Centralized normalization of harmonic voltages by the third-order passive filter

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The present paper addresses the problem of centralized harmonic voltage decrease in the high voltage network with distributed nonlinear loads using third-order passive filters.

1. The 220 kV network supplies electricity to the traction loads from the 27.5 kV winding of 40 MVA three-phase three-winding transformers. The traction substations are located at a distance of 40-60 km from one another. Therefore nonlinear loads are numerous and distributed along hundreds of kilometers of 220 kV supply network.

2. In the paper the expressions for calculation of the third-order filter parameters if $C_1 \neq C_2$ are obtained. The scheme of the third-order filter is given in Fig.1.

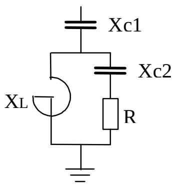

Fig. 1. Schematic diagram of the third-order filter.

Reactance X_{C1} is calculated by the set values of reactive power Q_{C1} and voltage U at the fundamental frequency. The remaining filter parameters should meet the following conditions:

1) resistance of filter at the n-th harmonic equals R_F ,
2) reactance of filter at the n-th harmonic equals zero,
3) $X_{C2} = mX_{C1}$,

where m – a coefficient taking into account relations between X_{C1} and X_{C2}.

The parameters of the third-order filter can be calculated by the expressions:

$$X_{C1} = \sqrt{3}U^2 / Q_{C1};$$

$$X_{C2} = mX_{C1},$$

where $$1 < m < \frac{R_F^2 n^2 + X_{C1}^2}{2nR_F X_{C1}},$$

$$R_F = \frac{K_{U(n)F}}{(K_{U(n)} - K_{U(n)F})\sqrt{g_{ns}{}^2 + b_{ns}{}^2}},$$

$K_{U(n)}$, $K_{U(n)F}$ - values of indices at the node without the filter and with it, g_{ns}, b_{ns} - conductance and susceptance of network at the filter connection node;

$$X_L = (-B + \sqrt{B^2 - 4AC})/(2An),$$

where $A = -X_{C1n}(1+m)$,

$$B = R_F^2 + X_{C1n}^2(1+2m),$$

$$C = -R_F^2 mX_{C1n}(1 + X_{C1n}^2);$$

$$R = R_F(X_L n^2 - mX_{C1})/(X_L n^2 - X_{C1}).$$

3. The obtained expressions are used to choose the third-order filters for the 220 kV network which supplies power to the traction load. The third-order filter selection includes the following:

1. characteristics of harmonic distortions in the considered network;
2. choice of node for installation of filters;
3. determination of parameters of the harmonic filters:
   1) calculation of the filter resistance R_F ,
   2) calculation of the parameter m ,
   3) calculation of the filter parameters (X_{C1}, X_{C2}, R, X_L) фильтра.

The filter parametrs of the 3rd, 5th and 7th harmonics were determined in a similar way.

4. The efficiency of filter operation was tested in 18 operating conditions of the supply main. The desired values of $K_{U(7)}$ were exceeded only in one operating condition at two nodes for 7th harmonic. The impact of the selected filters on operating conditions of harmonics 11, 13, 17, 19, 23 and 25 was analyzed at all the nodes. The impact of filters for harmonics 3, 5 and 7 on voltages of harmonics 11 and 13 at all the network nodes is negligible. There is practically no impact of filters for the harmonics 17, 19, 23 and 25.

5. Comparative estimation of the efficiency of decreasing voltages of harmonics 3, 5 and 7 is made by the third-order and C-type filters. It has been revealed that they reduce harmonic voltages virtually equally.