POWER FACTOR CORRECTION AND LOAD BALANCING IN THREE-PHASE DISTRIBUTION SYSTEMS

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ABSTRACT - This paper deals with the different methods for compensating unbalanced three phase load. Compensation of grounded, ungrounded star connected and delta connected three phase unbalanced load has been carried out. Three schemes have been proposed for neutral current compensation. A common approach has been followed for power factor correction and load balancing. Simulated results show that a proper combination of all three supply currents are in phase with their respective phase voltages with equal magnitude resulting in a balanced load on supply system.

I INTRODUCTION
In recent years, there has been greatly increased demand for controllable var sources to compensate large industrial loads such as electric arc furnaces, electric traction, commercial lighting, air conditioning etc. If not compensated, these loads create system unbalance and lead to wide fluctuations in the supply voltages. Such supply system can not be used to feed sensitive loads like computers, electronic equipment etc. The importance of balanced load on the supply system has already been felt by power experts a long back [1-21. The presence of unbalanced load results in reactive power burden and excessive neutral current, which in turn results in low system efficiency, poor power factor and disturbance to other consumers. Innumerable control methods have been proposed to draw balanced supply currents if reactive load is fed from balanced supply system. Gyugyi [3] discussed few basic theoretical concepts for reactive power generation including control aspects. Impedance and phase balancing of induction arc - and single phase electric traction as a load have been presented by Tremayne [4] and Knechke [5], respectively. A very conceptual approach for realizing balanced load while feeding single phase R-L load is reported by Kern et al [6] and three phase load by Sadek [7]. However, a new criterion based on optimization of the nns values of line currents is used for evaluating the reactive elements required for compensation in three phase three wire system by Vasu et al [8] and minimization of power line loss for optimal reactive power compensator has been discussed by Lin et al [9]. Further, the idea of electronic compensator has been introduced to compensate the reactive currents but only with arc-furnace as a load by Cox and Mihod [10]. Sumi et al [11] have described the system outline and operating results of 20 MVA static Var Generator. An analysis to determine the response of the STATCON in transmission line is provided by Schauer and Mehta [12]. Kearly et al have worked on microprocessor controlled model construction network for distribution feeder [13]. Ng et al [14] have used fuzzy approach for placing the capacitors in distribution system.

The vast majority of the work is restricted to single phase line to line loads, thrwphase, three-wire loads. However, this paper is an attempt to compensate all kinds of three-phase unbalanced loads i.e. grounded load, ungrounded star connected and delta connected unbalanced loads. In a three-phase, four-wire system under normal operating condition with the loads reasonably balanced, the current in the neutral is expected to be small, typically not more than 20 percent of the normal load current in the phases. However, excessive neutral current phenomenon arises, especially in unbalanced circuits such as fluorescent lighting loads. This type of system in particular, results in excessive neutral current, which can potentially affect both the neutral conductor and the transformer to which it is connected.

The objective of this paper is to balance a three-phase, four-wire system feeding a three-phase, four-wire unbalanced load and thee-phase, three-wire unbalanced load. Three schemes have been presented for neutral current compensation. Each scheme suggests selection of different reactive elements for making the load balanced and resistive at supply end. It also proposes the selection of optimized set out of three compensation methods according to nature of load. The basis of forming three sets lies on the selection of phases for neutral current compensation namely a-b, b-c and c-a. Thereby forming three solutions for one instant in case of three phase grounded unbalanced load (Fig.1(a)). Moreover, a unified approach is devised for compensation of three phase, three wire load.

II SYSTEM DESCRIPTION
System considered consists of a balanced three phase supply feeding the unbalanced loads. Fig.1 shows the line diagram.
representation of loads where supply voltages are:

\[ v_a = \text{v phase} \quad \text{LOO,} \quad v_b = \text{JVII120°,} \quad v_c = \text{VII140°} \]

For three-phase unbalanced grounded load as shown in Fig. 1(a), three schemes have been presented and then three-phase three-wire unbalanced load has been compensated using a common scheme. First scheme considers phases b and c (Fig.2(a)), second scheme selects phases a and b (Fig.2(b)) and third scheme chooses phases a and c (Fig.2(c)) for neutral current compensation. Suppose P, Pb and Pe are three loads of lagging power factor cos\(\alpha\), cos\(\beta\) and cos\(\gamma\), respectively fed from balanced supply. The current carried away by neutral \(U\) is given by summation of \(B\), \(I^p\) and \(I^q\) (load currents). \(L\) can be neutralized by injecting a current \(I\), equal in magnitude and 180° out of phase from \(L\). \(L\) current stands for neutral compensation current and \(L\) is the neutral current compensation angle.

