Feedback control and optimization method for voltage harmonic damping

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Abstract. **Two methods of voltage harmonic elimination are compared - the feedback control method and an optimisation approach. The first method has been presented in the literature, the second is a new proposed in the paper.**
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Voltage distortion resulting from the harmonic currents produced by power electronic equipment has become a serious problem to be solved [1]. The fundamental change is caused by the power electronic based distributed generation [2]. The converters interfacing wind or photovoltaic plants with the system can play a similar role as active power filters. Generally, individual low-power and high-power consumers are responsible for limiting distortion at the end of line feeder, while electric utilities are responsible for limiting voltage distortion at the point of common coupling in the distribution systems. Most of the previous works on harmonic compensation are based on current-controlled method. The shunt active filter based on voltage detection at the point of installation and the voltage-controlled method is more flexible to the current-controlled method [2].

The voltage-controlled method which does not require a harmonic current reference detects voltage harmonics v_h at the point of filter installation, and then injects a compensating current i_c as follows $i_c = G v_h$, where G is a control gain [1,2]. An active filter based on voltage detection forms a feedback control loop. The active filter behaves like resistor of $1/G$ equal for all harmonic except the fundamental frequency. For fundamental harmonic behaves as infinite resistance. The injected current dumps harmonic propagation in the distribution system.

The other method of voltage control is proposed in the presented paper. This method is based on an optimization approach. The voltage total harmonic distortion at the point of filter installation is chosen as the objective function which should be minimized. Magnitudes and phases of the current harmonics injected at the point of filter installation play the role of multidimentional variable X which minimizes the objective function. Multidimentional unconstrained nonlinear optimization attempts to find the local minimum of the chosen objective function. In this method not only magnitudes of current harmonics but also their phases are selected.

These two methods – feedback control and optimization approach – is illustrated and compared for simple example of the circuit shown in Fig. 1. The nonlinear load composed of resistance R_o and nonlinear inductor Ψ is supplied by the sinusoidal voltage $e = V \sin \omega t$ through resistance R_e. Magnetic curve of the nonlinear inductor is approximated as follows $i = k_1 \Psi + k_9 \Psi^9$, where I and Ψ are inductor current and magnetic flux. Due to the nonlinear inductance current i_e and voltage v_c contain harmonics.

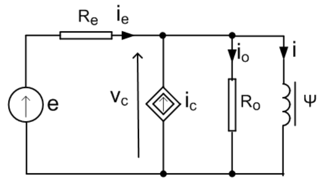

Fig. 1. Nonlinear circuit with controlled current source representing the compensator

Current controlled source i_c represents compensator and is controlled by voltage $v_c - v_1$, where v_1 is fundamental harmonic of the voltage v_c at the point of filter installation.

Two methods of the reference current i_c are compared. The first method assumes that $i_c = G(v_c - v_1)$ [1,2]. This method is called further as damping resistor method. The proposed approach, called optimization method, assumes that reference current i_c is computed in such a way that total harmonic distortion of the voltage v_c is minimized. The objective function to be minimized is the square power of voltage *THD*. The magnitudes and phases of compensator current harmonics play the role of searched variables. Two functions from optimization toolbox of MATLAB have been applied - FMINUNC and FMINSEARCH. Both the unconstrained nonlinear minimization functions find a local minimum of a cost function of several variables. Example of the obtained results is shown in Fig. 2.

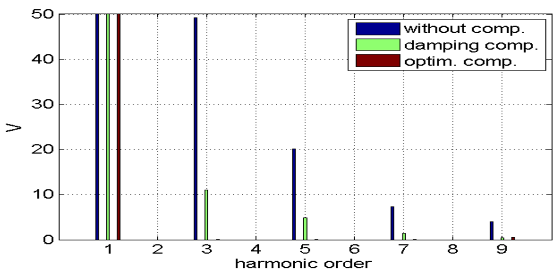

Fig. 2. Voltage harmonic contents for two compensation methods

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