(*Exchange circuit analysis by VD4*)

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Electro Systems Engineering
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1 The purpose of VD4 development

1-1 The present condition of functional grasp of electric equipment

Grasping correctly the function (electric power supply capability, the margin of apparatus and wiring, maintenance of proper voltage, influence by instant voltage descent, power factor adjustment) of electric equipment -- the plan of this electric equipment, construction, and maintenance management -- in any case, it is important.
This is indispensable to correspondence to the safety of electric equipment, economical efficiency, and load change.

However, the equipment of the present condition of electric equipment is not proper to load, or it has some which have not performed maintenance of proper voltage.

1-2 The necessity for VD4

Exchange circuit analysis is needed as a means of functional grasp of electric equipment.
Therefore, the special feature of change of incoming voltage, the capacity of a power transformer, the existence of an electric power capacitor, an electric system, the wiring method, and the load to change etc. must be examined, and the power distribution network which results in each load must be analyzed as one system after electric equipment.

▷ *The impedance composition calculation by **the Ohm method** was adopted as this means, and the voltage value and current value in each part grade, power factor, the rate of transformer load, transformer voltage rate of change, the short-circuit current, etc. were calculated correctly.*

*While the feature of the analysis by this **Ohm method** is easy work which depends even a formula (**E=IZ**), the complicated work of impedance composition is accompanied by it.*
For this reason, it is clear in manual calculation that it is not practical.
*Then, calculation processing in the minimum input time and effort and a short time was realizable using "**Excel**" of U.S. Microsoft Corp. with the high present flexibility.*

1-3 Copyright registration

*In case A.D. 2000 came around, in accordance with **VD2** (high-voltage circuit analysis) and **VD3** (induction motor circuit analysis), copyright registration of this exchange circuit analysis VD4 was carried out.*
*Although **VD** of **VD** series is the pet name attached from the initial of Voltage drop, it does not stop only at calculation of track voltage drop, but expects continuing developing into the diversity covering an exchange circuit at large as surprising calculation software for business.*

registration number **P the 6556th -- No.1** November 26, 1999 **Software Information Center** , Japan

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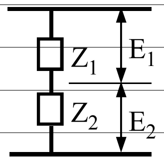
2 Composition of impedance

2-1 Series circuit



When synthetic impedance is set to $\boldsymbol{Z}$, *it is from* $\boldsymbol{E} = \boldsymbol{I}\boldsymbol{Z}$ *and* $\boldsymbol{E} = \boldsymbol{E}_1 + \boldsymbol{E}_2$

Since it is $\boldsymbol{IZ} = \boldsymbol{E}_1 + \boldsymbol{E}_2 = \boldsymbol{IZ}_1 + \boldsymbol{IZ}_2$, *synthetic impedance is set to* $\dot{Z} = \dot{Z}_1 + \dot{Z}_2$

$$Z = (R_1 + R_2) + j(X_1 + X_2) \qquad \text{at } Z_1 = R_1 + jX_1,\ Z_2 = R_2 + jX_2 \qquad \text{F-11}$$

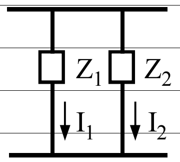
$$Z = R_1 + j\{X_1 - (1/X_c)\} \qquad \text{at } Z_1 = R_1 + jX_1,\ Z_2 = 1/jX_C \qquad \text{F-12}$$

Here, $X = \omega L = 2\pi fL$、 $XC = \omega C = 2\pi fC$

$$\cos\varphi = (R_1 + R_2)/Z \qquad \text{F-13}$$

$$\cos\varphi = R_1/Z \qquad \text{F-14}$$

2-2 Parallel circuit



When synthetic impedance is set to $\boldsymbol{Z}$, *it is from* $\boldsymbol{E} = \boldsymbol{I}\boldsymbol{Z}$ *and* $\boldsymbol{I} = \boldsymbol{I1} + \boldsymbol{I2}$

Since it is $\boldsymbol{IZ} = (\boldsymbol{I1} + \boldsymbol{I2})\boldsymbol{Z}$, $\boldsymbol{I1} = \boldsymbol{E}/\boldsymbol{Z1}$, $\boldsymbol{I2} = \boldsymbol{E}/\boldsymbol{Z2}$, $\boldsymbol{E} = \{(\boldsymbol{E}/\boldsymbol{Z1}) + (\boldsymbol{E}/\boldsymbol{Z2})\}\boldsymbol{Z}$

synthetic impedance is set to $\left(\dot{Z}\right)^{-1} = \left(\dot{Z}_1\right)^{-1} + \left(\dot{Z}_2\right)^{-1}$ *or* $\dfrac{1}{\dot{Z}} = \dfrac{1}{\dot{Z}_1} + \dfrac{1}{\dot{Z}_2}$

at $Z_1 = R_1 + jX_1$, $Z_2 = R_2 + jX_2$

$$\frac{1}{Z} = \left(\frac{R_1}{R_1^2 + X_1^2} + \frac{R_2}{R_2^2 + X_2^2}\right) - j\left(\frac{X_1}{R_1^2 + X_1^2} + \frac{X_2}{R_2^2 + X_2^2}\right) \qquad \text{F-21}$$

$$Z = \frac{R_1(R_2^2 + X_2^2) + R_2(R_1^2 + X_1^2)}{(R_1 + R_2)^2 + (X_1 + X_2)^2} + j\frac{X_1(R_2^2 + X_2^2) + X_2(R_1^2 + X_1^2)}{(R_1 + R_2)^2 + (X_1 + X_2)^2} \qquad \text{F-22}$$

at $Z_1 = R_1 + jX_1$, $Z_2 = 1/jX_C$

$$\frac{1}{Z} = \left(\frac{R_1}{R_1^2 + X_1^2}\right) - j\left(\frac{X_1}{R_1^2 + X_1^2} + \frac{1}{X_c}\right) \qquad \text{F-23}$$

$$Z = \frac{R_1}{(R_1X_C)^2 + (X_CX_1 - 1)^2} + j\frac{X_1 - X_C(R_1^2 + X_1^2)}{(R_1X_C)^2 + (X_1X_C - 1)^2} \qquad \text{F-24}$$

