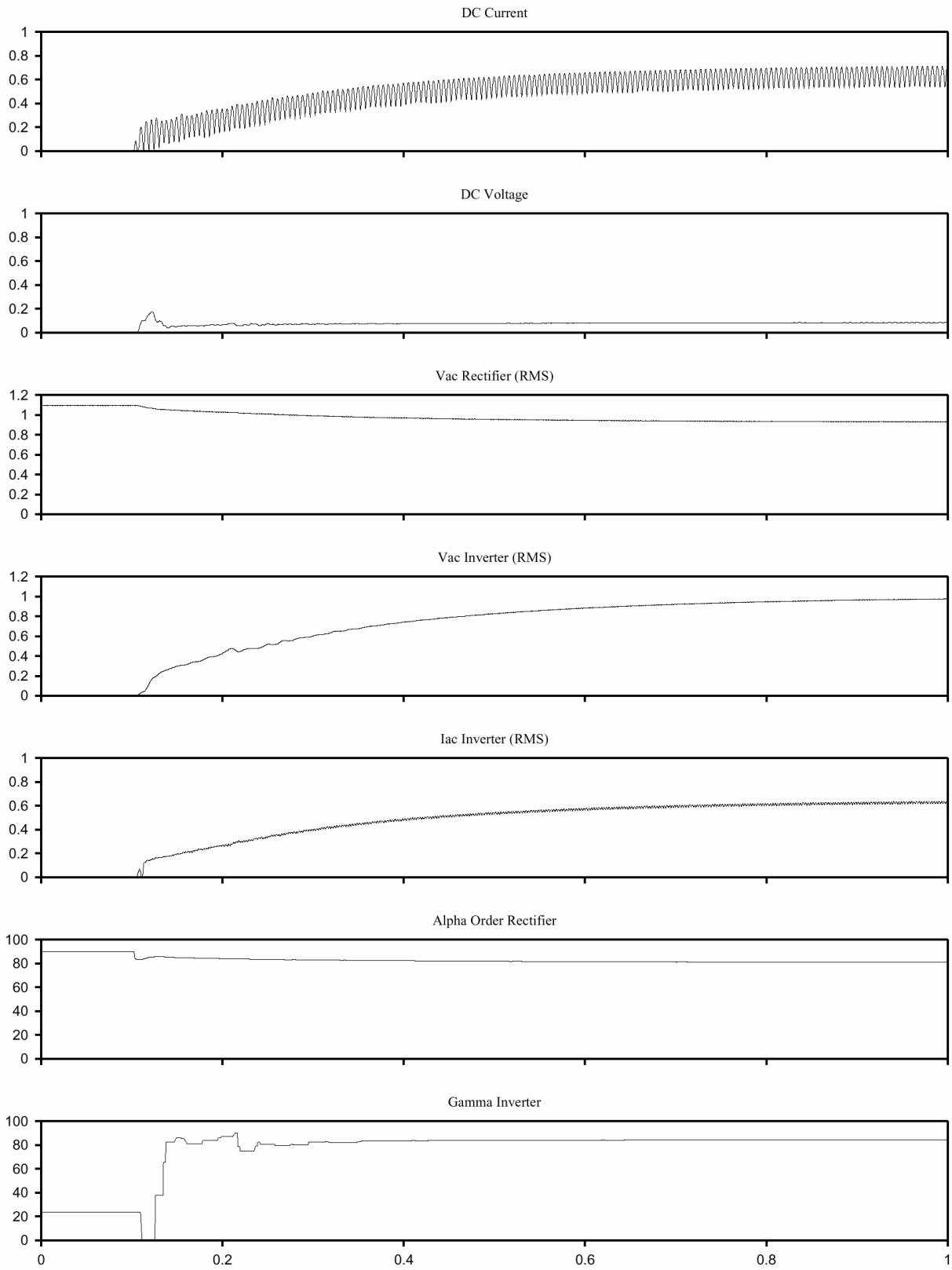

Figure 2. No load start up for long distance HVDC system

