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A Review Harmonics Voltage Stability and Power Quality Improvement Using PWM Technique

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Abstract—*Some AC voltage traction systems are particularly susceptible to harmonic distortion. They are weak single-phase networks with severely distorting SCR-based locomotive drives which continually change their point of connection on the network. Active filters offer substantial potential for reducing this distortion, but because of the network topology, the only effective control strategy's to inject harmonic compensating currents derived from harmonic voltages measured at the point of filter coupling. This paper shows how this may be done using synchronously rotating frames to extract individual harmonic voltages to act as current injection references. This paper highlights some of the challenges in obtaining a controller with sufficient accuracy and speed.*

Keywords—*Thyristor Controlled Reactor, Harmonics, Resonance, PWM.*

1. INTRODUCTION

Harmonic currents injected by locomotives can result in a range of traction system problems, including trackside over-voltages, increased voltage form factor and excessive low order harmonic currents being fed back into the HV supply. illustrates the pantograph voltage waveform obtained at the end of a feeder section loaded with four MW locomotives operating at full power. The voltage waveform shows a resonant over-voltage and an increased voltage form factor. Resonant over-voltages may promote premature failures of equipment connected to the system, while an increase in form factor means that maximum power available to each locomotive is reduced [1]. Clearly, it is highly desirable to reduce this voltage distortion by some form of filtering action. The solution proposed in this paper is to use a shunt active filter. The increasing number of power system blackouts in many countries in recent years, is a major source of concern. Power engineers are very interested in preventing blackouts and ensuring that constant and reliable electricity supply is available to all customers. Incipient voltage instability, which may result from continues load growth or system contingencies, is essentially a local phenomenon. However, sequences of events accompanying voltage instability may have disastrous effects, including a resultant low-voltage profile in a significant area of the power network, known as the voltage collapse phenomenon. Severe instances of voltage collapse, including the August 2003 blackout in North - Eastern U.S.A and Canada, have highlighted the importance of constantly maintaining an acceptable level of voltage stability. The design and analysis of accurate methods to evaluate the voltage stability of a power system and predict incipient voltage instability, are therefore of special interest in the field of power system protection and planning. In planning and operating power systems, the analysis of voltage stability for a given system state involves the examination of two aspects:

a) Proximity how close is the system to voltage instability Mechanism: when voltage instability occurs, what are the key contributing factors, what are the voltage-weak points, and what areas arc involved Proximity gives a measure of voltage security whereas mechanism provides information useful in determining system modifications or operating strategies which could be used to prevent voltage instability.

2. VOLTAGE STABILITY

The voltage stability of a power system refers to its ability to properly maintain steady, acceptable voltage levels at all buses in the network at all times, even after being subjected to adisturbance or contingency. A power system may enter a condition of voltage instability when the system is subjected to a steady increase in load demand or a change in operating conditions, or a disturbance (loss of generation in an area, loss of major transformer or major transmission line). This causes an increased demand in reactive power. Voltage instability is characterized by gradually decreasing voltage levels at one or more nodes in the power system. Both static and dynamic approaches are used to analyze the problem of voltage stability. Dynamic analysis provides the most accurate indication of the time responses of the system. Voltage stability is indeed a dynamic phenomenon and can be studied using extended transient/midterm stability simulations. However, such simulations do not readily provide sensitivity information or the degree of stability. They are also time consuming in terms of CPU and engineering required for analysis of results. Therefore, the application of dynamic simulations is limited to investigation of specific voltage collapse situations, including fast or transient voltage collapse and for coordination of protection and controls. Voltage stability analysis often requires examination of a wide range of system conditions and a large number of contingency scenarios. For such applications, the approach based on steady state analysis is more attractive and if used properly, can provide much insight into the voltage/reactive power problem.

3. REASONS OF VOLTAGE COLLAPSE

Voltage collapse is a process in which, the appearance of sequential events together with the voltage instability in a large area of system can lead to the case of unacceptable low voltage condition in the network, if no preventive action is committed. Occurrence of a disturbance or load increasing can leads to excessive demand of reactive power. Therefore, system will show voltage instability. If additional resources provide sufficient reactive power support, the system will be established in a stable voltage level. However, sometimes there are not sufficient reactive power resources and the excessive demand of reactive power can leads to voltage collapse. Voltage collapse can be initiated due to small changes of system conditions (e.g. load increasing) as well as large disturbances (e.g. line outage or generation unit outage). Under these conditions, shunt FACTS devices such as SVC and can improve the system security with fast and controlled injection of reactive power to the system. However, when the voltage collapse is due to excessive load increasing, FACTS devices cannot prevent the voltage collapse and only postpone it until they reach to their maximum limits. Under these situations, the only way to prevent the voltage collapse is load curtailment or load shedding. So, reactive power control using FACTS devices is more effective in large disturbances and contingencies should be considered in voltage stability analysis.