\[ L = |L| < \theta \]

After neutral current compensation the load becomes equivalent to three-phase three-wire unbalanced load (Fig.1(b)), this is transformed to equivalent delta connected load (Fig.1(c)). Three phase unbalanced delta co-ected load is compensated by two sets of lossless elements (susceptances) one for power factor correction (\(B\)), \(B_0\) and \(B_m\) and other for line currents balancing \(B_{b0}\) and \(B_{c0}\) as shown in Fig.3.

**El Neutral Current Compensation**

Neutral current compensation can be achieved by any one of the following three schemes.

**A. First Scheme**

This scheme realizes the balancing operation by providing neutral current compensation in phases b and c, for three-phase four-wire load as shown in Fig.2(a). The nature of passive lossless compensating elements will depend on angle of neutral compensation current \(L\), i.e. 8. Reactive elements chosen for b and c phases will be decided by angles \(F\) and \(7\). The angles \(F\) and 77 are the angles of compensating elements \(Z\), and \(Z\). These two impedances being lossless reactive elements (either capacitive or inductive) thus, these angles \(B\) and \(7\) will be decided by angles \(F\) and \(7\). The angle \(F\) is an angle of lossless reactive elements chosen for b compensating elements and \(7\) for c phases will be decided by angles \(F\) and \(7\). The above values of \(Z\), and \(Z\) in phases a and b make the system equivalent to three phase ungrounded star co-ected.

On solving above equations for \(|Llp|\) and \(Llp\):

\[ I_{lp} = -I_{lp} \sin(240°+\gamma); \quad |Llp| = |Llp| \]

Distribution of neutral current in compensating phases a and b is given by L and W. On solving above equations for the same:

\[ |Llp| = |Llp| \sin(120°+\beta); \quad |Llp| = |Llp| \]

By putting these susceptances in b and c phases, neutral grounded star connected system can be made equivalent to ungrounded star co-ected system and supply neutral current is zero as:

\[ l_{lb} + l_{lc} + l_{lb} + l_{lc} + l_{lc} = 0 \]

And, neutral compensated load becomes equivalent to:

\[ Z_m = Z_m/(Z_m+Z_m/2); \quad Z_m = Z_m/(Z_m+Z_m) \]

**B. Second Scheme**

This scheme provides neutral current compensation in phases a and b for a three-phase four-wire unbalanced load. For compensation of neutral reactance reactive elements will be placed in phases a and b. The arrangement of this scheme is shown in Fig.2(b). Nature of reactive elements will be reflected by angles \(a\) and \(p\). The angle \(a\) is an angle of lossless reactive elements co-ected across phase a for neutral compensation and may be either +90° or -90°. Angles \(a\) and \(p\) will change as 8 value changes.

For 30°<8<210°, \(a=90°\) or \(p=90°\) For 270°<8<360°, \(a=-90°\) or \(p=-90°\) For 210°<8<270°, \(a= -90°\) or \(p=90°\) For 270°<8<360°, \(c=90°\) or \(p=90°\)

If angle \(a\) or \(p\) is +ve then capacitor if -ve then inductor will be selected. The angle \(a\) is +ve if then capacitor and \(p\) if -ve then inductor will be selected. The corresponding susceptances for neutral current compensation will carry phase current \(I\), and \(Z_m\) in phases a and b respectively. On decomposing \(L\) and \(L\) in phase and quadrature axis of phase voltage \(V\). (Refer Fig.4(b)).

\[ |Ucos(eHU)|cos(a)+|I,cos(120°+p);\]

\[ |Llp| = |Llp| \sin(a)+|Llp| \sin(120°+\beta); \quad |Llp| = |Llp| \]

The corresponding susceptances are:

\[ B_{bo} = \text{IL} \sin(\alpha)/|V|; \quad B_{bo} = \text{IL} \sin(\beta)/|V| \]

Thus neutral current is zero as:

\[ r, + l, + W = 0 \]

Neutral compensated load becomes equivalent to:

\[ Z_m = Z_m/(Z_m+Z_m); \quad Z_m = Z_m/(Z_m+Z_m) \]

