Issue C

21 May 2012

APPLICATION GUIDE

AG013 - NEUTRAL VOLTAGE DISPLACEMENT (NVD) PROTECTION APPLIED TO CONDENSER BUSHINGS (CAPACITOR CONES)

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SUMMARY

Voltage Transformers don't tend to be fitted at distribution levels, due to their expense.

Instead, capacitor cones, or condenser bushings, may be used at 11kV and 33kV substations to provide a neutral voltage displacement output to a suitable relay.

Often, these bushings are starred together, and the star point is used to provide the displacement voltage to the relay.

This application is not new, and indeed has been provided by Areva previously in the form of MVTU13. See application diagram 10MVTU1302 (Figure 11).

Title	Name	Signature	Date
Senior Applications Engineer	A.W. Hassall		21/05/12

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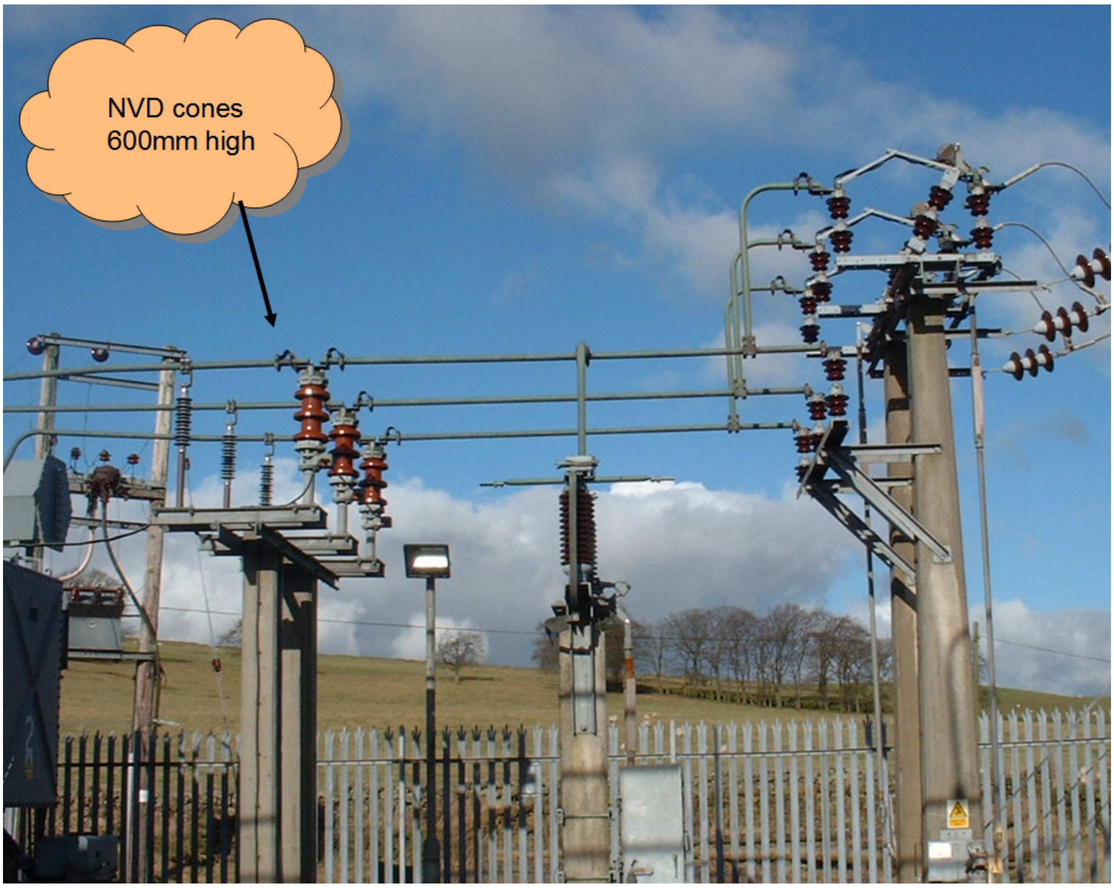
1. INTRODUCTION

Voltage Transformers don't tend to be fitted at distribution levels, due to their expense.