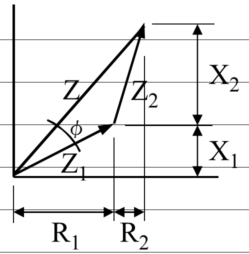
Here, $X = \omega L = 2\pi fL$、 $XC = \omega C = 2\pi fC$

$$\cos\varphi = [\{R_1(R_2^2 + X_2^2) + R_2(R_1^2 + X_1^2)\}/\{(R_1 + R_2)^2 + (X_1 + X_2)^2\}]/Z \qquad \text{F-25}$$

$$\cos\varphi = [R_1/\{(R_1X_C)^2 + (X_CX_1 - 1)^2\}]/Z \qquad \text{F-26}$$

2-3 The error by simple calculation of a series circuit

The error ε *when carrying out simple calculation of the* $\dot{Z} = \dot{Z}_1 + \dot{Z}_2$ *as* $Z = |Z_1| + |Z_2|$ *serves as the following formula.*



$$\varepsilon = \dot{Z}_1 + \dot{Z}_2 - |Z_1| - |Z_2| = \sqrt{(R_1 + R_2)^2 + (X_1 + X_2)^2} - \sqrt{R_1^2 + X_1^2} - \sqrt{R_2^2 + X_2^2}$$

$\dot{Z}_1 + \dot{Z}_2 \le |Z_1| + |Z_2|$ *is realized here.*

Although an error is not produced only when all of $\cos\varphi$ *of* $\boldsymbol{Z}$, $\boldsymbol{Z}_1$, *and* $\boldsymbol{Z}_2$ *are the same values by the upper formula, when that is not right, a simple calculation value becomes actually more large.*

To $\boldsymbol{Z}$ *when* $\cos\varphi$ *of* $\boldsymbol{Z}_1, \boldsymbol{Z}_2$ *is* ± 0.95 *,the* **error** *is set to* ＋5.26 %

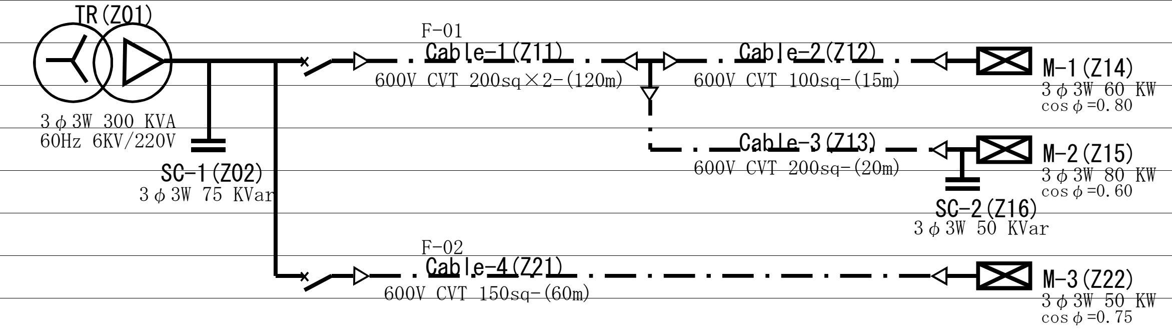
To $\boldsymbol{Z}$ *when* $\cos\varphi$ *of* $\boldsymbol{Z}_1, \boldsymbol{Z}_2$ *is* ± 0.85 *,the* **error** *is set to* ＋17.64 %

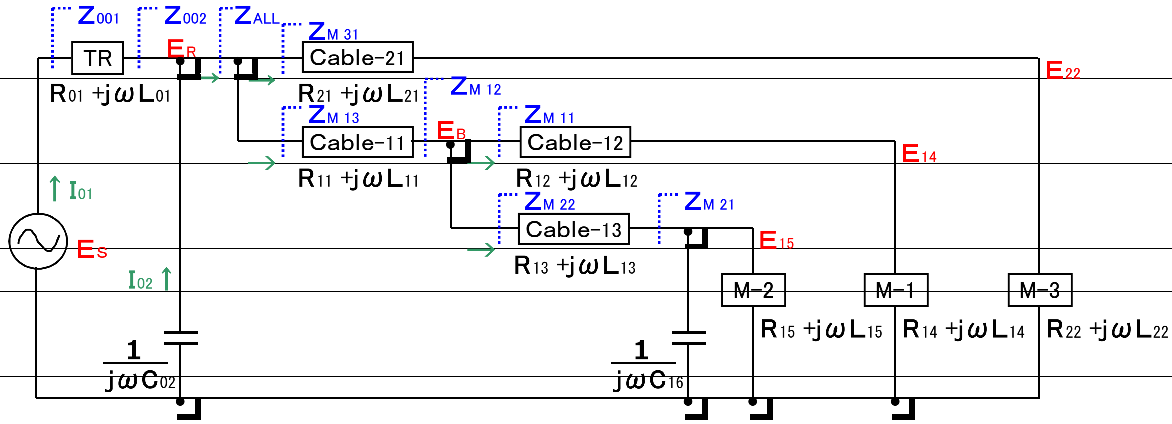
3 The circuit diagram for calculation

3-1 The circuit diagram

The following circuit is assumed in order to check the calculation value of the exchange circuit analysis by ***VD4.***

Calculation temperature is set to 50 [℃].





3-2 Calculation procedure *[ ] An inside sign expresses the impedance composition formula of a front page.*

Impedance composition calculation	The current value, voltage value calculation
01 : Z_{15} , Z_{16} ⇒ Z_{M21} [F-24]	11 : $I_{01} = E_S \,/\, Z_{001}$ (Transformer current)
02 : Z_{M21}, Z_{13} ⇒ Z_{M22} [F-11]	12 : $E_R = I_{01} \times Z_{002}$ (Power distribution side voltage)
	13 : $I_{ALL} = E_R \,/\, Z_{ALL}$ (All load current)
03 : Z_{14} , Z_{12} ⇒ Z_{M11} [F-11]	
04 : Z_{M11}, Z_{M22} ⇒ Z_{M12} [F-22]	14 : $I_{21} = E_R \,/\, Z_{M31}$ (Load current of M-3)
05 : Z_{M12}, Z_{11} ⇒ Z_{M13} [F-11]	15 : $E_{22} = I_{21} \times Z_{22}$ (Primary board side terminal voltage of M-3)
06 : Z_{22} , Z_{21} ⇒ Z_{M31} [F-11]	16 : $I_{11} = E_R \,/\, Z_{M13}$ (Load current of M-1,-2)
07 : Z_{M13}, Z_{M31} ⇒ Z_{ALL} [F-22]	17 : $E_B = I_{11} \times Z_{M12}$ (Branch part voltage)
	18 : $I_{12} = E_B \,/\, Z_{M11}$ (Load current of M-1)
08 : Z_{ALL}, Z_{02} ⇒ Z_{002} [F-24]	19 : $E_{14} = I_{12} \times Z_{14}$ (Primary board side terminal voltage of M-1)
09 : Z_{002}, Z_{01} ⇒ Z_{001} [F-11]	
	20 : $I_{13} = E_B \,/\, Z_{M22}$ (Load current of M-2)
10 : Z_{15} , Z_{16} ⇒ cos ϕ [F-26]	21 : $E_{15} = I_{13} \times Z_{M21}$ (Primary board side terminal voltage of M-2)

cosφ is average power factor of ***M-2*** .