4. ANALYSIS AND METHODS OF PREVENTION OF VOLTAGEINSTABILITY

A number of special algorithms have been proposed in the literature for voltage stability analysis using the static approach. In general, these have not found widespread practical application and utilities tend to depend largely on conventional power flow programs to determine voltage collapse levels of various points in a network. However, this approach is laborious and does not provide sensitivity information useful in making design decisions. Some utilities use Q-V curves at a small number of load buses to determine the proximity to voltage collapse and to establish system design criteria based on Q and V margins determined from the curves. One problem with the Q-V curve method is that it is generally not knownapriori at which buses the curves should be generated. In producing a Q-V curve, the system in the neighborhood of the bus is unduly stressed and results may be misleading. In addition, by focusing on a small number of buses, system-wide problems may not be readily recognized. An approach using V-Q sensitivity and piecewise linear power flow analysis to find the margin, measured in terms of total load growth, between a given operating condition and the voltage collapse point is already described There has been some indication that the linear power flow solution may not be sufficiently accurate as the collapse point is approached. Also V-Sensitivity information could be misleading when applied to a large system having more than one area with voltage stability problems. Most of the approaches proposed to date use conventional power flow models to represent the system steady state. This may not always be appropriate, especially as the system approaches critical condition. There is a need to consider more detailed steady state models for key system components such as generators, SVCs, induction motors and voltage dependent static loads. Load characteristics in particular could be critical and expanded sub-transmission representation in the voltage collapse areas may be necessary. There Isa need for analytical tools capable of predicting voltage collapse in complex networks, accurately quantifying stability margins and power transfer limits, identifying voltage-weak points and areas susceptible to voltage instability, and identifying key contributing factors and sensitivities that provide insight into system characteristics to assist in developing remedial actions. Modal analysis approach with the objective of meeting the above requirements is used instead of the conventional methods. It involves the computation of a small number of Eigen values and the associated eigenvectors of a reduced Jacobean matrix which retains the Q-V relationships in the network. However, by using the reduced Jacobean instead of the system state matrix, the focus icon voltage and reactive power characteristics. The Eigen values of the Jacobean identify different modes through which the system could become voltage unstable. The magnitude of the Eigen values provides a relative measure of proximity to instability. The eigenvectors, on the other hand, provide information related to the mechanism of loss of voltage stability. Fast analytical algorithms for selective computation of a specified number of the smallest Eigen values make the approach suitable for the analysis of large complex power systems.

Detection Method:

i. A shunt active filter acts as a controllable harmonic current source. In principle, harmonic compensation is achieved when the current source is commanded to inject harmonic currents of the same magnitude but opposite phase to the load harmonic currents. There are basically 3 methods of determining this current reference for the active filter [2] by measuring the load harmonic current to be compensated and using this as a reference command;

ii. By measuring source harmonic current and controlling the filter to minimize it;

iii. By measuring harmonic voltage at the active filter point of common coupling (PCC) and controlling the filter to minimize the voltage distortion. In a traction system, the locomotive load moves. However, previous research has shown that a shunt active filter is most effective in mitigating harmonics in a general distribution system when it is installed at the far end of a feeder [2] [3], hence this is also likely to be the most suitable location for the active filter considered in a traction application. Consequently the ac source will be physically quite distant from the active filter PCC. The only possible measurement for control is the harmonic voltage measurement approach. Hence the only realistic control strategy is to measure the feeder harmonic voltages at the active filter PCC, and to process the voltages to provide a current reference for the filter.

Harmonic extraction for 3-phase systems:

To obtain the current reference signal, it is necessary to extract the harmonic components from the voltage. In order to achieve this, either a frequency domain approach or a time domain approach can be used. The frequency domain approach is based on Fourier analysis and has poorer dynamic response [6] and hence is not as widely used. The time domain approach for a 3-phase system is based on the generalized Park Transformation. Essentially the measured 3-phase quantity (current or voltage) is transformed from the stationary reference frame to the synchronous reference frame rotating at some chosen frequency. The original harmonic component at the chosen frequency becomes a dc component in the transformed signal. The transformation is given by where van, vibe and vs. are the measured 3-phase quantity, and ad and vq are the corresponding direct and quadrature quantities in the synchronous frame of reference rotating at angular frequency of There are two obvious ways of getting rid of the fundamental component in the measured signal using the Park Transformation. The first is to transform into the synchronous frame rotating at the fundamental frequency, thus turning the fundamental component in the original signal into a pair of dc quantities (in the direct and quadrature axes respectively) and all the harmonics into non-dc (or ac) quantities. High-pass filter to extract the dc component in the synchronous frame may be used, followed by a transformation back to the stationary frame. This will then produce a signal free of the fundamental component. A second approach of removing the fundamental component using the Park transformation is to transform the measured distorted signal into a synchronous frame at some chosen harmonic frequency, thus shifting the chosen harmonic component into a pair of dc quantities in the synchronous frame, and all other components including the fundamental into ac quantities. The transformed signal can then be easily processed by a low-pass filter and reverse-transformed to give only the chosen harmonic component. Several of such transformation/ filtering blocks can be used to extract the individual harmonic components of interest. Their outputs may then be summed to produce the desired harmonic current reference to drive the active filter. In either case, the main benefit of filtering in the synchronous reference frame instead of direct notch/band-pass filtering in the stationary reference Frame is that the chosen frequency component (fundamental or otherwise) exists at dc.

