Digital Signal Processing for Protection and Control - Laboratory

Exercise 4: *Assessment of digital algorithms for power and impedance components measurement (4 hours)*

Exercise contents:

f_s=(900+(‘*group number’*)*100) Hz (change this frequency if tested algorithm requires other value)

For the measurement algorithms (A and B) given below make comparative analysis with regard to:

1. measurement accuracy and dynamics for the undistorted 50Hz sine signals (current and voltage);
2. algorithms’ accuracy for the signals containing decaying DC component (in current signal) of various time constants (50-300ms);
3. influence of harmonic and inter-harmonic components on the measurement quality;
4. algorithms’ quality for the cases of frequency change in the range 50±2Hz;
5. influence of sampling frequency on the measurement accuracy.

The algorithms to be examined are as follows:

A – averaging methods

Even group number:

$$P_1(n) = \frac{1}{N}\sum_{k=0}^{N-1} u_1(n-k)i_1(n-k)$$

$$Q_1(n) = \frac{1}{N}\sum_{k=0}^{N-1} u_1(n-k-N_1/4)i_1(n-k)$$

$$I_{1m}(n) = \sqrt{\frac{2}{N}}\sqrt{\sum_{k=0}^{N-1} i_1^2(n-k)}$$

Odd group number:

$$P_1(n) = \frac{1}{N}\sum_{k=0}^{N-1} u_1(n-k)i_1(n-k)$$

$$Q_1(n) = \frac{1}{N}\sum_{k=0}^{N-1} u_1(n-k)i_1(n-k-N_1/4)$$

$$I_{1m}(n) = \sqrt{\frac{2}{N}}\sqrt{\sum_{k=0}^{N-1} i_1^2(n-k)}$$

B – orthogonal components

- *orthogonalisation with*

Group 1, 4, 7 and 10 $\quad x_c(n) = x(n), \quad x_s(n) = x(n-N_1/4)$

Group 2, 5, 8 $\quad x_c(n) = x(n), \quad x_s(n) = \dfrac{x(n-k) - x(n)\cos(k\Omega_1)}{\sin(k\Omega_1)}, \quad k$=1

Group 3, 6, 9 $\quad$ full-cycle sine/cosine filters

- measurement with

Group 1, 4, 7 and 10

$$P_1(n) = \frac{1}{2}\left[u_{1C}(n)i_{1C}(n) + u_{1S}(n)i_{1S}(n)\right]$$

$$Q_1(n) = \frac{1}{2}\left[u_{1S}(n)i_{1C}(n) - u_{1C}(n)i_{1S}(n)\right]$$

Group 2, 5, 8

$$P_1(n) = \frac{1}{2\cos(k\Omega_1)}\left[u_{1S}(n)i_{1S}(n-k) + u_{1C}(n-k)i_{1C}(n)\right], \quad k=1$$

$$Q_1(n) = \frac{1}{2\cos(k\Omega_1)}\left[u_{1S}(n)i_{1C}(n-k) - u_{1C}(n-k)i_{1S}(n)\right], \quad k=1$$

Group 3, 6, 9

$$P_1(n) = \frac{1}{2\sin(k\Omega_1)}\left[u_{1S}(n)i_{1C}(n-k) - u_{1S}(n-k)i_{1C}(n)\right], \quad k=1$$

$$Q_1(n) = \frac{1}{2\sin(k\Omega_1)}\left[u_1(n-k)i_1(n) - u_1(n)i_1(n-k)\right], \quad k=1$$

For all groups:

$$I(n) = \sqrt{i_{1C}^2(n) + i_{1S}^2(n)}$$

$$R = \frac{2P}{I^2} \quad X(n) = \frac{2Q}{I^2}$$