No.

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3-3 Calculation by impedance composition

01 : Z_{15} , Z_{16} ⇒ Z_{M21} [F-24]

KW= 80　　cos φ = 0.6000　　E_s[V]= 220　　SC[KVA]= 50　　The completion

Z_{15}　80[KW]／cos φ =80×10^3／= 133333.3 [Ω]　　Z =E^2/[KVA]= 0.363　[Ω]

R15=√3·Z·cos φ = √3·0.363[Ω]·0.6= 0.377241 [Ω]，X14=√3·0.363[Ω]√(1-0.6^2)= 0.502988 [Ω]

Z16 : Z=E^2/[KVar]=220^2/(50·10^3)= 0.968000 [Ω]，1/X16=√3·0.968　→　X16= 0.596436 [Ω]

If　Z_{M21}=R_{M21}+J x_{m21} ,　　R_{15}= 0.377241　X_{15}= 0.502988　X_{16}= 0.596436

Z_{M21}= 0.697786 + j 0.494265 [Ω]

02 : Z_{M21}, Z_{13} ⇒ Z_{M22} [F-11]

R[Ω/Km]= 0.121　　X[Ω/Km]= 0.0845　　'al. temp. [℃]= 50　　Cable span[m]= 20　The completion

Z13 : R13=√3·0.121{1+0.00393·(50-20)}/{1+0.00393·(90-20)}·(20m/1000m) = 3.674808 [mΩ]

X13=√3·0.0845(60/50)·(20m/1000m)= 3.512599 [mΩ]

If　Z_{M22}=R_{M22}+jX_{M22} ,

R_{M21}= 0.697786　X_{M21}= 0.494265　R_{13}= 0.003675　X_{13}= 0.003513

Z_{M22}= 0.701461 + j 0.497778 [Ω]

03 : Z_{14} , Z_{12} ⇒ Z_{M11} [F-11]

KW= 60　　cos φ = 0.8000　　E_s[V]= 220　　The completion

Z_{14}　60[KW]／cos φ =60×10^3／= 75000　[Ω]　　Z =E^2/[KVA]= 0.645333 [Ω]

R14=√3·Z·cos φ = √3·0.645[Ω]·0.8= 0.8942　[Ω]，X14=√3·0.645[Ω]√(1-0.8^2)= 0.67065　[Ω]

R[Ω/Km]= 0.24　　X[Ω/Km]= 0.0883　　'al. temp. [℃]= 50　　Cable span[m]= 15　The completion

Z12 : R12=√3·0.24{1+0.00393·(50-20)}/{1+0.00393·(90-20)}·(15m/1000m) = 5.466657 [mΩ]

X12=√3·0.0883(60/50)·(15m/1000m)= 2.752922 [mΩ]

If　Z_{M11}=R_{M11}+J x_{m11} ,

R_{14}= 0.8942　X_{14}= 0.67065　R_{12}= 0.005467　X_{12}= 0.002753

Z_{M11}= 0.899667 + j 0.673403 [Ω]

04 : Z_{M11}, Z_{M22} ⇒ Z_{M12} [F-22]

If　Z_{M12}=R_{M12}+jX_{M12},

R_{M11}= 0.899667　X_{M11}= 0.673403　R_{M22}= 0.701461　X_{M22}= 0.497778

Z_{M12}= 0.394243 + j 0.286342 [Ω]

05 : Z_{M12}, Z_{11} ⇒ Z_{M13} [F-11]

R[Ω/Km]= 0.121　　X[Ω/Km]= 0.0845　　'al. temp. [℃]= 50　　Cable span[m]= 120　The completion

Z11 : R13=√3·0.121{1+0.00393·(50-20)}/{1+0.00393·(90-20)}·(120/1000)·(1/2)= 11.02443 [mΩ]

X11=√3·0.0845(60/50)·(120/1000)·(1/2) =　10.5378　[mΩ]

If　Z_{M13}=R_{M13}+jX_{M13} ,

R_{11}= 0.011024　X_{11}= 0.010538　R_{M12}= 0.394243　X_{M12}= 0.286342

Z_{M13}= 0.405268 + j 0.29688　[Ω]

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06 : Z_{22} , Z_{21} ⇒ Z_{M31} [F-11]

KW= 50 cos φ = 0.7500 E_s[V]= 220 The completion

Z_{22} 50[KW]／cos φ =50×10^3／= 66666.67 [Ω] Z =E^2/[KVA]= 0.726 [Ω]

R_{22}=√3･Z･cos φ ＝√3･0.726[Ω]･0.75 0.943102 [Ω] , X_{22}=√3･0.726[Ω]√(1-0.75^2) 0.831737 [Ω]

R[Ω/Km]= 0.159 X[Ω/Km]= 0.0839 al. temp.[℃]= 50 Cable span[m]= 60 The completion

Z_{21} : R_{21}=√3･0.159{1+0.00393･(50-20)}/{1+0.00393･(90-20)}･(60m/1000m)＝ 14.48664 [mΩ]

X_{21}=√3･0.0839(60/50)･(60m/1000m)= 10.46297 [mΩ]

If Z_{M31}＝R_{M31}+jX_{M31} ,

R_{22}＝ 0.943102 X_{22}＝ 0.831737 R_{21}＝ 0.014487 X_{21}＝ 0.010463

Z_{M31}＝ 0.957588 +j 0.8422 [Ω]

07 : Z_{M13}, Z_{M31} ⇒ Z_{ALL} [F-22]

If Z_{ALL}＝R_{ALL}+jX_{ALL} ,

R_{M13}＝ 0.405268 X_{M13}＝ 0.29688 R_{M31}＝ 0.957588 X_{M31}＝ 0.8422

Z_{ALL}＝ 0.285511 +j 0.220409 [Ω]

08 : Z_{ALL}, Z_{02} ⇒ Z_{002} [F-24]

E_s[V]= 220 SC[KVA]= 75 The completion

Z_{02} : Z=E^2/[KVar]＝220^2/(75･10^3)＝0.645333 [Ω] , 1/X_{02}=√3･0.645 → X02＝ 0.894654 [Ω]