4. THYRISTOR CONTROLLED REACTOR AS HARMONIC SOURCE

Thyristor controlled reactors that can provide a continuous, fast reactive power and voltage control may improve performance of power system in many aspects. These aspects are controlling of transient over-voltages at power frequency and preventing of voltage collapse increase in transient stability and decrease in system oscillations. Static VAR compensators consist of thyristor controlled reactors that are used for balancing the three phase sy~ems supplying unbalanced loads and for preventing the voltage oscillations caused by short duration.loads in transmission and distribution systems. The thruster-controlled reactor consists of reactor in series with two parallel inverse thrusters as These thrusters are gated symmetrically and control the fundamental component of current versus time [3]thruster-controlled reactor (TCR) is one of the conventional static Var compensators used in the field of power quality improvement [1]-[4]. It can absorb a continuous reactive power at the fundamental frequency of the power system network, but it releases significant odd harmonics which could cause many undesirable effects, like over currents, extra losses, and noises to telecommunication systems [5]. Therefore, elimination of harmonic current components associating the TCR performance is handled together with its installation. Tuned passive filters and active filters are usually used to eliminate these harmonics. Installation of these filters in the location of the TCR circuit offers low-impedance paths for odd harmonic current components, thus resulting in a significant reduction in their components passing to the ac source side.

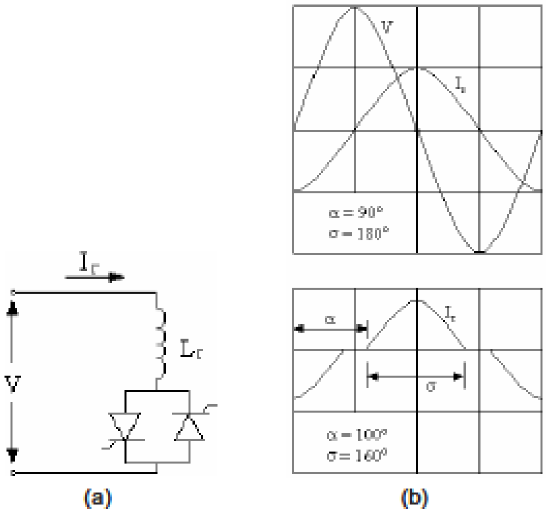

Figure 1 (a) Main element of a TCR

(b) Voltage and current waveforms in a TCR.

The design of these filters depends on the ac source impedance or the short circuit level at their locations. As high as is the short circuit level, as larger as is the filtering circuit rating. A tuned harmonic filter is of a capacitive nature at the fundamental frequency of the power system network, thus it generates an amount of reactive Thyristor Controlled Series Compensator (TCSC) is one of the important members of FACTS family that is increasingly applied with long transmission lines by the utilities in modern power systems, the studied system is compensated by a TCSC that consisting of a fixed capacitor in parallel with a thyristor controlled reactor and connected to a firm voltage source. The TCSC is controlled by varying the phase delay of the thruster firing pulses synchronized through a PWM to the line current waveform. Modeled TCSC has three operation modes; bypassed thyristors mode, blocked thyristors mode, and Vernier mode, respectively. In Vernier mode, dynamic operation of the modeled TCSC is achieved with the continuous variation of the thryristors firing angle.

5. CONCLUSION

The use of a PWM technique in traction systems to mitigate the level of harmonic voltages created by the traction vehicles has promising potential. However, by looking at the principle of the Synchronous frame filter, this paper has shown that the application of an active filter to a traction system is not as straightforward as it might first seem, partly because it is a single-phase system and that impacts directly on the harmonic extraction strategy. Most active filters reported in the literature are targeted at a general 3-phase distribution network and hence little attention has been paid to the dynamic performance. A good compromise between accuracy and speed cannot be achieved with a simple filter. To be useful in a traction system, a more sophisticated controller is required to provide a faster response to fast load changes. Such a controller is currently under development, and will be the subject of a future paper.

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