Neutral compensated load becomes equivalent to:

\[ Z_m = Z_m/(Z_m+Z_m); \quad Z_m = Z_m/(Z_m+Z_m) \]
C. Third Scheme
This scheme selects phases a and c for compensation (Fig. 2(c)).
According to neutral compensating current angle compensating
reactive elements for phases a and c will be selected.
For $330^\circ < \theta < 360^\circ$ and $0^\circ < \theta < 90^\circ$;
For $15^\circ < \theta < 150^\circ$; $a=+90^\circ$; $y= -90^\circ$
For $15^\circ < \theta < 270^\circ$; $a=-90^\circ$; $y= -90^\circ$
The vector decomposition of currents carried by neutral compensating
reactive elements, along in phase and quadrature
axis of phase voltage $V$, results in (Refer Fig.4(c)).
<table>
<thead>
<tr>
<th>angular deviation</th>
</tr>
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</table>
| $I_Icos(x)$=|$I_{\alpha}$|$I_{\beta}$cos$240^\circ$+$I_{\lambda}$cos$\theta$+$I_{\epsilon}$cos$240^\circ$+$r$
| $I_{\alpha}$=$|I_{\alpha}$|$I_{\beta}$sin$240^\circ$+$I_{\lambda}$sin$\theta$+$I_{\epsilon}$sin$240^\circ$+$r$
From above equations, $I_{\alpha}$ and $I_{\epsilon}$ are solved as :
| $I_{\alpha}$+$I_{\beta}$+$I_{\lambda}$+$I_{\epsilon}$ = 0.0
Neutral compensated load becomes equivalent to:
Neutral current compensated load becomes equivalent to:
IV. POWER FACTOR CORRECTION AND
BALANCING OF UNBALANCED LOAD
Neutral current compensated load now becomes equivalent to
three phase unbalanced grounded star connected load, which
is the second category of loads as shown in Fig. 1(a). Star-Delta
transformation of equivalent star co-eccted load will be:
\[ Y_a=\frac{z_a}{z_a+z_a+z_a+z_a}, Y_b=\frac{z_b}{z_b+z_b+z_b+z_a}, Y_c=\frac{z_c}{z_c+z_c+z_c+z_a} \]
This \( \text{valent delta} \) connected load is similar to third category
of load (unbalanced delta connected load refer Fig. 1(c)). Thus,
all kinds of loads either equivalent to delta m-eccted load or
delta connected loads are compensated in the following manner
for the active power compensation and load balancing.
The power factor of each phase is corrected by adding a set of suscceptances $B_{\alpha}$ & $B_{\beta}$, $B_{\gamma}$.
On separating real and imaginary parts of admittances $Y_a$, $Y_b$, $Y_c$,

\[ B = B_{\alpha} + B_{\beta} + B_{\gamma} \]
\[ G_{\alpha} = \Re(Y_a); \]
\[ G_{\beta} = \Re(Y_b); \]
\[ G_{\gamma} = \Re(Y_c) \]
Susceptanm $B_{\alpha}$, $B_{\beta}$, and $B_{\gamma}$, are co-eccted across lines a-b,
b-c and c-a to realize the reactive part of the respective
suscceptances of $Y_a$, $Y_b$ and $Y_c$. Now, the three equivalent load
elements become resistive ones of conductances $G_{\alpha}$ & $G_{\beta}$ and $G_{\gamma}$, respectively.