If Z_{002}＝R_{002}+jX_{002} , R_{ALL}＝ 0.285511 X_{ALL}＝ 0.220409 X_{02}＝ 0.894654

Z_{002}＝ 0.402269 +j 0.146554 [Ω]

09 : Z_{002}, Z_{01} ⇒ Z_{001} [F-11]

TR[KVA]= 300 TR[%R]= 1.4100 TR[%X]= 3.26 E_s[V]= 220 The completion

Z_{01} : Z=E^2/[KVar]＝220^2/(300･10^3) 0.161333 [Ω]

R_{01}＝√3･0.1613･(1.41/100)＝ 0.00394 [Ω] , X_{01}＝√3･0.1613･(3.26/100)＝ 0.00911 [Ω]

R_{002}＝ 0.402269 X_{002}＝ 0.146554 R_{01}＝ 0.00394 X_{01}＝ 0.00911

Z_{001}＝ 0.406209 +j 0.155664 [Ω]

10 : Z_{15} , Z_{16} ⇒ cos φ [F-26]

R_{15}＝ 0.377241 X_{15}＝ 0.502988 X_{16}＝ 0.596436 Z_{M21}＝ 0.697786 ＋ j 0.494265 [Ω]

cos φ ＝ 0.81602

11 : I_{01} ＝E_S ／Z_{001} (*Transformer current*)

Z_{001}＝ 0.406209 +j 0.155664 [Ω] E_s[V]= 220 The completion

I_{01}＝ 505.7306 [A]

12 : E_R ＝ I_{01} × Z_{002} (*Power distribution side voltage*)

Z_{002}＝ 0.402269 +j 0.146554 [Ω] I_{01}[A]= 505.7306 [A]

E_R＝ 216.5205 [V]

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13 : $I_{ALL} = E_R \ / Z_{ALL}$ (***All load current***)

Z_{ALL} = 0.285511 + j 0.220409 [Ω]　　E_R = 216.5205 [V]

I_{ALL} = 600.297 [A]

14 : $I_{21} = E_R \ / Z_{M31}$ (***Load current*** : M-3)

Z_{M31} = 0.957588 + j 0.8422 [Ω]　　E_R = 216.5205 [V]

I_{21} = 169.786 [A]

15 : $E_{22} = I_{21} \times Z_{22}$ (***Primary board side terminal voltage*** : M-3)

Z_{22} = 0.943102 + j 0.831737 [Ω]　　I_{21} = 169.786 [A]

E_{22} = 213.5006 [V]

16 : $I_{11} = E_R \ / Z_{M13}$ (***Load current*** : M-1, -2)

Z_{M13} = 0.405268 + j 0.29688 [Ω]　　E_R = 216.5205 [V]

I_{11} = 430.9948 [A]

17 : $E_B = I_{11} \times Z_{M12}$ (***Branch part voltage***)

Z_{M12} = 0.394243 + j 0.286342 [Ω]　　I_{11} = 430.9948 [A]

E_B = 210.0053 [V]

18 : $I_{12} = E_B \ / Z_{M11}$ (***Load current*** : M-1)

Z_{M11} = 0.899667 + j 0.673403 [Ω]　　E_B = 210.0053 [V]

I_{12} = 186.8747 [A]

19 : $E_{14} = I_{12} \times Z_{14}$ (***Primary board side terminal voltage*** : M-1)

Z_{14} = 0.8942 + j 0.67065 [Ω]　　I_{12} = 186.8747 [A]

E_{14} = 208.8792 [V]

20 : $I_{13} = E_B \ / Z_{M22}$ (***Load current*** : M-2)

Z_{M22} = 0.701461 + j 0.497778 [Ω]　　E_B = 210.0053 [V]

I_{13} = 244.1542 [A]

21 : $E_{15} = I_{13} \times Z_{M21}$ (***Primary board side terminal voltage*** : M-2)

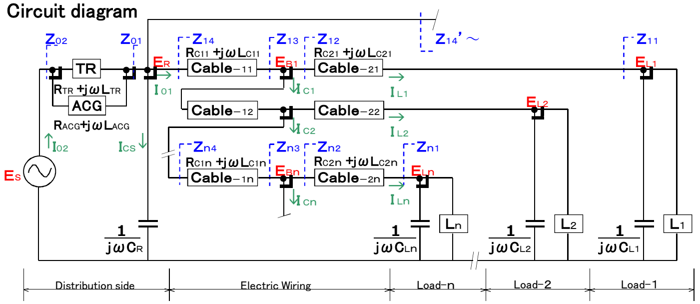
Z_{M21} = 0.697786 + j 0.494265 [Ω]　　I_{13} = 244.1542 [A]

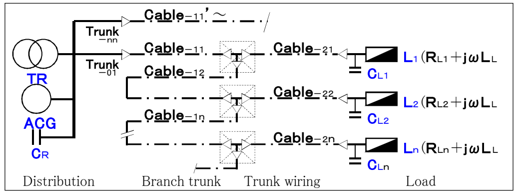
E_{15} = 208.7773 [V]

*The above and the manual calculation result of **1** to **21** are the following page. Please check that it is in agreement with each value of a **4-1 VD4** calculation sheet. The value of VD4 data sheet was used for each data required for manual calculation.*