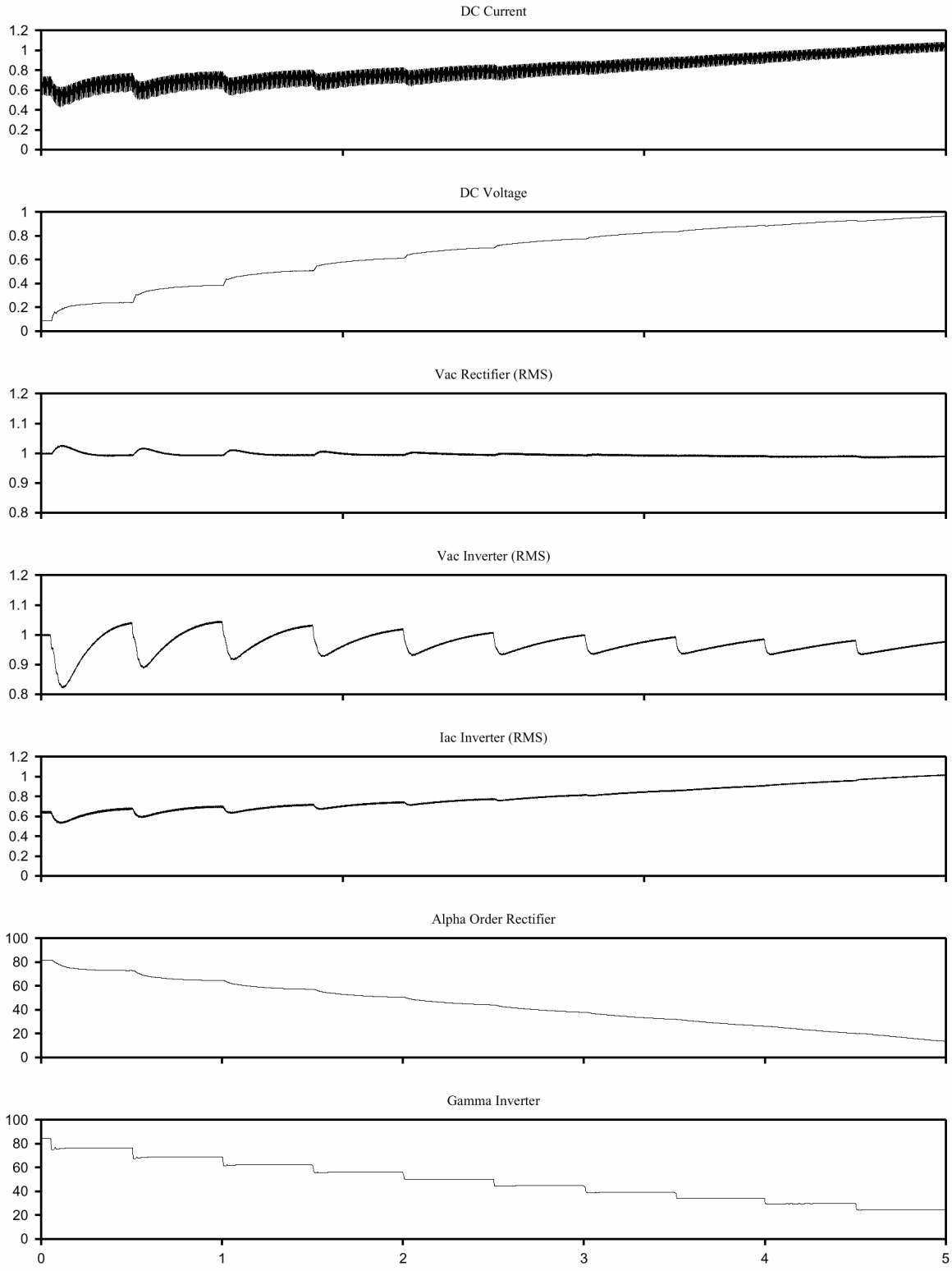

Figure 3. Ramping up the load in 0.1pu steps for a long distance HVDC feeding passive loads