1. INTRODUCTION

1.1 Introduction

Power systems are currently experiencing a level of unprecedented stress. Continuously increasing demand with environmental and resource constraints are increasingly threatening the reliable and secure operation of networks. The HVDC links are of key importance for the satisfactory operation of power systems. As more and more HVDC links are being built, the need to develop methods for assessing the performance of these transmission systems is increasing. The performance of HVDC transmission system can be analyzed by analyzing various performance indices of the system. Performance indices include system stability, harmonics, control and protection system etc.

The detail stability analysis of the grid inclusive of DC links is possible with systematic development of sequence networks. The positive as well as negative damping is provided by various parameters of the power system. The damping effect caused by HVDC link is analysed with the help of these sequence networks. Influence of type and location of fault on the damping is also analyzed.

A bipolar HVDC transmission system consists of two converter stations connected by a DC overhead line. In HVDC system during the operation of converters, characteristic and non-characteristic harmonics are generated. The harmonics flow through the plant and utility power system resulting in voltage distortion, power losses and equipment failures. Harmonics of every order can appear with an additional direct current component in the valve side windings of the converter transformer. Uncharacteristic DC harmonics component if circulates within the valve side windings may drive the transformer in saturation. It is undesirable that this situation should arise where adequate continuous inspection of the nature of the harmonics is possible.

AC and DC Filters are provided in the system. Design of these filters is based on speculations of system and loading conditions. In practice the system is designed such that the decision of an AC filter branch to switch on and off depends on demanded reactive power as well as required harmonic elimination. Performance evaluation of the filters is done whenever an urge is felt. As such there is no continuous record of harmonic levels or filter performance evaluation. Practically it is possible that harmonic levels are almost crossing the acceptable limits- for particular season, at particular time of the day and/or for a typical
system load pattern and the fact remain unnoticed. This may result in slow deterioration of system components.

A scheme, that explores existing set up with few additions and provides continuous measurement and detail analysis of the harmonics as well as analysis of filter performance, is proposed.

Operation of HVDC link is highly automated. The automation can be further enhanced by means of package of software tools, presented as an operating engineer’s aid. The analysis of HVDC transmission system occurrences indicate that these events are recurring events. By analyzing various factors involved with these occurrences, a software package, ‘HVDC-Fault Localization’, in the form of an expert system is developed. With advances in applied artificial intelligence, increasing amount of knowledge can be stored and used for applications by people with relatively little expertise. Most of the interest in expert system is not because of their proven capacity but because of their potential.

1.2 Necessity

HVDC transmission system can be regulated rapidly and flexibly and thus it is possible to improve the performance of the HVDC transmission system itself and the AC system consisting of HVDC links.

Operation of AC transmission grid with a HVDC transmission system is associated with peculiar events. There can be situations of failures of system components such as converter transformer failure etc. Moreover the HVDC transmission system respond to disturbances on the AC system. Considerable monitoring equipment is provided to verify the performance of HVDC related control systems and to identify possible damage to facilities resulting from AC system events. Analysis of these events is conducted by the supplier. The owners may not be advised of the cause of the event due to information policy issues. Unbiased analysis of these events is always necessary.

The research and literature available generally is either related to pure theoretical analysis verified by software simulation or system occurrences modeled and verified by software simulations. The actual system occurrences are rarely verified by analytical analysis.
Stability analysis is to be conducted to determine the HVDC response to system contingencies. The results of transient analysis studies are used to refine the HVDC stability models especially when considering unbalanced faults, such as line-to-line-to ground and line-to-line faults.

Harmonic analysis is conducted to determine filtering requirements. An understanding of the protection and control functions of the HVDC is necessary to determine the full extent of AC/DC system interactions. The protection and control functions of an HVDC can prevent the spread of disturbances; they can also prevent the spread the adverse impact of disturbance [1-3].

The HVDC should still be fully monitored to allow modifications on the basis of lessons learnt from actual system events. Analysis of actual events revealed the information about specific conditions. This can be utilized to adapt operating procedures that would prevent those particular system configurations. Modifications to operating procedures are useful for improvement of the system performance.

1.3 Objectives

The objectives of the thesis are to develop methodology and evolve contributions with reference to following points to:

- Analyze the system data and transient records of fault events or disturbance
- Analyze system parameters in order to investigate the deficiencies in the overall performance
- Develop new methods
- Formulate new hypothesis
- Simulation of the system
- Mathematical analysis and verification
- Establish new methodology and contributions for improvement of overall system performance
The analytical model has intended for analysis of practically observed issues associated with the operation of HVDC systems. Actual system data is used as very important tool for analysis.

The objectives of this study are to optimize control parameters, and to see if any special control functions or operational restrictions are needed so that fast and robust performance is attained.

The research work regarding the performance analysis has led towards:

- Variation in system parameters and its effect on performance
- Effect of harmonics

The conclusions of the research will provide improvement in operation of the system. These guidelines will contribute in enhancement of overall performance of the electrical power systems.

1.4 Theme

Performance of the system is analyzed on the basis of performance indices. Fast power control of HVDC system is the major factor to provide stability benefits to the associated AC system. The effect of parameters of HVDC link on accelerating power and hence on transient stability of the AC network is analyzed. The sequence impedances networks are derived and equivalent circuits have been modeled. The effect of type of fault on transient stability is investigated.
Ever decreasing values for the permissible harmonic limits necessitates continuous
analysis. Measures to be taken for better performance of filters are investigated. A system for
evaluation of additional filter requirement is developed. Performance of system control and
protection is studied. Measures to be taken to reduce harmonic distortions are investigated.
Alternative schemes are considered. Parameters of regulators are optimized. Fault analysis
results have led to contributions. It is observed that variations in system parameters during a
disturbance are unpredictable. The records of various faults and related data are analyzed.
The analysis is carried out by mathematical and computational methods in order to avoid
pole tripping or to reduce the outage timings of HVDC link.

Figure 1.2: Analysis - Criteria and Stages Involved

1.5 Organization

In the first chapter i.e. ‘Introduction’, as it is observed, the topic of the thesis is
introduced. Necessity, objectives and theme of the research are discussed. The second topic
of the thesis is ‘Literature Survey’. It includes basic concepts about converter operation,
HVDC terminology. Recent HVDC technologies, various configurations, merits, economical
considerations, environmental issues are introduced. A basic bipolar HVDC transmission
system is elaborated. Conventional methodology for mathematical modeling of the converter
and other subsystems are included in the preceding paragraphs. In the thesis, Chandrapur-
Padghe HVDC system data is referred for analysis. Filter scheme available in the system is discussed.

Chapter third includes of Chandrapur-Padghe system information. Details of control and protection system are given. The transmission network of MSETCL has been considered for analysis. This transmission grid part of western grid is elaborated. The impedance networks developed are discussed further. The chapter also describes the continuous harmonic monitoring scheme developed. Details of D. C. line fault location system are given.

‘Performance Analysis’ i.e. fourth chapter includes verification of the results of stability analysis. Results of the mathematical analysis are verified with simulation results. Harmonic measurements with both methods viz. ‘CCM_CVT’ and ‘Filter Current Measurement’ are verified. Results of fault location system are deduced. In the preceding chapters, ‘Conclusions’ and ‘Contributions’ are mentioned.