JGC PHILIPPINES, INC.

VOLTAGE DROP CALCULATION FOR LIGHTING AND CONVENIENCE SOCKET CIRCUITS

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- Definition of Terms
- Philippine Electrical Code Provisions
- Formula for Voltage Drop Calculation
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EFFECTS OF VOLTAGE VARIATION

INDUCTION MOTORS

Characteristic	Proportional to	Voltage variation	
		90% of nameplate	110% of nameplate
Starting and maximum running torque	Voltage squared	–19%	+21%
Percent slip	$(1/\text{voltage})^2$	+23%	–19%
Full load speed	Synchronous speed—slip	–0.2 to –1.0%	+0.2 to 1.0%
Starting current	Voltage	–10%	+10%
Full load current	Varies with design	+5 to +10%	–5 to –10%
No load current	Varies with design	–10 to –30%	+10 to +30%
Temperature rise	Varies with design	+10 to +15%	–10 to –15%
Full load efficiency	Varies with design	–1 to –3%	+1 to +3%
Full load power factor	Varies with design	+3 to +7%	–2 to –7%
Magnetic noise	Varies with design	Slight decrease	Slight increase

Reference: IEEE Std. 141-1993

EFFECTS OF VOLTAGE VARIATION

LIGHTING FIXTURES

FLUORESCENT LAMPS	**Light output is directly proportional to the applied voltage for magnetic ballast.**
	Light output for electronic ballast may be more or less dependent on input voltage.
High Intensity Discharge (HID) Lamps	**Mercury lamps with typical reactor ballast will have a 12% change in light output for a 5% change in voltage input**
	HID lamps may extinguish if input voltage drops below 75% of rated voltage.

Reference: IEEE Std. 141-1993

EFFECTS OF VOLTAGE VARIATION

RESISTANCE HEATING DEVICES

- **Heat output of resistance heaters varies approximately as the square of the impressed voltage.**

- **A 10% drop in voltage will cause a drop of approximately 19% in heat output.**

Reference: IEEE Std. 141-1993

EFFECTS OF VOLTAGE VARIATION

CAPACITORS

- **The reactive power of the capacitor varies as the square of the impressed voltage.**

- **A 10% drop in voltage will cause a drop of approximately 19% in reactive power output.**

Reference: IEEE Std. 141-1993

TO SUMMARIZE:

- **The voltage impressed in an equipment has an effect on the performance of a device or equipment.**

- **Excessive voltage drop can cause heating of equipment. Thus, degradation of insulation is possible.**

Reference: IEEE Std. 141-1993

DEFINITION OF TERMS

- **System Voltage- the root-mean-square phase-to-phase voltage of a portion of an ac electric system.**

- **Nominal System Voltage – the voltage by which a portion of the system is designated and to which certain operating characteristics of the system are related.**

Reference: IEEE Std. 141-1993

DEFINITION OF TERMS

- **Voltage Drop-** is the amount of voltage loss that occurs through all or part of the circuit due to impedance.

$$\% V_D = V_D/V_N \times 100\%$$

Where:

V_D – Voltage drop (volts)

V_N – nominal system voltage (volts)