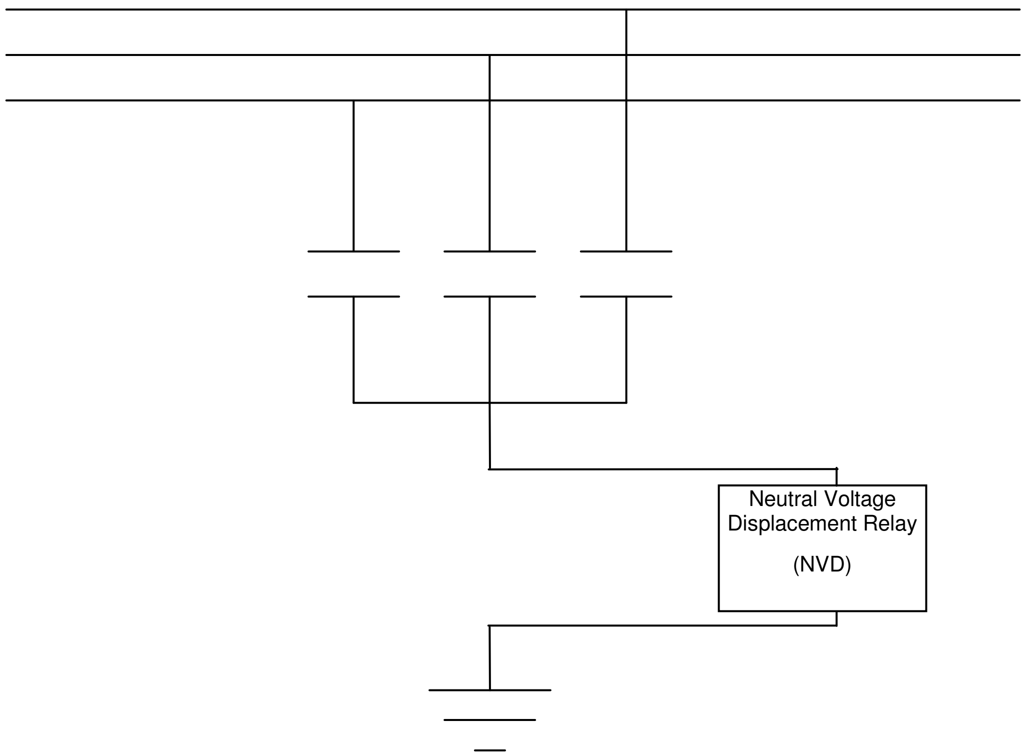
Instead, capacitor cones, or condenser bushings, may be used at 11kV and 33kV substations to provide a neutral voltage displacement output to a suitable relay.

Figure 1:



Often, these bushings are starred together, and the star point is used to provide the displacement voltage to the relay. See Figure 2.

Figure 2:



This application is not new, and indeed has been provided by Areva previously in the form of MVTU13. See application diagram 10MVTU1302 (Figure 11).

2. REFERENCES

Reference	Doc. Number	Doc. Name
A	10MVTU1302 Sheet 3	APPLICATION DIAGRAM:-STATIC MODULAR DEF. TIME DELAYED NEUTRAL DISPLACEMENT VOLTAGE RELAY TYPE MVTU13

3. DESCRIPTION

3.1. THEORY

Consider a single-phase fault to ground on B-Phase: -

Figure 3:

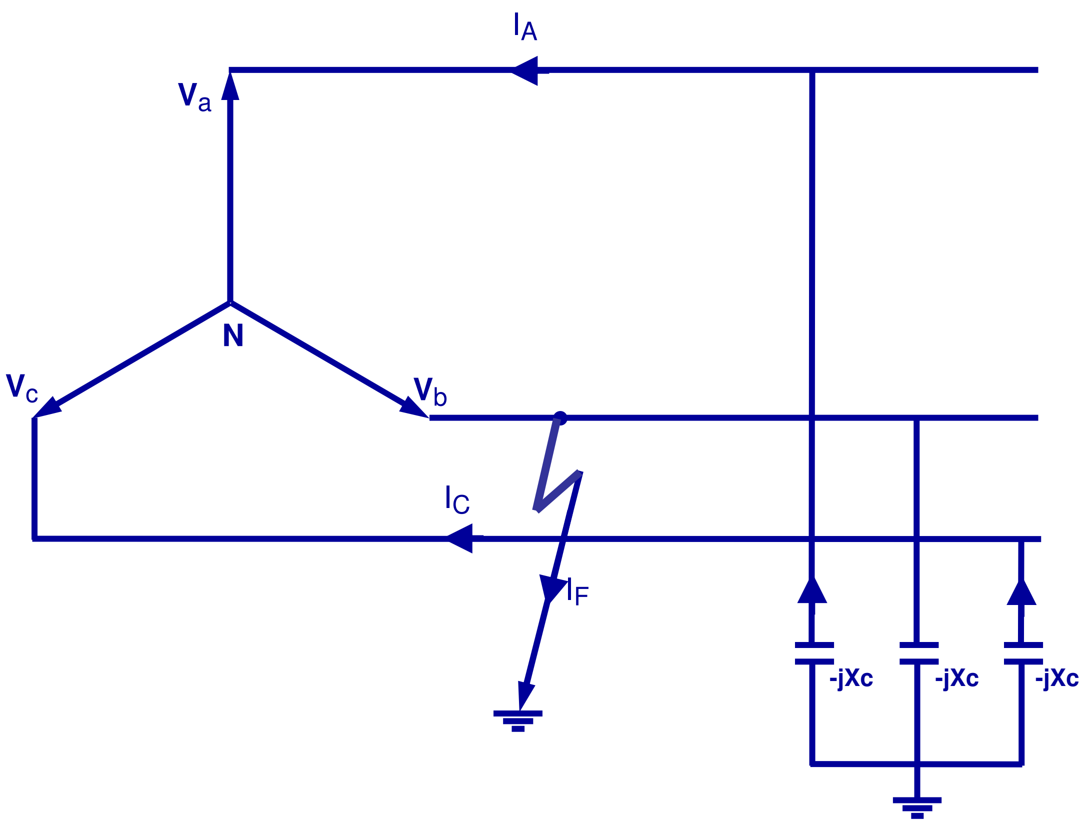


Figure 4 shows three healthy voltages, three capacitor currents that lead their respective voltages by 90º and sum to zero.

Figure 4:

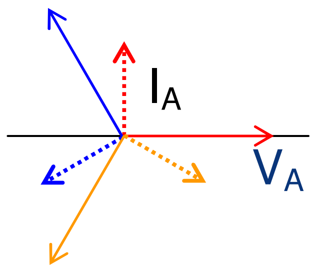
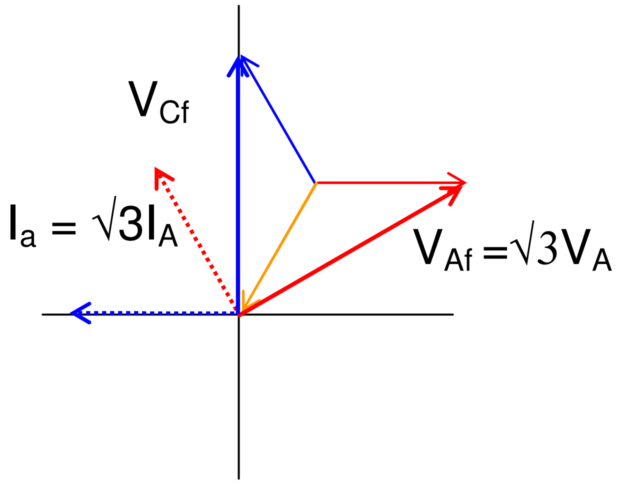


Figure 5 shows B phase earthed, A and C voltages are √3 times their healthy magnitude & at 60º to each other, giving correspondingly altered capacitor currents Ia and Ic.