Trunk number	Application section	Electric system: Sec. voltage Es[V] / φ W V / Frequency [Hz] / Calculation temp.	Distribution side apparatus – Power transformer: Form	Number / % Z / Capacity/Rated current	SCs Capacity [Kvar]	Load side apparatus – Load equipment capacity: Load classification	Output [KW]	Efficiency η	Power factor cos φ	Input [KVA]	Demand factor Df	Load current [A]	Z L [Ω] / R L [Ω] / X L [Ω]	SCL Capacity [Kvar] / Avrg. PF	Selection-1 (Branch trunk) Cable name: Cross section	No.	Cable span	Construct / Permission current[A]	Selection-2 (Trunk) Cable name: Cross section	No.	Cable span	Construct / Permission current[A]	Transmission: Voltage ER [V] / All load [A] / TR current [A] / Branch part [V]	Reception: Voltage EL[V] / EL／E[%] / (E-EL)／E[%]	Current IL [A] / Current Ic [A] (Total)	Distribution side Breaker Name -AF	-AT	Remarks
															Z c1 (Trunk)				Z c2 (Branch trunk)					Z n1 (Ln+CL1)				
F-01	Outdoor form CB (TR-1) power switchboard -> M-1 power board	3φ 3W 220 V	oil cooled type	1	75.0	M-1	60.0	1.000	0.800	75.00	1.00	196.8	1.1178		600V CV-T			Cabletray	600V CV-T			Exposure piping	216.52 [V]	208.88 [V]	186.87 [A]	MCCB-3P		Load factor of TR-1
				3.552		AC M/C																	600.30 [A]	94.9451 [%]	600.30 [A]			64.23 %
		60.0 [Hz]		300.0 [KVA]									0.8942	0.8000	200.0	2	120.0[m]		100.0	1	15.0[m]		505.73 [A]	5.0549 [%]		600	500	TR-1 voltage rate of change
		50.0 [°C]		787.3 [A]									0.6707		11.0244 + j 10.5378 [mΩ]				5.4667 + j 2.7529 [mΩ]					0.8942 + j 0.6707 [Ω]				3.47 [V] 1.58%
	F-01 trunk branch P-Box -> M-2 power board					M-2	80.0	1.000	0.600	133.33	1.00	349.9	0.6287	50.0					600V CV-T			Exposure piping		208.78 [V]	244.15 [A]			
						Prod. power																		94.8988 [%]	244.15 [A]			
													0.3772	0.8160					200.0	1	20.0[m]			5.1012 [%]				
		50.0 [°C]											0.5030						3.6748 + j 3.5126 [mΩ]				210.01 [V]	0.6978 + j 0.4943 [Ω]				
F-02	Outdoor form CB (TR-1) power switchboard -> M-3 power board					M-3	50.0	1.000	0.750	66.67	1.00	175.0	1.2575		600V CV-T			Cabletray					216.52 [V]	213.50 [V]	169.79 [A]			
						Prod. power																		97.0457 [%]		MCCB-3P		
													0.9431	0.7500	150.0	1	60.0[m]							2.9543 [%]		225	225	
		50.0 [°C]											0.8317		14.4866 + j 10.4630 [mΩ]									0.9431 + j 0.8317 [Ω]				
F-01	Outdoor form CB (TR-1) power switchboard -> M-1 power board	3φ 3W 220 V	oil cooled type	1	100.0	M-1	60.0	1.000	0.800	75.00	1.00	196.8	1.1178		600V CV-T			Cabletray	600V CV-T			Exposure piping	217.10 [V]	209.43 [V]	187.37 [A]	MCCB-3P		Load factor of TR-1
				3.552		AC M/C																	601.89 [A]	95.1977 [%]	601.89 [A]			62.07 %
		60.0 [Hz]		300.0 [KVA]									0.8942	0.8000	200.0	2	120.0[m]		100.0	1	15.0[m]		488.71 [A]	4.8023 [%]		600	500	TR-1 voltage rate of change
		50.0 [°C]		787.3 [A]									0.6707		11.0244 + j 10.5378 [mΩ]				5.4667 + j 2.7529 [mΩ]					0.8942 + j 0.6707 [Ω]				2.9 [V] 1.31%
	F-01 trunk branch P-Box -> M-2 power board					M-2	80.0	1.000	0.600	133.33	1.00	349.9	0.6287	50.0					600V CV-T			Exposure piping		209.33 [V]	244.80 [A]			
						Prod. power																		95.1513 [%]	244.80 [A]			
													0.3772	0.8160					200.0	1	20.0[m]			4.8487 [%]				
		50.0 [°C]											0.5030						3.6748 + j 3.5126 [mΩ]				210.56 [V]	0.6978 + j 0.4943 [Ω]				
F-02	Outdoor form CB (TR-1) power switchboard -> M-3 power board					M-3	50.0	1.000	0.750	66.67	1.00	175.0	1.2575		600V CV-T			Cabletray					217.10 [V]	214.07 [V]	170.24 [A]			
						Prod. power																		97.3039 [%]		MCCB-3P		
													0.9431	0.7500	150.0	1	60.0[m]							2.6961 [%]		225	225	
		50.0 [°C]											0.8317		14.4866 + j 10.4630 [mΩ]									0.9431 + j 0.8317 [Ω]				
F-01	Outdoor form CB (TR-1) power switchboard -> M-1 power board	3φ 3W 220 V	oil cooled type	1	75.0	M-1	60.0	1.000	0.800	75.00	1.00	196.8	1.1178		600V CV-T			Cabletray	600V CV-T			Exposure piping	145.32 [V]	140.19 [V]	125.43 [A]	MCCB-3P		Load factor of TR-1
				3.552		AC M/C																	8393.15 [A]	63.7249 [%]	8393.15 [A]			1056.48 %
		60.0 [Hz]		300.0 [KVA]									0.8942	0.8000	200.0	2	120.0[m]		100.0	1	15.0[m]		8317.63 [A]	36.2751 [%]		600	500	TR-1 voltage rate of change
		50.0 [°C]		787.3 [A]									0.6707		11.0244 + j 10.5378 [mΩ]				5.4667 + j 2.7529 [mΩ]					0.8942 + j 0.6707 [Ω]				74.67 [V] 33.94%
	F-01 trunk branch P-Box -> M-2 power board					M-2	80.0	1.000	0.600	133.33	1.00	349.9	0.6287	50.0					600V CV-T			Exposure piping		140.13 [V]	163.87 [A]			
						Prod. power																		63.6938 [%]	163.87 [A]			
													0.3772	0.8160					200.0	1	20.0[m]			36.3062 [%]				
		50.0 [°C]											0.5030						3.6748 + j 3.5126 [mΩ]				140.95 [V]	0.6978 + j 0.4943 [Ω]				
F-02	Outdoor form CB (TR-1) power switchboard -> M-3 power board					M-3	1000000	1.000	0.750	1333333.33	1.00	3499092.5	0.0001		600V CV-T			Cabletray					145.32 [V]	.51 [V]	8103.88 [A]			Short current of M-3
						Prod. power																		0.2316 [%]		MCCB-3P		8.1038 [KA]
													0.0000	0.7500	150.0	1	60.0[m]							99.7684 [%]		225	225	
		50.0 [°C]											0.0000		14.4866 + j 10.4630 [mΩ]									0.0 + j 0.0000 [Ω]				

Circuit diagram





Distribution side $E_R = I_{02} \cdot Z_{01}$

Transformer current $I_{02} = E_S / Z_{02}$ [A]
All load current $I_{01} = E_R / Z_{14}$ [A]

Load side voltage $E_{L1} = (Z_{01} \cdot Z_{13} \cdot Z_{11}) \cdot E_S / (Z_{02} \cdot Z_{14} \cdot Z_{12})$ [V]
Load side current $I_{L1} = (Z_{01} \cdot Z_{13}) \cdot E_S / (Z_{02} \cdot Z_{14} \cdot Z_{12})$ [A]

This calculation is based on the Ohm method.