SOURCE: Novec

PHILIPPINE ELECTRICAL CODE PROVISIONS

- **According to PEC (Article 2.15.1.2 (A) FPN No. 2)**

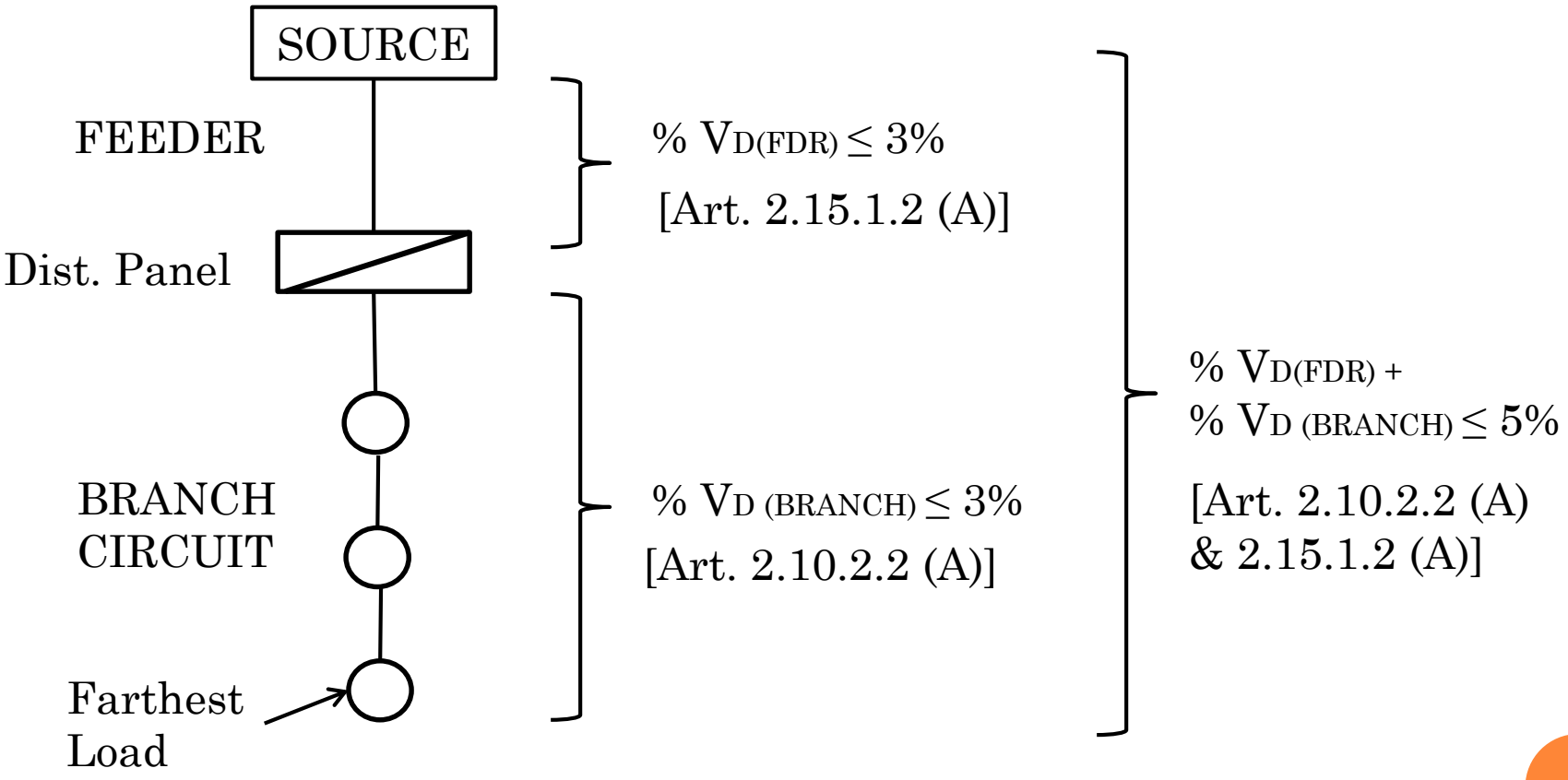
"**Conductors for feeders** as defined in Article 1.1 sized to prevent a voltage drop exceeding **3 percent** at the **farthest** outlet of power, heating and lighting loads, or combinations of such loads, and where the maximum total voltage drop on **both feeders and branch circuit** to the farthest outlet **does not exceed 5 percent**, provide reasonable efficiency of operation."