Figure 5:



The vector sum of the A & C phase capacitor currents is: -

$I_f = \sqrt{3} \times Ia,$

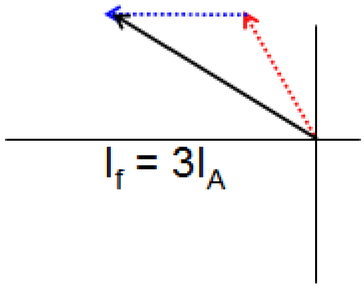
$= \sqrt{3} \times \sqrt{3} \times I_A,$

$= 3 \times I_A.$

Thus, the total fault current I_f equals three times a single capacitor healthy condition current I_A.

Figure 6 shows the vector sum of the fault condition I_f.

Figure 6:



Thus, I_f is the current which will flow in the Neutral Displacement Relay under fault conditions (neglecting the impedance of the relay itself).

For example, for a 60pF capacitor on a 33kV system, the single capacitor healthy condition current I_A is given by: -

$I_A = V_A / X_C$

$I_A = V_A / (1/2\pi fC)$

$= \frac{33 \times 10^3}{\sqrt{3}} / (1/(2 \times \pi \times 50 \times 60 \times 10^{-12}))$

$= 0.359mA$

Therefore, the total fault current which would flow in an NVD relay (neglecting the impedance of the relay itself): -

$I_f = 3 \times 0.359 = 1.08mA$

Table 1 shows the total fault current I_f for a 60pF capacitor, and also I_f for a 90pF capacitor, and for a 150pF capacitor.

Table 1:

C (pF)	60.00	90.00	150.00
Xc (MΩ)	53.08	35.39	21.23
V_A (kV)	19.00	19.00	19.00
I_A (mA)	0.359	0.539	0.898
I_f (mA)	1.08	1.62	2.69

If I_f is the total fault current which would flow in an NVD relay (neglecting the impedance of the relay itself), then knowing this current (I_f) and the input impedance of the relay (Rr) we can calculate the voltage which will be produced across it (Vr) during a fault condition: -

$Vr = I_f \times Rr$

Thus, we would recommend setting the relay to less than half this voltage: -

$Vs < Vr/2$

3.2. APPLICATION

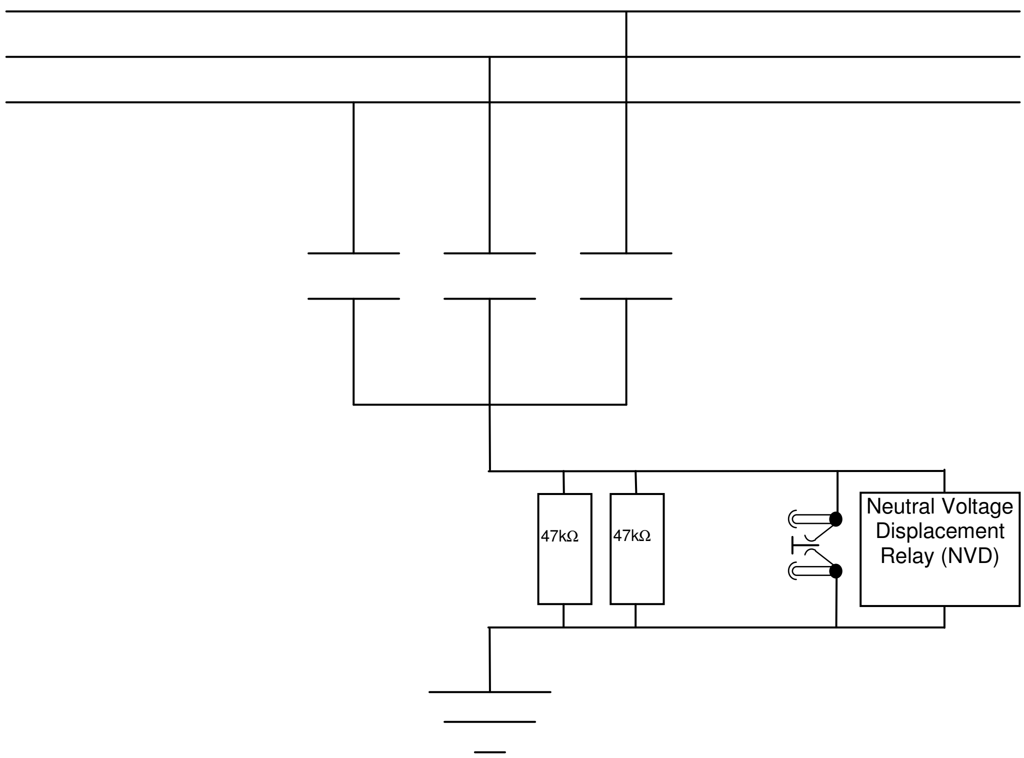
In practice, MiCOM relay input impedance varies somewhat with voltage, and will have some effect on actual setting.