The miting taistive network becomes balanced load when one
more set of reactive components $B_{\alpha}$, $B_{\beta}$ and $B_{\gamma}$ is connected
across respeative phases. Assuming connection of $B_{\alpha}$, $B_{\beta}$ and $B_{\gamma}$
demakes currents $=u_{\alpha}$, $L_{\alpha}$ = $L_{\alpha}120^\circ$, $L_{\beta}$ = $L_{\alpha}240^\circ$
From Fig.3, according to ohm's Law, we can write:
\[ I_\alpha = (V_{\alpha}+V_{\alpha}+jB_{\alpha})/L_{\alpha} \]
\[ I_{\beta} = (V_{\beta}+V_{\beta}+jB_{\beta})/L_{\beta} \]
\[ I_{\gamma} = (V_{\gamma}+V_{\gamma}+jB_{\gamma})/L_{\gamma} \]
On applying Kirchoff's current law at nodes a, b and c respectively. We have:
\[ I_\alpha = I_\alpha 0^\circ - I_\alpha 120^\circ - I_\alpha 240^\circ \]
\[ I_\beta = I_\beta 0^\circ - I_\beta 120^\circ - I_\beta 240^\circ \]
\[ I_{\gamma} = I_{\gamma} 0^\circ - I_{\gamma} 120^\circ - I_{\gamma} 240^\circ \]
On solving Equations (1), (2) and (3) after separating real and
imaginary parts of three line currents:
\[ B_{\alpha} = \Re(Y_{\alpha}) \]
\[ B_{\beta} = \Re(Y_{\beta}) \]
\[ B_{\gamma} = \Re(Y_{\gamma}) \]
These equations give the due of susceptances required for
current magnitude equallzation. Elements so obtained are
connected in p d e l with $B_{\alpha}$, $B_{\beta}$ and $B_{\gamma}$, as shown in Fig.3
to make the system totally balanced. Total susceptances in lines
for power factor correction and load balancing will be:
\[ B_{\alpha} = B_{\alpha} + B_{\beta} + B_{\gamma} \]
\[ B_{\beta} = B_{\alpha} + B_{\beta} + B_{\gamma} \]
\[ B_{\gamma} = B_{\alpha} + B_{\beta} + B_{\gamma} \]
Fig.3 shows the equivalent balanced representation of load on
the supply end. Figs. 4(a), 4(b), 4(c), 4(d) and 4(e) are the
phasor diagrams of tidy compensated loads. Figs.4(a), 4(b) and
4(c) correspond to three phase pounded loads, which have been
compensated by three schemes. Figs.4(d) and *e) are for three
phase ungrounded star co-eccted and delta connected load respectivev.

V. RESULTS AND DISCUSSION
A comparative analysis of all three schemes for three phase
unbalanced grounded load is shown in Table 1 for the three
phase unbalanced load (15kW 0.8pf lagging 20kW unity power
factor, 25kW 0.85pf lagging). For the considered load, first
scheme demands an inductor of 10.3mH in phase b and capacitor
of 205.3pF in phase c. Second scheme requires inductors of
values 49.3mH and 8.51mH in phases a and b respectively and
third scheme needs capacitors of 982.2pF and 1188.9pF in
phases a and c for neutral current compensation. Power factor
compensation requires three capacitors of values, 257.6$, 290.7pF
and 150.7pF using first scheme and 328.6pF, 355.9pF and
219.9pF using second scheme in phase a-b, b-c and c-a.
For load balancing capacitors of 69.7pF and 37.9pF in between
phases a-b, b-c and inductance of 94.9mH in between c and a are
needed by the first scheme. Second scheme also requires two
capacitors and an inductor of values 67.2pF, 41.2pF and
93.4mH in phases a-b, b-c and c-a, respectively. Third scheme uses two capacitors of 65.58pF and 21.91pF and an inductor of 115.7mH in phases a-b, b-c and c-a respectively. After compensation all currents are in phase with their respective voltages and power consumed per phase is equal as given in Table 1.

Table 2 presents the compensation results for three phase star connected ungrounded load. For the given load specifications, capacitors of 380.8pF, 59.65pF and 290.8pF are needed in phases a-b, b-c and c-a respectively for reactive power/power factor compensation. Further, load balancing requires two capacitors of 82.54pF, 11.62pF in phases a-b, b-c and one inductor of 107.6mH in phase a. Last column of table shows per phase current and per phase power after compensation. Table 3 shows the results corresponding to three phase unbalanced delta connected load. For the given load values, two capacitances of values 184.9pF, and 254.6pF are needed in phases a-b and c-a for reactive power correction and no capacitive or inductive element in phase b-c for power factor correction is needed. Load balancing requires an inductor of 213.3mH in phase a-b, a capacitor of 94.89pF in phase b-c and an inductor of 213.4mH in phase c-a. Last column shows that equivalent balanced per phase power is 19.99kW and current is 78.7A.

