POWER QUALITY ENHANCEMENT BY DC LINK SUPPLIED INDUSTRIAL SYSTEM

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Abstract: *In this paper HVDC is investigated for its ability to supply a passive industrial system. The objective of the paper is to assess the potential and limitation of the use of dc distribution in the industrial power system. The performance of the dc supplied distribution system is compared with pure ac supplied distribution system of simi lar ratings under balanced faults on the grid side and motor starting on the load side. It is shown that HVDC applied to industrial system able to mitigate voltage dips.*

Key words: HVDC, voltage dips.

Introduction

Classic HVDC system

A classic HVDC system operating in bipolar mode, shown in Fig 1, consists of Ac filters, shunt capacitor banks or other reactive-compensation equipment, converter transformers, converters, dc reactors, dc filters, and dc lines or cables.

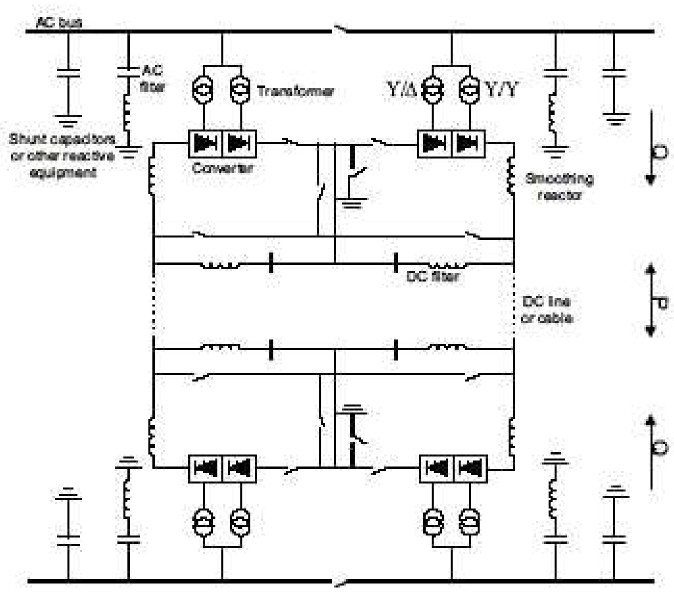


Fig1. Basic configuration of HVDC system

The power transmitted over the HVDC link is controlled through the control system where one of the converters controls the dc voltage and the other converter controls the current through the dc circuit. The control system acts through firing angle adjustments of the valves and through tap changer adjustments on the converter transformers to obtain the desired combination of voltage and current. The control systems of the two stations of a bipolar HVDC system usually communicate with each other through a telecommunication link.

Control strategies:

In this system only current control is employed in the rectifier side and both current control loop and gamma control loop is employed in the inverter side. Control model for both rectifier and inverter are based essentially on proportional and integral control blocks.

The operation at minimum gamma angle at the inverter and current control at the rectifier results in better voltage regulation than the operation with minimum delay angle at the rectifier and current control at the inverter. The current during line faults are automatically limited with rectifier station in the current control. While there is a need to a minimum extinction angle of the inverter at constant gamma angle, which is slightly above, the minimum required for the commutation margin. The main drawback of constant gamma control is the negative resistance characteristics of the converter which makes it difficult to operate stably when the ac system is weak.

Under normal conditions the inverter operates at constant gamma angle control. Under conditions of reduced ac voltage at the rectifier, it is necessary to shift the current control to the inverter to avoid run down of the dc link when the rectifier control hits minimum limit. This implies that current controller must also be provided at the inverter in addition to the gamma controllers a smooth transition from gamma control to current control takes place whenever the link current starts falling. Current reference at the inverter side is kept lower than the rectifier side to avoid clash of between the two current controllers.