Thus, we recommend use of a 23½kΩ resistor combination in parallel with this input, to fix the impedance. This value is realised by two 47kΩ resistors in parallel. Utilising two in parallel also gives increased security.

If continuously energised a pair of 0.1W resistors are adequate.

Note that there is the risk of high voltage developing on removal of the relay or PCB from its case. The fixed resistors on the input will prevent this risk, but we would also recommend use of the available externally connected shorting contact in each case. A shorting contact is available on each relay. Please see figure 7.

Figure 7:



WARNING:

As the proposal is to situate the relay in a primary circuit location (as per previous similar applications), the relevant utility must satisfy itself that any necessary safety measures are in place.

3.3. RELAY SELECTION

There are various possibilities in the MiCOM range for Neutral Voltage Displacement protection fed from capacitor cones, and these are: -

1. P94V - has a separate neutral voltage input.

2. P141/2/3/5 - residual voltage measurement is derived from phase inputs, but neutral voltage may be connected into one of the phase inputs. This assumes that voltage inputs are not used for other purposes.

3. P144 - has a separate neutral voltage input.

3.4. VOLTAGE SETTING

For this application, it is important to obtain a sensitive enough voltage setting.

P94V has a minimum setting of 1V, which again should be adequate for most applications (see table 2 below).

P141/2/3/5 has a minimum setting on the residual OV/NVD protection of 1V, which should be adequate for most applications (see table 3 below).

P144 has a minimum setting on the residual OV/NVD protection of 4V, which should also be adequate for most applications (see table 3 below).

The operating voltage to be applied can be calculated for various capacitor ratings as demonstrated earlier.

The tables below detail maximum settings for each type of relay for various rating capacitors, assuming 23½kΩ resistance applied in conjunction with the relay.

Table 2: P94V

C (pF)	60.00	90.00	150.00
Xc (MΩ)	53.08	35.39	21.23
V_A (kV)	19.00	19.00	19.00
I_f (mA)	1.08	1.62	2.69
Rr (kΩ)*	19	19	19
Vr (V)	20	30	51
Vs (V)	10.00	15.00	25.00