PHILIPPINE ELECTRICAL CODE PROVISIONS

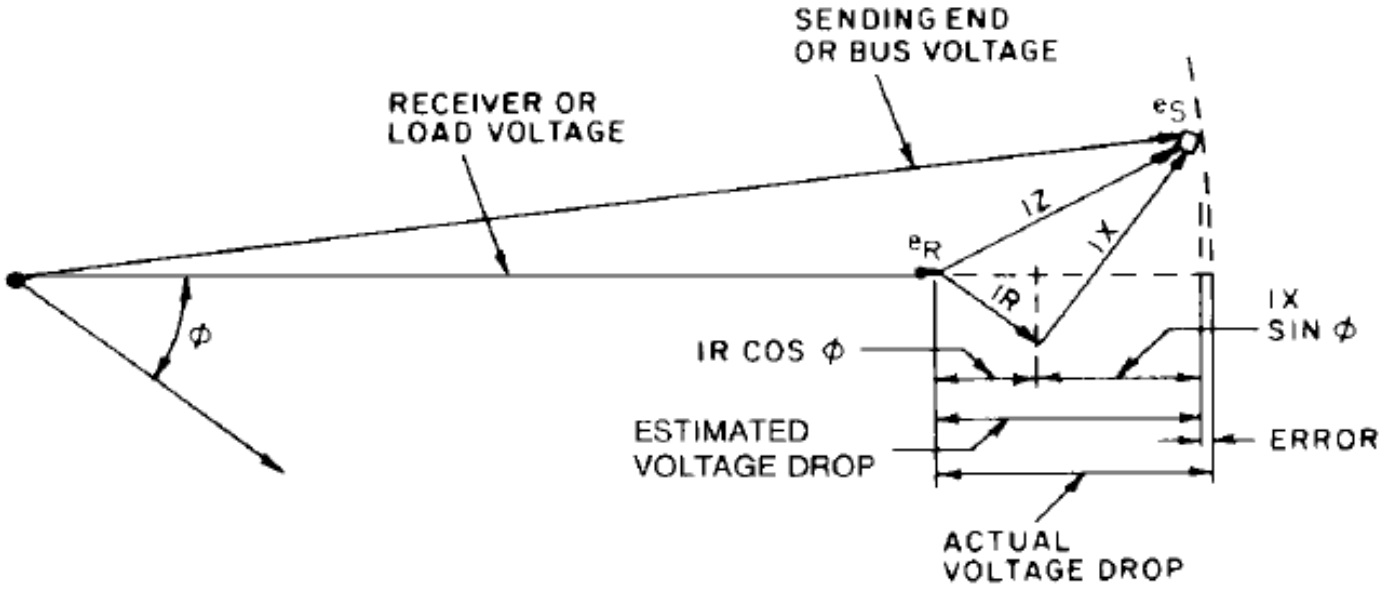
- **According to PEC (Article 2.10.2.2 (A) FPN No. 4)**

"**Conductors for branch circuits** as defined in Article 1.1 sized to prevent a voltage drop exceeding **3 percent** at the **farthest** outlet of power, heating and lighting loads, or combinations of such loads, and where the maximum total voltage drop on **both feeders and branch circuit** to the farthest outlet **does not exceed 5 percent**, provide reasonable efficiency of operation."

PHILIPPINE ELECTRICAL CODE PROVISIONS



FORMULA FOR VOLTAGE DROP CALCULATION



Phasor Diagram of Voltage Relations For Voltage Drop Calculations

Reference: IEEE Std. 141-1993

FORMULA FOR VOLTAGE DROP CALCULATION

Approximate Formula for Voltage Drop:

$$V_D = KI\,(R\cos\phi + X\sin\phi)$$ ⇨ **Equation 1**

Where:

V_D – Voltage drop (volts)
K – multiplying constant (2 for single phase, $\sqrt{3}$ for three phase)
I – current flowing in conductor (amperes)
R – line resistance of conductor (ohms)
X – line reactance of conductor (ohms)
ϕ – angle whose cosine is the load power factor
$\cos\phi$ – load power factor in decimals
$\sin\phi$ – load reactive factor in decimals

Reference: IEEE Std. 141-1993

FORMULA FOR VOLTAGE DROP CALCULATION

- Formula for resistance of a copper conductor with reference to cross-sectional area and length of a conductor:

$$R = \rho L / A \quad \Rightarrow \quad \text{Equation 2}$$

Where:

R – Resistance (ohms)

ρ – material resistivity (ohm-m)

For copper $\rho_{Cu@20C} = 1.7241 \times 10^{-8}$ ohm-m @ 20°C

For aluminum $\rho_{Al@20C} = 2.65 \times 10^{-8}$ ohm-m @ 20°C

L – length of the conductor (m)

A – cross-sectional area of the conductor (m^2)

Reference: IEEE Std. 141-1993

FORMULA FOR VOLTAGE DROP CALCULATION

- For correction of resistivity according to ambient temperature

$$\rho_{T\text{-}AMB} = \rho_{20°C} [\, 1 + \alpha\, (T_{AMB} - 20°C)]$$ ⇨ Equation 3

Where:
α –temperature coefficient of resistivity (/°C)
$\alpha_{Cu} = 3.93 \times 10^{-3}$ /°C for copper
T_{AMB} – ambient temperature (°C)