A passive industrial system

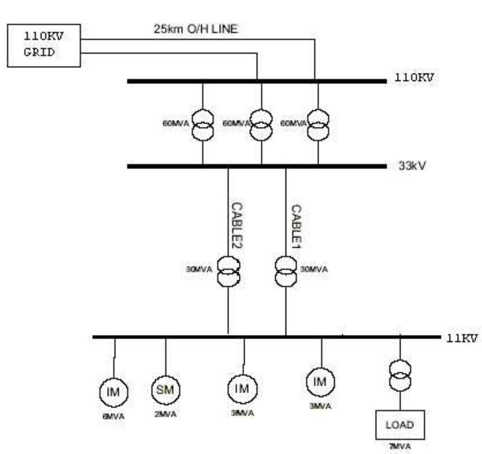


Fig2. Pure ac supplied industrial system

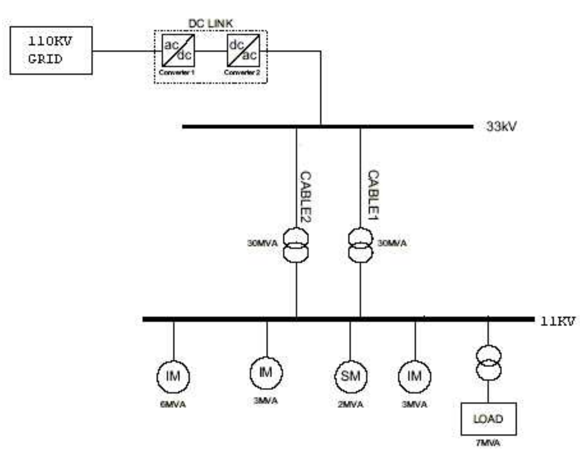


Fig3. A dc supplied industrial system

The difference between a pure industrial ac system and a dc link supplied industrial system has been investigated; a comparison between an ac grid supplying a passive industrial system and a dc link supplying the same industrial system is done. The investigations in each case study are carried out for three-phase fault. In each case the effect of fault duration and fault recovery on the system are studied. The investigations are chiefly concerned with the quality of supply within the industrial distribution system itself and so the studies are concerned only with that section of the network between the point of connection to the main utility and the load. An important aspect of industrial distribution system analysis is the reaction of the main loads to disturbances. The system is used for fault investigations and the study of fault propagations throughout a network.

The two systems shown in Figure 2 and Figure 3 are simulated in PSCAD/EMTDC. A fictitious passive industrial distribution system is used as the system model. This system contains different types of loads and is feed from the public supply. For example, this system includes a synchronous machine, three different induction motors, and some smaller loads (for instance, heating, lighting, computers). In the simulation, simplified models (only resistor and inductor) are used for the smaller loads. At this stage of the study, the aim is not to create a feasible design for an industrial distribution network, but to study the effect of disturbances on different types of loads and fault propagation.

Simulation

Motor starting on 11KV bus

In ac supplied industrial system starting of induction motor causes the voltage dips across 11KV bus, 33KV bus, and also 110KV bus.

To a dc supplied industrial system, starting of the same induction machine at 11kV bus causes voltage drop at 11kV bus, 33kV bus, but no voltage drop at 110kV bus. So dc link can mitigate voltage dip propagation to upstream voltage levels. In this specific system voltage dips due to motor starts are not a concern for the public supply (at 110kV grid). However, if the connection to the public supply would have been at 11kV (e.g. with a smaller industrial system), the dc link could have been used to mitigate motor-starting dips in the public supply. Comparing pure ac supplied industrial system and dc supplied system shows that the motor-starting dip is deeper and longer in the dc-supplied system. The same current limitation that reduces the dip upstream of the link causes a more severe dip downstream. However none of the resulting dips should be of much concern to standard industrial load

Upstream fault

Three-phase to ground Fault is simulated in the 110KV grid for the period of 0.1 sec. During the fault period the resistance of the ground is reduced few ohms from several thousand ohms. The recovery of the voltage from the fault for ac supplied distribution system and the dc supplied distribution system is studied.

For the balanced fault the dc system will delay the drop in voltage. This is due to the stored energy in the dc link. Increasing the dc link rating will mitigate the some extent of voltage dips due balanced fault.