*Relay and Resistor Combination

Table 3: P14x

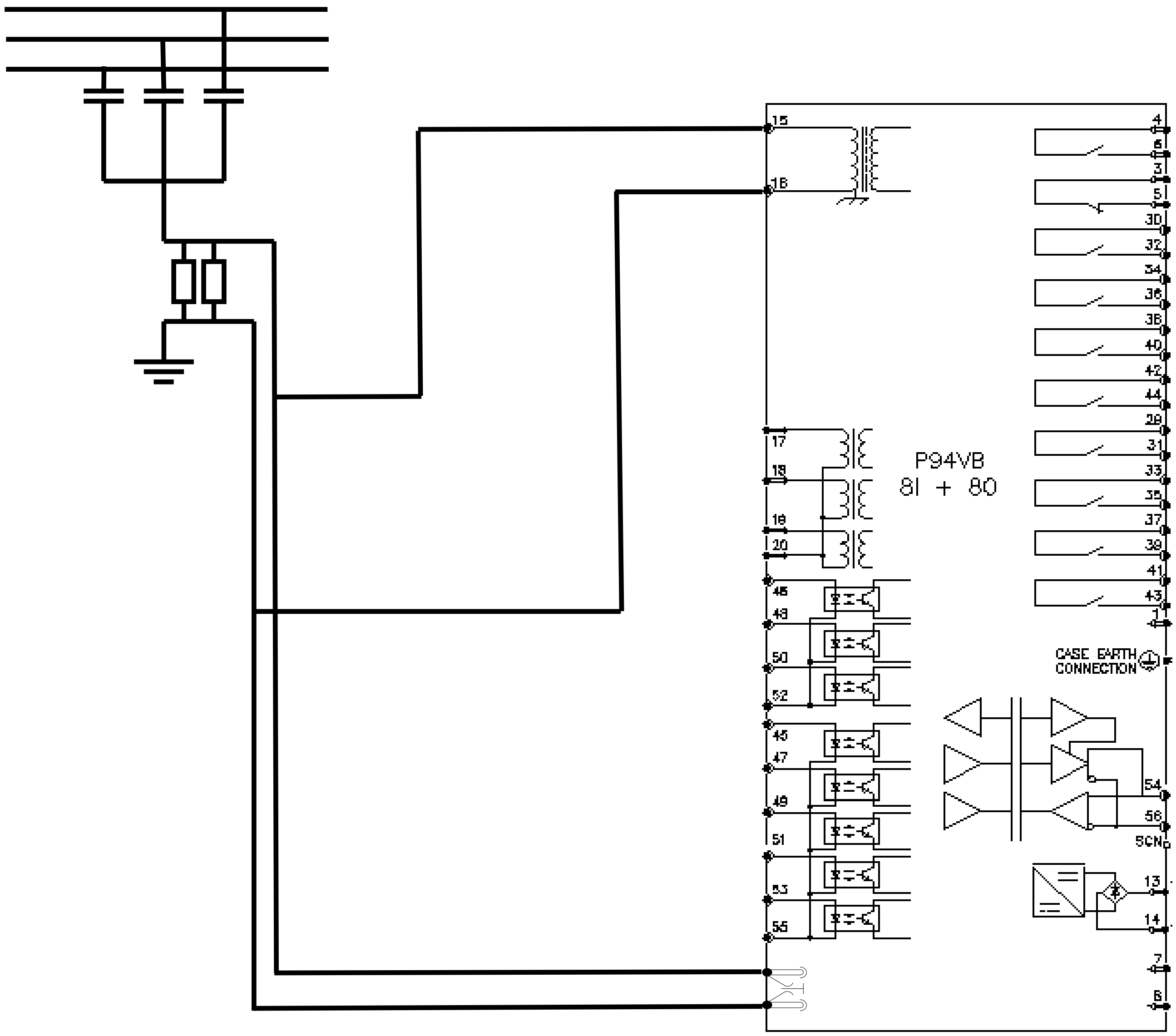
C (pF)	60.00	90.00	150.00
Xc (MΩ)	53.08	35.39	21.23
V_A (kV)	19.00	19.00	19.00
I_f (mA)	1.08	1.62	2.69
Rr (kΩ)*	22.00	22.00	22.00
Vr (V)	23.63	35.44	59.06
Vs (V)	11.81	17.72	29.53

