Unbalanced Star Load: Neutral Shift (Millman) and Phase Voltages

Neutral displacement voltage of an unearthed star load with unequal resistive and reactive phase impedances on a balanced supply, by Millman's theorem.

Method: Millman's theorem

Input parameters

Unit system: SI

Parameter	Value	Unit
Line voltage	415.00	V
Phase A resistance	10.000	Ω
Phase A reactance	0	Ω
Phase B resistance	20.000	Ω
Phase B reactance	0	Ω
Phase C resistance	40.000	Ω
Phase C reactance	0	Ω

Calculated results

Parameter	Value	Unit
Neutral shift voltage	90.560	V
Voltage across phase A	156.86	V
Voltage across phase B	271.68	V
Voltage across phase C	313.71	V

Notes for this case

• Millman: V_N = Σ(E_i/Z_i)/Σ(1/Z_i) for a star load with no neutral connection; each phase sees E_i − V_N. With a broken neutral, lightly loaded phases rise towards line voltage and damage equipment, which is why single-phase loads need a solid neutral.

Formula and method

$$V_N = \frac{\sum_i E_i/Z_i}{\sum_i 1/Z_i}, \quad V_{i,load} = E_i - V_N$$

Variables

V_{LL}	Line voltage	V
R_a	Phase A resistance	Ω
X_a	Phase A reactance	Ω
R_b	Phase B resistance	Ω
X_b	Phase B reactance	Ω
R_c	Phase C resistance	Ω
X_c	Phase C reactance	Ω
V_N	Neutral shift voltage	V
V_a	Voltage across phase A	V
V_b	Voltage across phase B	V
V_c	Voltage across phase C	V

Method and standards

Neutral shift.

Assumptions and limits

- Balanced positive-sequence supply; linear loads.

References

Millman's theorem

Report details

Report reference	FCC-BCF7-6MR1 (the same inputs always give the same reference)
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Release checks	3 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/electrical/circuits/millman-neutral-shift

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.