Memo.

Project Name	4-1 VD4 Calculation sheet	Exchange circuit analysis calculation-VD4 Electro Systems Engineering Service		Approved K, Sakai	Checked	Terminal voltage -01

Attention ⇒

TR Capa.	1φ oil cooled-50Hz % R	% X	% Z
10	2.0100	1.7400	**2.6585**
20	1.7700	1.8200	**2.5388**
30	1.5600	2.3700	**2.8373**
50	1.4300	2.2700	**2.6829**
75	1.5300	1.9500	**2.4786**
100	1.5400	2.2900	**2.7597**
150	1.4100	2.3600	**2.7491**
200	1.3500	2.7000	**3.0187**
300	1.3100	3.7000	**3.9251**
500	1.1100	4.1100	**4.2573**

TR Capa.	1φ molded-50Hz % R	% X	% Z
10	2.7200	3.5000	**4.4327**
20	1.9900	4.6400	**5.0487**
30	1.5600	4.2800	**4.5554**
50	1.8100	3.5400	**3.9759**
75	1.5400	3.6000	**3.9156**
100	1.5700	3.8800	**4.1856**
150	1.4100	4.3300	**4.5538**
200	1.3500	4.8800	**5.0633**
300	1.1100	4.9900	**5.1120**

TR Capa.	1φ oil cooled-60Hz % R	% X	% Z
10	1.9200	1.9300	**2.7224**
20	1.6800	2.0400	**2.6427**
30	1.5100	2.6000	**3.0067**
50	1.3900	2.5500	**2.9042**
75	1.4300	2.1500	**2.5821**
100	1.4200	2.5400	**2.9100**
150	1.3700	2.7300	**3.0545**
200	1.3100	3.1400	**3.4023**
300	1.2900	4.2800	**4.4702**
500	1.1000	4.7500	**4.8757**

TR Capa.	1φ molded-60Hz % R	% X	% Z
10	2.7200	3.5000	**4.4327**
20	1.9900	4.6400	**5.0487**
30	1.5600	4.2800	**4.5554**
50	1.8100	3.5400	**3.9759**
75	1.5400	3.6000	**3.9156**
100	1.5700	3.8800	**4.1856**
150	1.4100	4.3300	**4.5538**
200	1.3500	4.8800	**5.0633**
300	1.1100	4.9900	**5.1120**

IV (Piping) Cross section	Resistance [60℃] [Ω/Km]	Reactance [50Hz] [Ω/Km]
2.0	10.7000	0.0992
3.5	6.0200	0.0914
5.5	3.8500	0.0914
8.0	2.6700	0.0914
14.0	1.5000	0.0830
22.0	0.9530	0.0858
38.0	0.5630	0.0761
60.0	0.3510	0.0786
100.0	0.2090	0.0761
150.0	0.1370	0.0744
200.0	0.1070	0.0740
250.0	0.0840	0.0724
325.0	0.0666	0.0719

600V CVT Cross section	Resistance [90℃] [Ω/Km]	Reactance [50Hz] [Ω/Km]
8.0	3.0100	0.1140
14.0	1.7100	0.1070
22.0	1.0800	0.1020
38.0	0.6260	0.0939
60.0	0.3970	0.0905
100.0	0.2400	0.0883
150.0	0.1590	0.0839
200.0	0.1210	0.0845
250.0	0.0981	0.0826
325.0	0.0765	0.0807
400.0	0.0634	0.0792
500.0	0.0520	0.0795
600.0	0.0448	0.0785

TR Capa.	3φ oil cooled-50Hz % R	% X	% Z
20	2.1400	0.9800	**2.3537**
30	1.9100	1.0900	**2.1991**
50	1.8100	1.3100	**2.2343**
75	1.7800	1.7300	**2.4822**
100	1.7300	1.7400	**2.4537**
150	1.6100	1.9100	**2.4980**
200	1.6300	2.6000	**3.0687**
300	1.5000	2.8200	**3.1941**
500	1.2500	4.0600	**4.2481**
750	1.3100	4.9200	**5.0914**
1000	1.1900	5.0200	**5.1591**
1500			
15000			

TR Capa.	3φ molded-50Hz % R	% X	% Z
20	3.3900	2.8200	**4.4096**
30	2.8300	2.4900	**3.7695**
50	1.9800	3.1000	**3.6784**
75	1.7000	3.6000	**3.9812**
100	1.8700	3.8300	**4.2621**
150	1.5700	3.9300	**4.2320**
200	1.4900	4.3500	**4.5981**
300	1.4400	4.4300	**4.6582**
500	1.0700	4.0900	**4.2276**

TR Capa.	3φ oil cooled-60Hz % R	% X	% Z
20	1.9700	1.0100	**2.2138**
30	1.7800	1.2400	**2.1693**
50	1.7000	1.4600	**2.2409**
75	1.6400	1.9300	**2.5327**
100	1.6000	1.9300	**2.5070**
150	1.5000	2.1200	**2.5970**
200	1.5300	2.9000	**3.2789**
300	1.4100	3.2600	**3.5519**
500	1.1800	4.6100	**4.7586**
750	1.2400	5.3500	**5.4918**
1000	1.1200	5.6800	**5.7894**
1500	1.0000	6.0000	**6.0828**
15000		9.0000	**9.0000**

TR Capa.	3φ molded-60Hz % R	% X	% Z
20	3.1600	3.0300	**4.3780**
30	2.8400	3.1100	**4.2116**
50	1.9300	3.1200	**3.6687**
75	1.6600	4.1700	**4.4883**
100	1.9100	4.4000	**4.7967**
150	1.5600	4.6900	**4.9426**
200	1.4400	4.8800	**5.0880**
300	1.3400	5.0700	**5.2441**
500	1.0600	5.4700	**5.5718**

600V CV-2C/3C Cross section	Resistance [90℃] [Ω/Km]	Reactance [50Hz] [Ω/Km]
2.0	12.0000	0.0992
3.5	6.7600	0.0914
5.5	4.3400	0.0914
8.0	3.0100	0.0870
14.0	1.7100	0.0828
22.0	1.0800	0.0820
38.0	0.6260	0.0771
60.0	0.3970	0.0773
100.0	0.2400	0.0777
150.0	0.1590	0.0747
200.0	0.1210	0.0757
250.0	0.0985	0.0742
325.0	0.0771	0.0725