Relevant waveforms for three phase grounded star connected unbalanced load, three phase ungrounded star connected and three phase delta connected load have also been devised. Fig. 5 shows the results corresponding to a load of 15kW 0.8pf lagging, 20kW unity pf and 25kW 0.8pf lagging in three phase grounded star connected load configuration (as shown in Fig. 1(a)). Fig.6(a) indicates the load currents in phase a-b, c-a and neutral current in phase c-a. Figs. 5(b), 5(c) and 5(d) depict the neutral current compensation by the three schemes. It has been clearly shown in Fig.6(a) that at any instant sum of i^a, i^b and i^c is zero, which effectively represents the neutral current elimination by the first scheme. Fig.6(c) shows the neutral current compensation by second scheme and at any instant the sum of w and L and neutral current i^c. In Figs. 5(a) according to the third scheme, neutral current compensation is carried out in phases a and c and i^a is neutralized by i^b, i and i^c in Fig.6(a), and in Figs. 5(b), 5(c) and 5(d) give the detailed description of balanced load current i^c when balancing is done by the three schemes. Fig.50 shows that current i, is equal to sum of i^a, i^b and i^c, which is expected according to the first scheme. Similarly Fig.6(c) shows that sum of i^a and i^b and i^c is equal to i^c. Finally, Fig.6(e) shows the voltage v, and the three balanced supply currents f, g and h obtained after compensation by all the three schemes.

Fig.6 gives the appropriate waveforms for three phase ungrounded star connected unbalanced load and Fig.6 for three phase delta connected unbalanced load. Fig.6(a) shows the equivalent load current in phase a-b, c-a in case of three phase ungrounded star connected load. Fig.6(b) produces i current balancing and at any instant, is the sum of i^a -i^b and -i^c. Fig.6(c) shows the balanced load currents i^a, i^b and i^c, after compensation Fig.6(a) presents the load currents L^a, L^b and L^c in case of three phase delta connected load. Fig.6(b) shows the balanced phase current i^a, which at any instant is the sum of i^a + i^b -i^c. Lastly, Fig.6(c) shows the load currents f, g, h drawn by load thereby presenting balanced load to the supply system.

VI. CONCLUSIONS

Three different compensation schemes for unbalanced three phase four wire load have been investigated. All the three schemes are able to make the system perfectly balanced. A common scheme for three-phase three-wire unbalanced load (either star connected or delta connected) has been analyzed and found to balance the load completely. These schemes can be realized by variable lossless impedance compensators using elements which may act as variable reactances. Results may be utilized for the proper design of a controller for balancing the loads in three phase ac system.

VII. ACKNOWLEDGEMENT

The first author gratefully acknowledges the "Council of Scientific and Industrial Research, INDIA" for the financial support receiving under the Senior Research Fellowship scheme, Award No. 9/143(285)/94-EMR-I, because of which this work reported in this paper was possible.

VIII. REFERENCES

2. L. Gyugyi, "Reactive power generation and control by thyristor circuits", EEE Trans. on Ind. Appl., v01.4-1S, no.9, pp 521-531, 1979.
### TABLE 3.1: Compensation of three-phase unbalanced grounded load

**Load Specifications:** (15kW 0.8 pf, 20kW unity pf, 25kW 0.85 pf)

<table>
<thead>
<tr>
<th>Schemes</th>
<th>For neutral current compensation</th>
<th>For power factor/reactive power compensation</th>
<th>Load balancing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$L_{bn}=10.3mH$</td>
<td>$C_{c}=205.3pF$</td>
<td>$C_{a}=69.7pF$</td>
</tr>
<tr>
<td>First Scheme</td>
<td>$C_{c1}=290.7pF$</td>
<td>$C=205.3pF$</td>
<td>$L_{ca}=94.0mH$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C^\approx 8.51mH$</td>
<td>$C=982.2pF$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$C_{2}=1188.9pF$</td>
</tr>
<tr>
<td>Second Scheme</td>
<td>$L_{c1}=49.3nF$</td>
<td>$C_{b1}=328.6pF$</td>
<td>$C_{a}=67.2pF$</td>
</tr>
<tr>
<td></td>
<td>$L_{c2}=8.51mH$</td>
<td>$C_{b2}=41.2pF$</td>
<td>$L_{c}=78.72$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$I_{a}=78.7L120^\circ$</td>
</tr>
<tr>
<td>Third Scheme</td>
<td>$L_{c}=982.2pF$</td>
<td>$C_{b1}=290.8pF$</td>
<td>$C=65.58pF$</td>
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<tr>
<td></td>
<td>$L_{c2}=1188.9pF$</td>
<td></td>
<td>$C=380.8pF$</td>
</tr>
<tr>
<td></td>
<td>$L_{c1}=471.2mH$</td>
<td></td>
<td>$L_{c}=107.6mH$</td>
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<tr>
<td></td>
<td>$L_{c2}=51.41mH$</td>
<td></td>
<td>$I_{a}=78.7L240^\circ$</td>
</tr>
</tbody>
</table>