- Substituting equation 3 to equation 2, the resistance of a conductor with reference to ambient temperature, length and cross-sectional area is:

$$R = \rho_{20°C} [\, 1 + \alpha\, (T_{AMB} - 20°C)]L/A$$ ⇨ Equation 4

FORMULA FOR VOLTAGE DROP CALCULATION

- For lighting and small power, the power factor is high (more than 0.90). Hence, we can consider a pf = 1.0, and ϕ = 0 degrees.
- Solving voltage drop for single-phase lighting loads using equations 1 and 4:

$$\rho_{20°C}\,[\,1 + \alpha\,(T_{AMB} - 20°C)]L/A$$

2 1 0

$$V_D = KI\,(R\cos\phi + X\sin\phi)$$

$$V_D = 2I\,\rho_{20°C}\,[\,1 + \alpha\,(T_{AMB} - 20°C)]L/A \quad \Rightarrow \quad \text{Eq. 5}$$

Reference: IEEE Std. 141-1993

FORMULA FOR VOLTAGE DROP CALCULATION

- Solving single phase voltage drop for using copper conductor, and ambient temperature of 40°C:

3.93×10^{-3} /°C

1.7241×10^{-8} ohm-m

40 °C

$$V_D = 2I \rho_{Cu@20°C} [1 + \alpha_{Cu} (T_{AMB} - 20°C)]L/A$$

$$V_D = 3.719 \times 10^{-8} I L/A$$ ⇨ Equation 6

Reference: IEEE Std. 141-1993

SAMPLE CALCULATION NO. 1

Given:

System Voltage, V_N = 230V, 1 phase

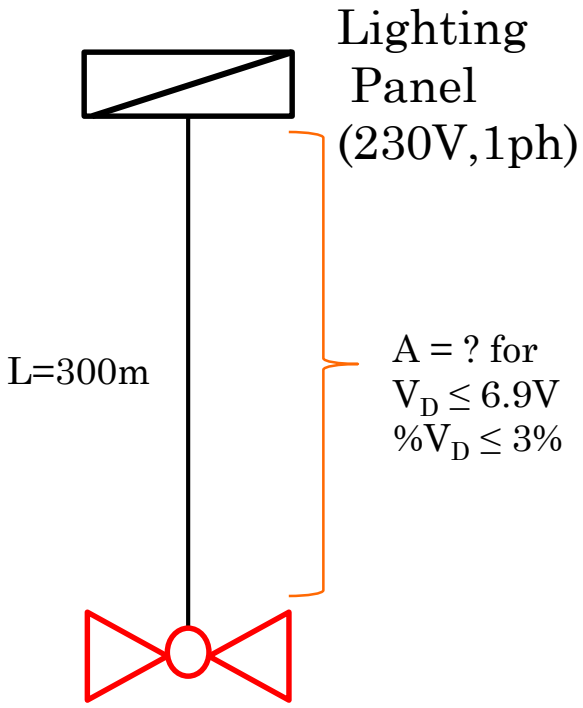
Allowable Voltage Drop (%), $\%V_D$ = 3%

Allowable Voltage Drop (V), V_D = 6.9 V

Problem:

Two- 250W flood lights will be installed 300m from the lighting panel. What will be the minimum copper conductor size required to meet the allowable voltage drop at ambient temperature of 40°C and 1.30A load for each flood light?

Solution:



USING EQUATION 6:

$$\% V_D = [3.719x10^{-8} I L/A]/V_N \times 100\%$$

$$I = 2 \times 1.3 \text{ Amp} = 2.6 \text{ Amp}$$

$$A = 3.719x10^{-8} I L/ V_D$$

SUBSTITUTING:

$$A = 3.719x10^{-8} (2.6 \text{ Amp}) (300m)/ 6.9V$$

$$A = 4.2x10^{-6} m^2$$

CONVERT TO mm^2:

$$A = 4.2x10^{-6} m^2 \times (1000mm/1m)^2$$

$A = 4.2 mm^2$

USE NEXT SIZE, SAY $6mm^2$

CALCULATE % V_D USING 6 mm^2:

