Fig. 1. Three-phase three-wire circuit, including the instantaneous voltages and currents.

Fig. 2. Experimental system configuration that was designed, built, and tested in 1982 [2].
Fig. 3. Experimental waveforms before and after a step change was made in the dc load resistor of the thyristor rectifier, where the control angle of the thyristors was kept zero [2].

Fig. 4. Experimental harmonic spectra of \( i_{\text{Sa}} \) (left) and \( i_{\text{a}} \) (right), where three spectra in each of the two measured results correspond to the fundamental (50 Hz), 5\(^{th}\)-harmonic (250 Hz), and 7\(^{th}\)-harmonic (350 Hz) currents from the left to the right [2].
Equations

The above equations of (1)
\[
e_a = \sqrt{2}E \cos \omega t \\
e_b = \sqrt{2}E \cos(\omega t - 2\pi/3) \\
e_c = \sqrt{2}E \cos(\omega t + 2\pi/3)
\]

\[
i_{Ca} = \sqrt{2}I_q \cos(\omega t \pm \pi/2) \\
i_{Cb} = \sqrt{2}I_q \cos(\omega t - 2\pi/3 \pm \pi/2) \\
i_{Cc} = \sqrt{2}I_q \cos(\omega t + 2\pi/3 \pm \pi/2)
\]

\[p_C = e_a i_{Ca} + e_b i_{Cb} + e_c i_{Cc} = 0 \ldots \ldots \ldots \ldots \ldots \ldots (1)\]

\[
\begin{bmatrix}
e_{\alpha} \\
e_{\beta}
\end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} e_a \\
e_b \\
e_c
\end{bmatrix} \ldots \ldots (2)
\]

\[
\begin{bmatrix}
i_{\alpha} \\
i_{\beta}
\end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_a \\
i_b \\
i_c
\end{bmatrix} \ldots \ldots (3)
\]

\[
\begin{bmatrix}
i_p \\
i_q
\end{bmatrix} = \begin{bmatrix} \cos \omega t & \sin \omega t \\ -\sin \omega t & \cos \omega t \end{bmatrix} \begin{bmatrix} i_{\alpha} \\
i_{\beta}
\end{bmatrix} \ldots \ldots (4)
\]

\[e_a + e_b + e_c = 0 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (5)\]

\[i_{\alpha} + i_{\beta} + i_c = 0 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (6)\]
\[ p = e_\alpha i_\alpha + e_\beta i_\beta + e_c i_c \]
\[ = e_\alpha i_\alpha + e_\beta i_\beta \] ........................................ (7)

\[ q = e_\alpha i_\beta - e_\beta i_\alpha \] ........................................ (8)

\[
\begin{bmatrix}
    p \\
    q
\end{bmatrix} =
\begin{bmatrix}
    e_\alpha & e_\beta \\
    -e_\beta & e_\alpha
\end{bmatrix}
\begin{bmatrix}
    i_\alpha \\
    i_\beta
\end{bmatrix} ........................................ (9)
\]

\[
\begin{bmatrix}
    i_\alpha \\
    i_\beta
\end{bmatrix} =
\begin{bmatrix}
    e_\alpha & e_\beta \\
    -e_\beta & e_\alpha
\end{bmatrix}^{-1}
\begin{bmatrix}
    p \\
    q
\end{bmatrix} ........................................ (10)
\]

\[
\begin{bmatrix}
    i_\alpha \\
    i_\beta
\end{bmatrix} =
\begin{bmatrix}
    e_\alpha & e_\beta \\
    -e_\beta & e_\alpha
\end{bmatrix}^{-1}
\begin{bmatrix}
    p \\
    0
\end{bmatrix} +
\begin{bmatrix}
    e_\alpha & e_\beta \\
    -e_\beta & e_\alpha
\end{bmatrix}^{-1}
\begin{bmatrix}
    0 \\
    q
\end{bmatrix}
\]

\[
\equiv
\begin{bmatrix}
    i_{\alpha p} \\
    i_{\beta p}
\end{bmatrix} +
\begin{bmatrix}
    i_{\alpha q} \\
    i_{\beta q}
\end{bmatrix} ........................................ (11)
\]

\[
\begin{bmatrix}
    p_\alpha \\
    p_\beta
\end{bmatrix} =
\begin{bmatrix}
    e_{\alpha i_\alpha} \\
    e_{\beta i_\beta}
\end{bmatrix} =
\begin{bmatrix}
    e_{\alpha i_{\alpha p}} \\
    e_{\beta i_{\beta p}}
\end{bmatrix} +
\begin{bmatrix}
    e_{\alpha i_{\alpha q}} \\
    e_{\beta i_{\beta q}}
\end{bmatrix} \] (12)

\[ p = p_\alpha + p_\beta \]
\[ = e_{\alpha i_{\alpha p}} + e_{\beta i_{\beta p}} + e_{\alpha i_{\alpha q}} + e_{\beta i_{\beta q}} \]
\[ = \frac{e_\alpha^2 p}{e_\alpha^2 + e_\beta^2} + \frac{e_\beta^2 p}{e_\alpha^2 + e_\beta^2} + \frac{-e_\alpha e_\beta q}{e_\alpha^2 + e_\beta^2} + \frac{e_\alpha e_\beta q}{e_\alpha^2 + e_\beta^2} \] (13)
\( e_{\alpha i\alpha p} + e_{\beta i\beta p} \equiv p_{\alpha p} + p_{\beta p} = p \) \hspace{1cm} (14)
\[ e_{\alpha i\alpha q} + e_{\beta i\beta q} \equiv p_{\alpha q} + p_{\beta q} = 0 \] \hspace{1cm} (15)

The below equations of (15)

\[ i_{\alpha p} = e_{\alpha p}/(e_{\alpha}^2 + e_{\beta}^2) \]
\[ i_{\alpha q} = -e_{\beta q}/(e_{\alpha}^2 + e_{\beta}^2) \]
\[ i_{\beta p} = e_{\beta p}/(e_{\alpha}^2 + e_{\beta}^2) \]
\[ i_{\beta q} = e_{\alpha q}/(e_{\alpha}^2 + e_{\beta}^2) \]

\[ p_{\alpha p} = e_{\alpha p}^2/(e_{\alpha}^2 + e_{\beta}^2) \]
\[ p_{\alpha q} = -e_{\alpha}e_{\beta q}/(e_{\alpha}^2 + e_{\beta}^2) \]
\[ p_{\beta p} = e_{\beta p}^2/(e_{\alpha}^2 + e_{\beta}^2) \]
\[ p_{\beta q} = e_{\alpha}e_{\beta q}/(e_{\alpha}^2 + e_{\beta}^2) \]