*Relay and Resistor Combination

3.5. CONNECTIONS

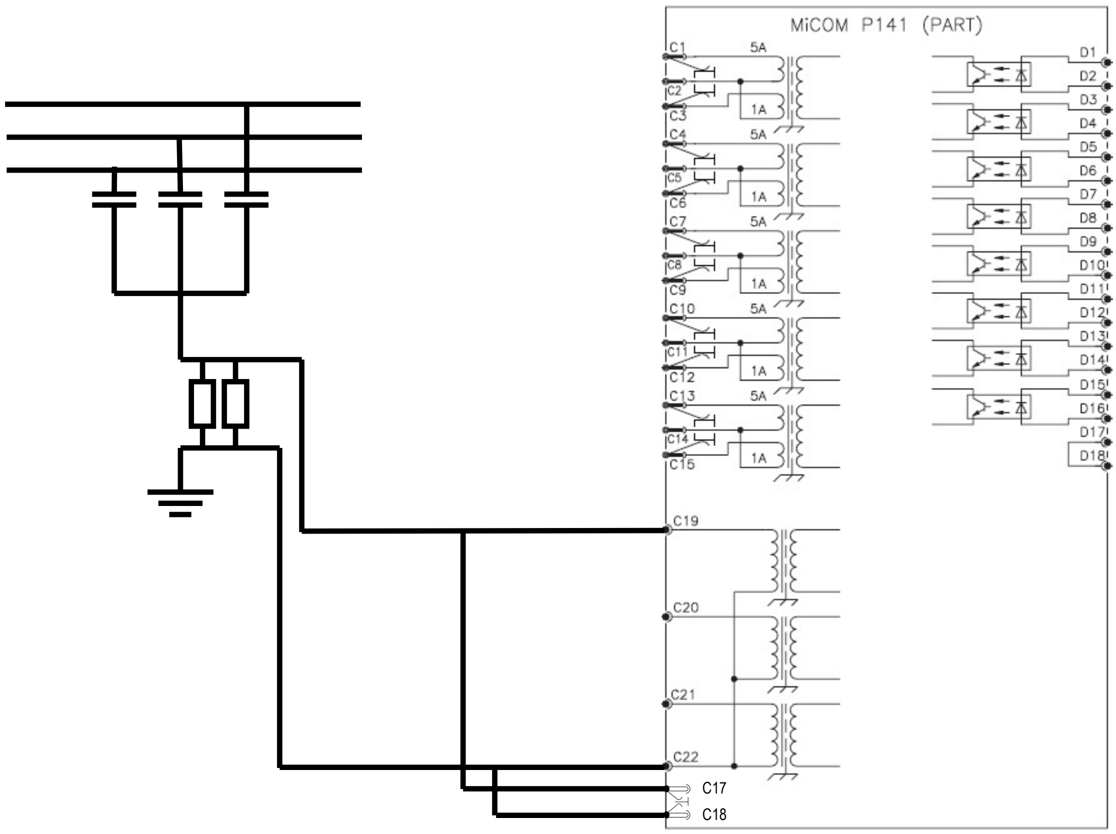
P94V:

Figure 8:



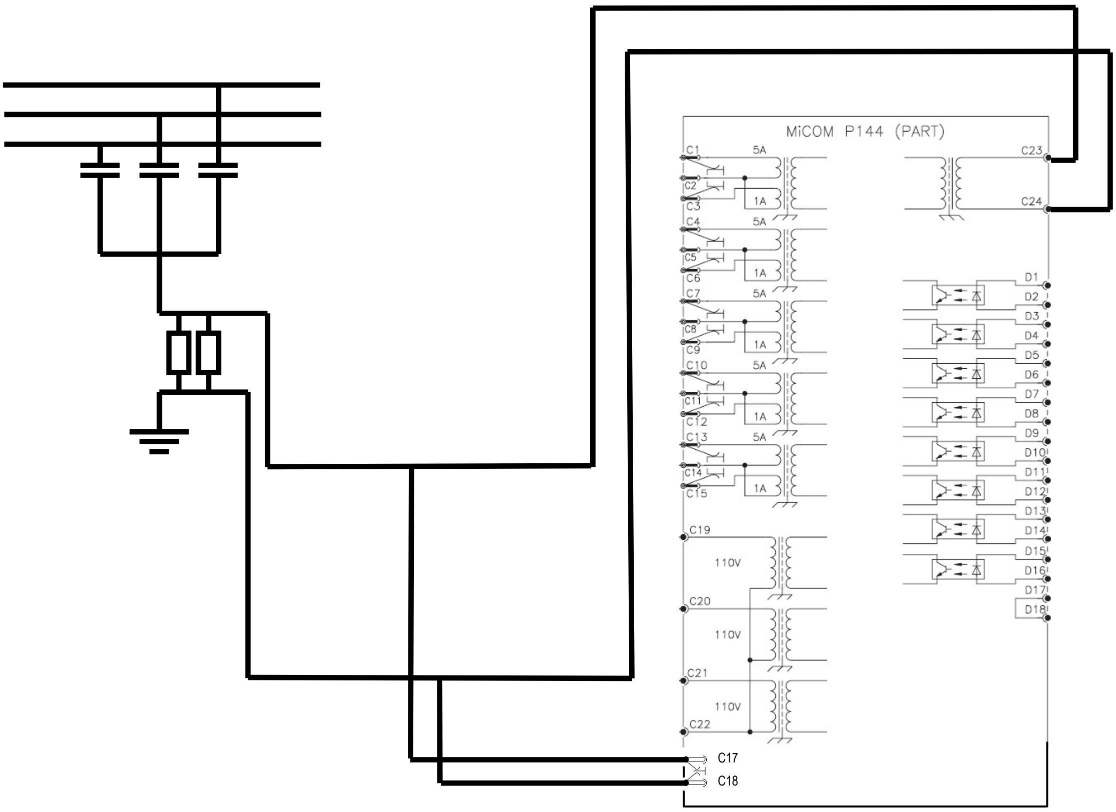
P14x:

Figure 9:



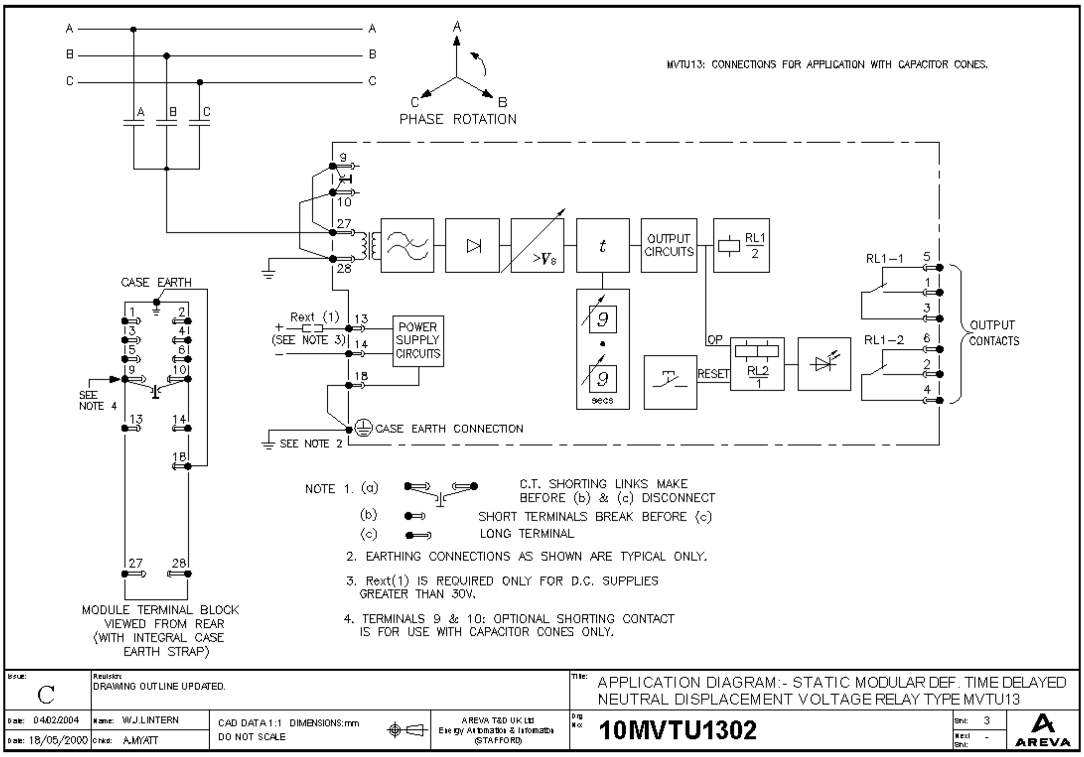
P144:

Figure 10:



3.6. APPLICATION DIAGRAM 10MVTU1302

Figure 11:



REVIEW HISTORY

Issue	Name	Position
C	A.W. Hassall	Senior Applications Engineer

VERSION CONTROL

Issue	Author(s)	Reason for change	Date
A	A.W. Hassall	Original	30/01/08
B	A.W. Hassall	Complete Review	18/05/09
C	A.W. Hassall	Convert to ALSTOM Format/Add AGILE	21/05/12