$$\% V_D = [3.719x10^{-8} I L/A]/V_N \times 100\%$$

$$\% V_D = [3.719x10^{-8} (2.6Amp) (300m)/(6 x10^{-6}m^2)]/230V \times 100\%$$

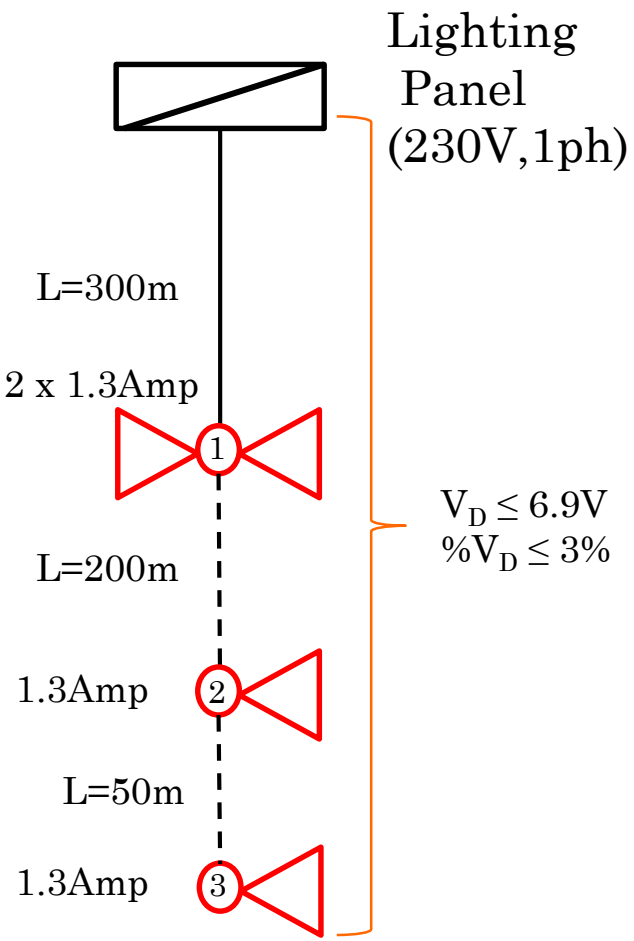
$\% V_D = 2.10 \%$

SAMPLE CALCULATION NO. 2

Problem:

Two- additional 250W flood lights, 50m apart, will be connected to the junction box of the flood lights in Sample Calculation No. 1. The first flood light is 200m from the junction box. What will be the minimum copper conductor size required to meet the allowable voltage drop assuming all conductor sizes are same?

Solution:



$V_{DTOTAL} \leq 6.9\ V$

$V_{DTOTAL} = V_{D1} + V_{D2} + V_{D3}$

$V_{D1} = 3.719x10^{-8}\ (2.6+1.3+1.3\ Amp)(300m)/A_1$

$V_{D1} = 5.80164x10^{-5}/A_1$

$V_{D2} = 3.719x10^{-8}\ (1.3+1.3\ Amp)(200m)/A_2$

$V_{D2} = 1.93388x10^{-5}/A_2$

$V_{D3} = 3.719x10^{-8}\ (1.3\ Amp)(50m)/A_3$

$V_{D3} = 2.41735x10^{-6}/A_2$

$A = A_1 = A_2 = A_3$

$V_{DTOTAL} = (5.80164x10^{-5}/A) + (1.93388x10^{-5}/A) + (2.41735x10^{-6}/A)$

$A = 1.156\ x\ 10^{-5}\ m2\ (1000mm/1m)2$

$V_{DTOTAL} = (5.80164x10^{-5}/A) + (1.93388x10^{-5}/A) + (2.41735x10^{-6}/A)$

$A = 1.156 \times 10^{-5}\ m^2\ (1000mm/1m)^2$

$A = 11.56\ mm^2$

USE NEXT SIZE, SAY 16mm²

$V_{DTOTAL} = (5.80164x10^{-5} + 1.93388x10^{-5} + 2.41735x10^{-6})(1/16mm^2)(1000mm/1m)^2$

V_{DTOTAL} = 4.99 V

$\%\ V_{DTOTAL} = 4.99\ V/230\ V \times 100\%$

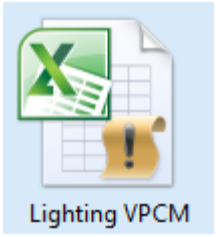
% V_{DTOTAL} = 2.17 %

Imagine what it is like when doing voltage drop calculation for multiple circuits and hundreds of lighting fixtures?