### TABLE 3.2: Compensation of three-phase star connected ungrounded load

<table>
<thead>
<tr>
<th>Transformer Specifications</th>
<th>Equivalent A-connected load</th>
<th>For power Factor/reactive power compensation</th>
<th>Load balancing</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2,=3.44 L 36.9^\circ$</td>
<td>$Z_a=3.23 L 0^\circ$</td>
<td>$C_{ab}=380.8 pF$</td>
<td>$C_{aa}=82.54pF$</td>
</tr>
<tr>
<td>$Z_a=2.19 L 31.8^\circ$</td>
<td>$Z_c=7.21 L 7.76^\circ$</td>
<td></td>
<td>$P_a=20.41; I_a=80.4L0^\circ$</td>
</tr>
<tr>
<td>$Z_c=7.69 L 44.6^\circ$</td>
<td>$Z_{c1}=290.8pF$</td>
<td></td>
<td>$I_a=80.4; I_a=80.4L120^\circ$</td>
</tr>
</tbody>
</table>

### TABLE 3.3: Compensation of three-phase unbalanced A-connected load

<table>
<thead>
<tr>
<th>Transformer Specifications</th>
<th>Equivalent A-connected load</th>
<th>For power Factor/reactive Power compensation</th>
<th>Xload Balancing</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{ab}=15kW0.8pf$</td>
<td>$Z_{ab}=10.3 L 36.9^\circ$</td>
<td>$C_{ab}=184.9pF$</td>
<td>$L_{a}=213.4mH$</td>
</tr>
<tr>
<td>$P_{b}=20kW1.0pf$</td>
<td>$Z_{b}=9.68 L 0^\circ$</td>
<td></td>
<td>$I_{a}=78.7L120^\circ$</td>
</tr>
<tr>
<td>$P_{c}=25 kW0.85 pf$</td>
<td>$Z_{c}=6.58 L 31.8^\circ$</td>
<td></td>
<td>$I_{a}=78.7L240^\circ$</td>
</tr>
</tbody>
</table>

484
(a) Grounded star connected

(b) Ungrounded star connected

(c) Delta connected

Fig. 1 Representation of three phase unbalanced load

(a) First scheme (compensation in b and c phases)

(b) Second scheme (compensation in a and b phases)

(c) Third scheme (compensation in a and c phases)

Fig. 2 Neutral current compensation of three phase unbalanced grounded load
Fig. 3 Representation of equivalent balanced load

Fig. 4 (b) Using second scheme for three phase grounded star connected unbalanced load

Fig. 4 (d) For three phase ungrounded star connected unbalanced load

Fig. 4 (a) Using first scheme for three phase grounded star connected unbalanced load

Fig. 4 (c) Using third scheme for three phase grounded star connected unbalanced load

Fig. 4 (e) For three phase delta connected unbalanced load

Fig. L Phasor representations for compensations of all kinds of load
Fig. 5(a) Load currents and neutral current

Fig. 5(b) Neutral current compensation in first scheme

Fig. 5(c) Neutral current compensation by second scheme

Fig. 5(d) Neutral current compensation by third scheme

Fig. 5(e) Voltage van and three balanced supply currents

Fig. 5(f) Current ia balancing by first scheme

Fig. 5(g) Current ia balancing by second scheme

Fig. 5(h) Current ia balancing by third scheme

Fig. 5. Waveforms for compensation of three phase grounded load (Load specifications: 15kW 0.8 pf lag, 20kW unity pf; 25 kW 0.85pf lag)
Fig 6(a) Load currents in delta equi. of ungrounded star load

Fig 6(b) Currents balancing

Fig 6(c) Voltage van and three phase balanced supply currents

Fig 6 Waveforms for compensation of three-phase ungrounded SKK connected load

Fig 7(a) Load currents when load is delta connected

Fig 7(b) Currents balancing

Fig 7(c) Voltage van and three phase balanced supply currents

Fig 7 Waveforms for compensation of three-phase delta connected load