Results

1. Per unit value of Rms voltage across various buses under motor starting

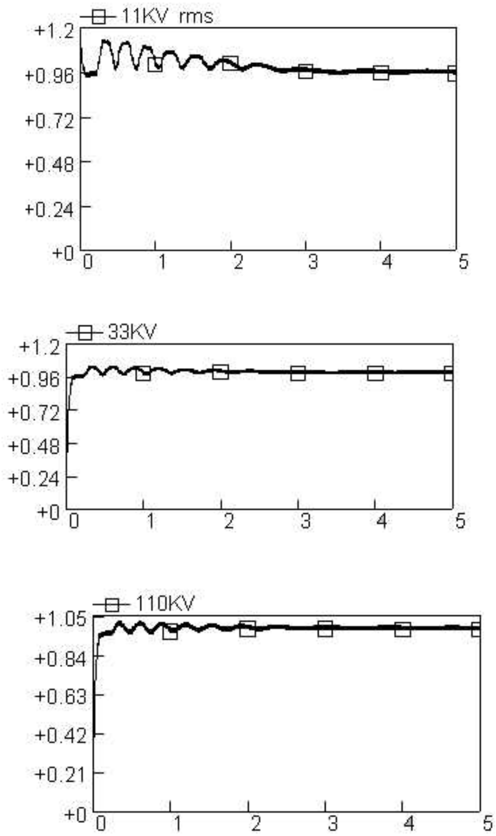


Fig4a. AC supplied system

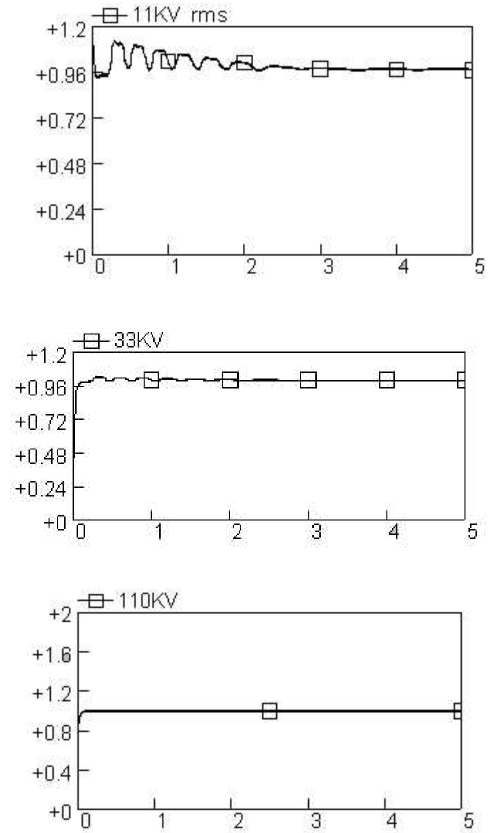
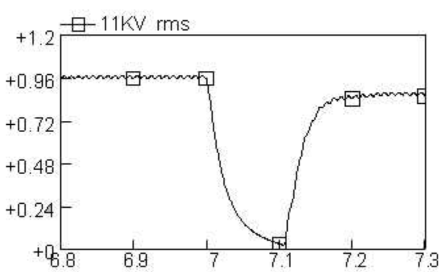
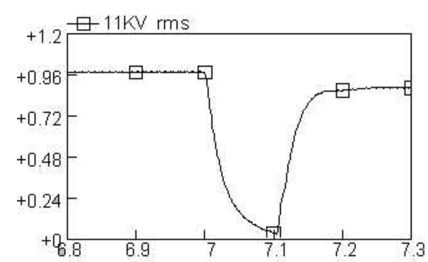


Fig4b. DC supplied system

2. Recovery of rms voltage from the three phase to ground fault (in p.u)





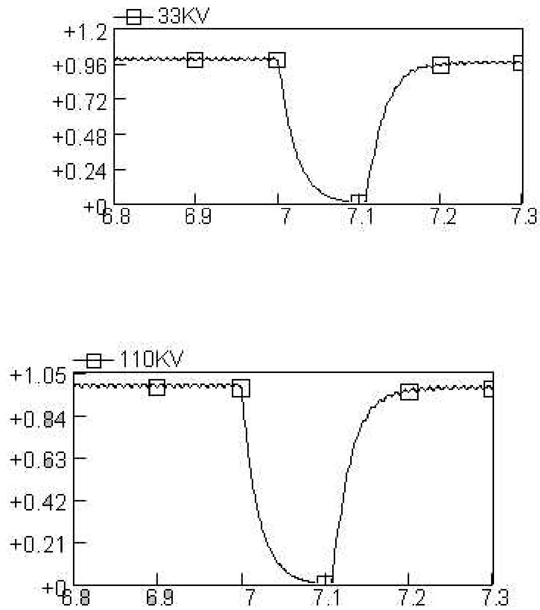


Fig5a. AC supplied system

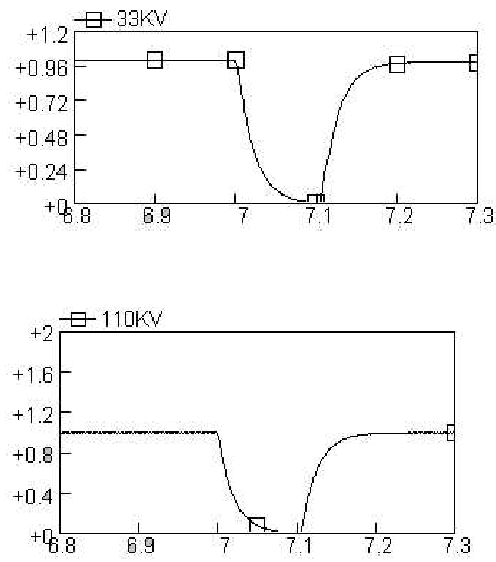


Fig5b. DC supplied system

Conclusion

The dc link mitigates the effect of motor starting on the public supply. However the resulting voltage dips in the industrial system is longer and deeper. This is not necessarily a problem as sensitive load may be supplied from another part of the system as the large motors. Therefore supplying large industrial power system through dc distribution system would improve the power quality of the public distribution system.

The performance during a voltage dip depends significantly on the behavior of the control system when current limitation is activated. The strategy for using the limited amount of current depends on the type of application of the dc link. Increasing the rating of the dc link will mitigate to some extent the voltage dips due to a balanced fault.

References

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Appendix

Components for the ac supplied industrial system:

Induction motor 1:
Rated RMS phase voltage: 7.967kV
Rated RMS phase current: 0.1255kA
Based angular frequency: 314.159265rad/s

Induction motor 2:
Rated RMS phase voltage: 7.967kV
Rated RMS phase current: 0.2510kA
Based angular frequency: 314.159265rad/s

Induction motor 3:
Rated RMS phase voltage: 7.967kV
Rated RMS phase current: 0.1255kA
Based angular frequency: 314.159265rad/s

Synchronous motor:
Rated RMS phase voltage: 7.967kV
Rated RMS phase current: 0.1046kA
Based angular frequency: 314.159265rad/s

RL loads:
Rated RMS phase voltage: 7.967kV
R: 19:044- L: 0.06062H