USER ⇒ Cross section	Resistance [90℃] [Ω/Km]	Reactance [50Hz] [Ω/Km]
2.0		
3.5		
5.5		
8.0		
14.0		
22.0		
38.0		
60.0		
100.0		
150.0		
200.0		
250.0		
325.0		
400.0		
500.0		

TR Capa.	3φ User-50Hz ⇒ % R	% X	% Z

ACG Capa.	3φUSER[50Hz] ⇒ % R	% X	% Z

4-2

Data Sheet [V D 4]

ELECTRICAL LOAD LIST (Sammary sheet)

Approved			
Checked	*K,Sakai*	Drawn	
ESE LOAD LIST-Ver 2.0 ('02.7/31)			

Electro Systems Engineering Service

Project name
5-2 Exchange circuit analysis by VD4
Load list sammary sheet

Primary group No.	Sub-station No.	Transformer				All Loads			with no Capacitor				with Capacitor				Capa-citor	Reactor	Remarks
									Demand loads			Transformer	Demand loads			Transformer			
		TR.No.	Capacity	Classification	Type	[KW]	[KVar]	[KVA]	[KW]	[KVar]	[KVA]	Load factor [%]	[KW]	[KVar]	[KVA]	Load factor [%]	[KVar]	[KVar]	
			[KVA]																
22KV-52F01	No.1 S/S	TR-1	300	New	oil cooled	190.0	195.8	275.0	190.0	195.8	272.8	90. 94	190.0	45.8	195.4	65. 14	159.00	9.00	
			[KVA]			[KW]	[KVar]	[KVA]	[KW]	[KVar]	[KVA]		[KW]	[KVar]	[KVA]		[KVar]	[KVar]	
			300			190	195.8	275.0	190.0	195.8	272.8		190.0	45.8	195.4		159.0	9.0	

Prm.Group No.	22KV-52F01	3φ3W 60[Hz]	All loads [KW]	190.0	with no Capacitor		with Capacitor		Notes.Capacitor installed in the secondary side.
Substation No.	No.1 S/S	Prm.[V] 6000V	All loads [KVar]	195.8	TR. Load factor [%]	90.94	TR. Load factor [%]	65.14	
Sec.Group No.		Sec.[V] 220[V]	All loads [KVA]	275.0	Demand [KW]	190.0	Demand [KW]	190.0	Capacitor
New Transformer No.	TR-1	300 [KVA]	Installation place	Outdoors	Demand [KVar]	195.8	Demand [KVar]	45.8	159.00 [KVar]
			type of Transformer		Demand [KVA]	272.8	Demand [KVA]	195.4	Reactor
			oil cooled		Ave.Power factor	0.696	Ave.Power factor	0.972	9.00 [KVar]

Project name

5-2 Exchange circuit analysis by VD4

Load list

LOAD LIST 2002.07/31 Ver 2.0

Electro Systems Engineering Service

Trunk No.	Board name	Load No.	Load name	Kind of load	Rated Out-put[KW]	Number	Automatic Output(%) Eff.	Automatic Output(%) Power F.	Automatic Output(%) Load F.	Manual input(%) Eff.	Manual input(%) Power F.	Manual input(%) Load F.	Load [KW]	Input [KVA]	Power F. of Load	Demand factor	Demand [KW]	Demand [KVar]	Demand [KVA]	Remarks
F-01	M-1		空調動力	IM-4P	60.00	1				100.00	80.00	100.00	60.00			1.00	60.00	45.00	75.00	
	M-2		生産動力	others	80.00	1				100.00	60.00	100.00	80.00			1.00	80.00	106.67	133.33	208.3[KVA](Df=1)
F-02	M-3		生産動力	IM-4P	50.00	1				100.00	75.00	100.00	50.00			1.00	50.00	44.10	66.67	66.6[KVA](Df=1)

Notes-1) Let the rate of load be the average value of the induction motor of the right above grade to Calculation axis power [KW] × (1＋ margin [%]).
Notes-2) The efficiency and powerfactor to the rate of load of an induction motor are computed by straight line proportionality calculation from a value 50 or 75,100%.

Margin of motor selection[%]→ 10

50Hz-200V				FEE,PF of Induction motor (50Hz-200V)					
				at 50% Load		at 75% Load		at 100% Load	
Output KW	Load factor	EFF(%)	PF(%)	EFF(%)	PF(%)	EFF(%)	PF(%)	EFF(%)	PF(%)
0.15									
0.20	79.55	71.95	65.02	68.1	50.8	71.9	63.4	72.2	72.3
0.40	68.18	75.98	65.83	74.6	57.1	76.5	69.1	76.0	77.8
0.75	69.70	80.49	65.41	78.6	55.4	81.0	68.1	80.5	76.0
1.50	68.18	82.37	63.59	80.7	54.5	83.0	67.0	83.1	75.1
2.20	76.45	86.67	72.20	85.4	59.6	86.7	71.8	86.1	78.7
3.70	72.48	87.04	72.49	86.5	61.7	87.1	73.7	86.3	80.4
5.50	76.03	89.28	75.88	88.3	63.4	89.3	75.6	88.9	82.4
7.50	78.79	89.42	78.39	88.8	65.3	89.5	77.5	89.0	83.4
11.00	76.45	91.88	76.46	91.3	64.7	91.9	76.1	91.5	82.3
15.00	78.79	92.27	78.38	91.6	66.3	92.3	77.5	92.1	83.3
18.50	82.31	92.80	78.13	91.9	64.5	92.8	76.4	92.8	82.3
22.00	83.68	93.06	81.60	92.7	69.1	93.2	80.0	92.8	84.6
30.00	78.79	92.92	80.01	92.7	68.1	93.0	79.3	92.5	84.0
37.00	82.31	94.00	85.59	93.9	77.1	94.2	84.8	93.5	87.5
45.00	82.83	92.84	82.28	92.4	70.7	92.9	81.0	92.7	85.1
55.00	82.64	94.01	80.87	93.9	68.4	94.1	79.0	93.8	85.1

