Control strategy and site selection of a shunt active filter for damping of harmonic propagation in power distribution systems

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power methods of accounting for harmonics in billing are considered. These large differences indicate that the choice of weighting factor will be crucial for harmonically adjusted power factor or apparent power measuring methods.

Adherence to IEEE Standard 519-1992 will reduce harmonics in the system and system losses related to the current harmonics. It will also promote fair and equal revenue billing of all customers connected on the system.

Discusser: A. Emanuel

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Control Strategy and Site Selection of a Shunt Active Filter for Damping of Harmonic Propagation in Power Distribution Systems

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This paper deals with a shunt active filter which will be installed by an electric utility, putting much emphasis on the control strategy and the best point of installation of the shunt active filter on a feeder in a power distribution system. The objective of the shunt active filter is to damp harmonic propagation rather than to minimize voltage distortion throughout the feeder. Harmonic mitigation is a welcome "by-product" of the shunt active filter, which comes from damping of harmonic propagation.

A virtual model for a radial distribution system in a residential area is used for analysis and computer simulation. The rated bus voltage is 6.6kV (line-to-line), and the rated frequency is 50Hz. The equivalent inductive reactance upstream, including the leakage reactance of a primary distribution transformer of 15MVA, is to be estimated from the short circuit capacity of 110MVA. The transformer supplies four distribution feeders consisting of feeders 1 ~ 4. For the sake of simplicity, only feeder 2 is considered under the assumption that feeders 1, 3 and 4 are disconnected from the transformer. Overhead distribution lines, which are classified into a primary line and branch lines in feeder 2, are assumed to be LR circuits because it is reasonable to neglect the effect of stray capacitors of the distribution lines on the 5th and 7th harmonic voltage and current. Feeder 2 supplies electric power to eleven medium-voltage consumers of 200-240kW, which install shunt capacitors without any reactor, and to six low-voltage consumers of 50-130kW, which have no shunt capacitor. The total capacity of the loads is 2.99MW, and that of the shunt capacitors for power factor improvement is 0.99Mvar. Harmonic propagation occurs in feeder 2 around the 7th harmonic frequency (350Hz), so that the 7th harmonic voltage is amplified by four times at the rated load of 2.99MW and by eight times at no load. This results from series and/or parallel resonance between inductive reactances of the distribution lines, along with the equivalent inductive reactance upstream, and capacitive reactances of the shunt capacitors on feeder 2.

First of all, this paper reveals how the stability of a shunt active filter is affected by the control strategy and the point of installation on the primary line in feeder 2. Three types of harmonic detection methods in time domain, that is, load current detection, supply current detection, and voltage detection, are taken into consideration. Each harmonic detection method plays an important role in the control strategy of the shunt active filter. The open-loop transfer function and its Bode diagram in each detection method give us the following analytical results: A shunt active filter based on either the load current or supply current detection operates properly, if neither shunt capacitor nor shunt passive filter is connected to a network downstream of the point at which the shunt active filter is installed. Thus, either of the two methods has already been applied to shunt active filters installed in the vicinity of an or a few identified harmonic-producing load(s). But the computer simulation shows that the shunt active filter based on either of the two methods becomes unstable when it is installed on the beginning terminal and midpoint of the primary line in feeder 2. Instability or sustained oscillation appears in a frequency range from 400Hz to 450Hz. On the other hand, the voltage detection method has a phase margin over 900 regardless of location. From the viewpoint of stability, it is the most suitable for shunt active filters which are intended to be dispersively installed on power distribution systems or industrial power systems. These analytical results agree well with those obtained by computer simulation.

Next, this paper presents a basic concept of site selection of a single shunt active filter based on the voltage detection, and its effect on damping of harmonic propagation. The shunt active filter, which is installed on the beginning terminal in the primary line, has no capability of damping harmonic propagation in feeder 2. The shunt active filter, which is installed in the vicinity of an identified harmonic-producing load, is effective in the mitigation of harmonic voltage at the point of installation. However, it may be impossible for an electric power company to identify all of harmonic-producing loads on power distribution systems. Even if it is possible, it would be impractical, from an economical point of view, to install a shunt active filter in the vicinity of each harmonic-producing load. Thus, this paper points out that installation of the shunt active filter on the end terminal of the primary line is the most effective and practical way, not only to damp harmonic propagation throughout feeder 2, but also to solve harmonic interference caused by many unidentified harmonic-producing loads on feeder 2. The validity of this new concept is verified by theory and computer simulation.

Finally, this paper presents an optimal gain in the voltage detection method, leading to a practical application of the shunt active filter into power distribution systems.

Discussers: Z. Yao, V. Rajagopalan, S. Lahaie

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Determination of Needed FACTS Controllers That Increase Asset Utilization of Power Systems

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Flexible AC Transmission System (FACTS) is a concept promoting the use of power electronic based and other static controllers to enhance controllability and increase power transfer capability. The basic idea behind the FACTS concept is to enable the transmission systems to become active elements, playing active roles in increasing the flexibility of power transfer requirements and in securing stability of the dynamics of integrated power systems. Therefore, FACTS Controllers should be designed with dynamic characteristics that effectively enhance the dynamic performance of the associated power system.

Power System engineers are currently facing challenges to increase the power transfer capability of existing transmission systems. FACTS offers an economical solution to accommodate that need while maintaining sufficient steady-state and transient stability margins.

The main purpose of this paper is to present a static/dynamic approach for allocation of FACTS Controllers. The proposed approach is based on the combined use of a continuation power flow, an optimal power flow and an eigenvalue analysis. The algorithm allocates shunt connected controllers (Static Var Compensators - SVC) to solve voltage collapse problems that may occur during major faults or due to load level increases. Series connected controllers (Thyristor Controlled Series Capacitors TCSC) are allocated to guarantee the maximum transient synchronizing torque between electrical areas during severe faults.

The studied transmission system is shown in Figure 1. It is com-