60Hz-220V				FEE,PF of Induction motor (60Hz-220V)					
				at 50% Load		at 75% Load		at 100% Load	
Output KW	Load factor	EFF(%)	PF(%)	EFF(%)	PF(%)	EFF(%)	PF(%)	EFF(%)	PF(%)
0.15									
0.20	79.55	75.09	64.63	71.1	51.2	75.0	63.1	75.5	71.5
0.40	68.18	78.60	66.51	77.0	58.0	79.2	69.7	78.8	77.2
0.75	69.70	83.21	66.27	81.4	56.5	83.7	68.9	83.3	76.2
1.50	68.18	85.18	57.21	83.8	55.1	85.7	58.0	85.8	75.9
2.20	76.45	88.59	73.18	87.4	61.0	88.6	72.8	88.5	79.4
3.70	72.48	88.41	73.02	87.6	62.5	88.5	74.2	88.1	80.6
5.50	76.03	90.20	77.63	89.0	66.1	90.2	77.4	90.1	83.0
7.50	78.79	90.45	79.37	89.6	67.5	90.5	78.6	90.2	83.7
11.00	76.45	92.59	77.73	92.0	67.4	92.6	77.4	92.4	83.1
15.00	78.79	92.68	80.11	91.8	68.4	92.7	79.4	92.6	84.1
18.50	82.31	93.23	80.08	92.3	67.7	93.2	78.5	93.3	83.9
22.00	83.68	93.53	82.65	92.9	71.8	93.6	81.3	93.4	85.2
30.00	78.79	93.28	82.24	92.6	72.1	93.3	81.6	93.2	85.8
37.00	82.31	93.65	86.52	93.1	79.1	93.8	85.7	93.3	88.5
45.00	82.83	93.71	84.86	93.2	75.5	93.8	83.8	93.5	87.2
55.00	82.64	94.54	83.58	94.1	73.0	94.6	82.2	94.4	86.7

5-3
DATA sheet

Electro Systems Engineering
ESE SERVICE
URL : www.onyx.dti.ne.jp/~eses/
E-mail : eses@onyx.dti.ne.jp
639 Yamanoboh－chyoh,Kashihara－city,Nara, 634-0071
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FACSIMILE:03-3241-5361

6 Exchange circuit analysis by VD4

*Following, The contents of description of **6-1** and **6-2** can be performed if each input value is corrected with **VD4** calculation sheet. Please correct an item to change and realize an output value and calculation speed.*

6-1 Short-circuit current calculation

*If 50 [KW] of the load side apparatus output KW (cell number [P58]) of a **4-1 VD4** calculation sheet is changed into 1000000[KW] ,The short-circuit current 8.1038[KA] (symmetrical value) by the side of primary [of an on-site board (M-3)] is called for. Moreover, if Output KW is made into 100000[KW], a short-circuit current will be set to 7.9375[KA]. The contact resistance by the short circuit accident at this time becomes 0.0005+j0.0004[Ω].*
*Next, if the span of an **F-02** trunk cable is made into 0 [m] in order to ask for the short-circuit current by the side of transformer secondary (symmetrical value), 22.0374 [KA] will be outputted to a remarks column.*
*Cell number : refer to **Z60** and **AL59***

6-2 About a power factor improvement

*If 75 [Kvar] of the power distribution side apparatus SC_R (cell number [N18]) of a **4-1 VD4** calculation sheet is made into "DEL", the following value will change.*

1) All load current [A] : 600. 30 → 595. 55
2) Power distribution side voltage [V] : 216. 52 → 214. 81
3) Transformer current[A] : 505. 73 → 595. 55
4) Load factor of transformer [%] : 64. 23 → 75. 67
5) Transformer voltage rate of change[%] : 1. 58 (3. 47[V]) → 2. 35 (5. 19[V])
6) **M-1** Terminal voltage[V] : 208. 88 → 207. 23 Load current[A] : 186. 87 → 185. 40
M-2 Terminal voltage[V] : 208. 78 → 207. 13 Load current[A] : 244. 15 → 242. 22
M-3 Terminal voltage[V] : 213. 50 → 211. 81 Load current[A] : 169. 79 → 168. 44

Next, if this SC_R is made into 100 [Kvar], the above-mentioned value will change conversely.
*Column number : refer from **34** to **45***

6-3 About a series reactor

*In **VD4**, the input of an in-series reactor is unnecessary. When the in-series reactor is installed, since the capacity equivalent to a reactor is expected, to the power capacitor, this calculation is unnecessary.*

6-4 Reliability of Load list

*A **Load list** is created in order to grasp the special feature of load. Therefore, the track reactance drop by wiring is not taken into consideration. Although load side apparatus [load current] of VD4 disregards the voltage rate of change of a transformer and is displayed as a reference value over rated voltage, an actual load current value turns into a value smaller than this. It is a value (64.23% -> 67.58%) with the more larger actually rate of transformer of a **Load list** also from this.*

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7 The plan of electric equipment

7-1 Master plan

The master plan document and examination document which are hung up over the next can be drawn up by ***VD4*** *and* ***Load list****.*

1) The number and rated capacity of the power transformer can be assumed by ***Load list****.*

2) Determination of a incoming system and incoming voltage, and assumption of an electric system.

3) Assumption of a power factor improvement system.

4) Assumption of the number of circuits of a trunk, and trunk size.

7-2 Enforcement plan

The data base for a Enforcement plan which are hung up over the next can be drawn up by ***VD4*** *and* ***Load list****.*

1) Road list can determine the number and rated capacity of the power transformer.

2) The determination of an electric system. Assumption of primary terminal voltage and load current of on-site board.

3) Determination of a power factor improvement system, and assumption of improvement power factor.

4) Determination of the number of circuits of a trunk, and trunk size. Assumption of a trunk margin.

8 Maintenance management of electric equipment

8-1 Various imitation construction

VD4 *can perform the next imitation construction.*

1) Tap adjustment of the power transformer accompanying incoming voltage change.

2) Change construction of an electric system.

3) Establishment, extension, withdrawal, or replacement construction of a power transformer and a power capacitor.

4) Route change construction or exchange construction of a trunk cable accompanying load capacity change.

5) The short circuit examination in a required part. (symmetrical value)

8-2 Various diagnostic tests

VD4 *can perform the next diagnostic test.*

1) The transformer capacity check and wiring capacity check accompanying load change.

2) The check of margin of a trunk cable.The countermeasure check accompanying the increase in load capacity

3) The check of the terminal voltage by reexamination of circumference temperature.

4) The check of power capacitor capacity and the minimum power factor.

5) Guess the route by calculating the span of the old trunk cable which is unknown.etc.

8-3 Karte [Data base] registration

You have to cope with quickly future extension-and-alteration construction, renewal construction of apparatus, etc. by database-izing of the present electric equipment. It is important in order that this may aim at safety of electric equipment, and efficient employment [sick prevention]. Furthermore, if the ***Load list*** *which is the foundation of each load data of* ***VD4*** *is also data-base-ized collectively, it is much more thoroughgoing.*

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