Photo credit to: Vectorstock.com

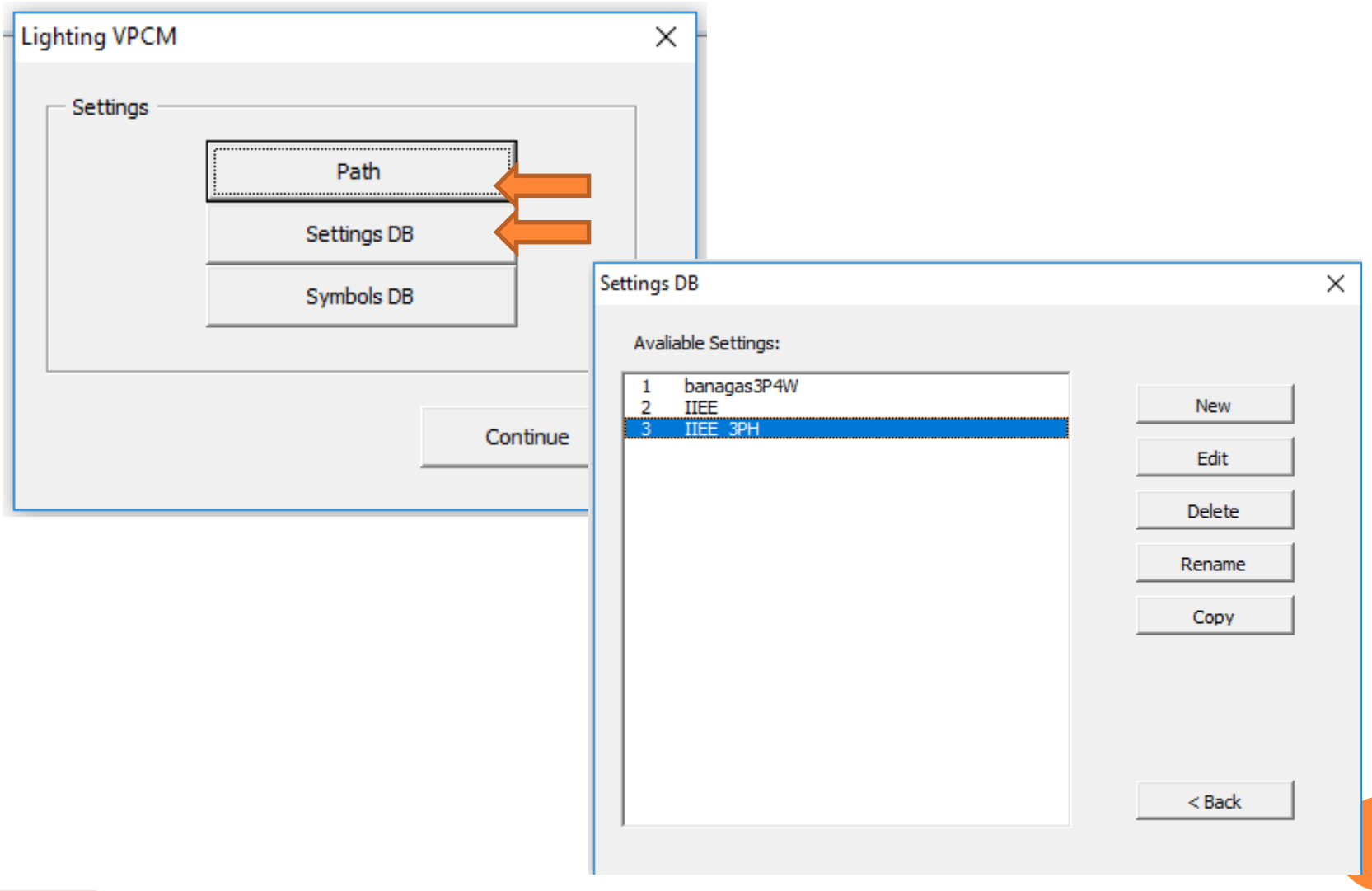
IN JGC, WE DEVELOP OUR IN-HOUSE SOFTWARE:

Lighting VPCM



V- Voltage Drop Calculator
P- Panel Schedule
C- Cable Schedule
M- Material Take-Off (MTO)

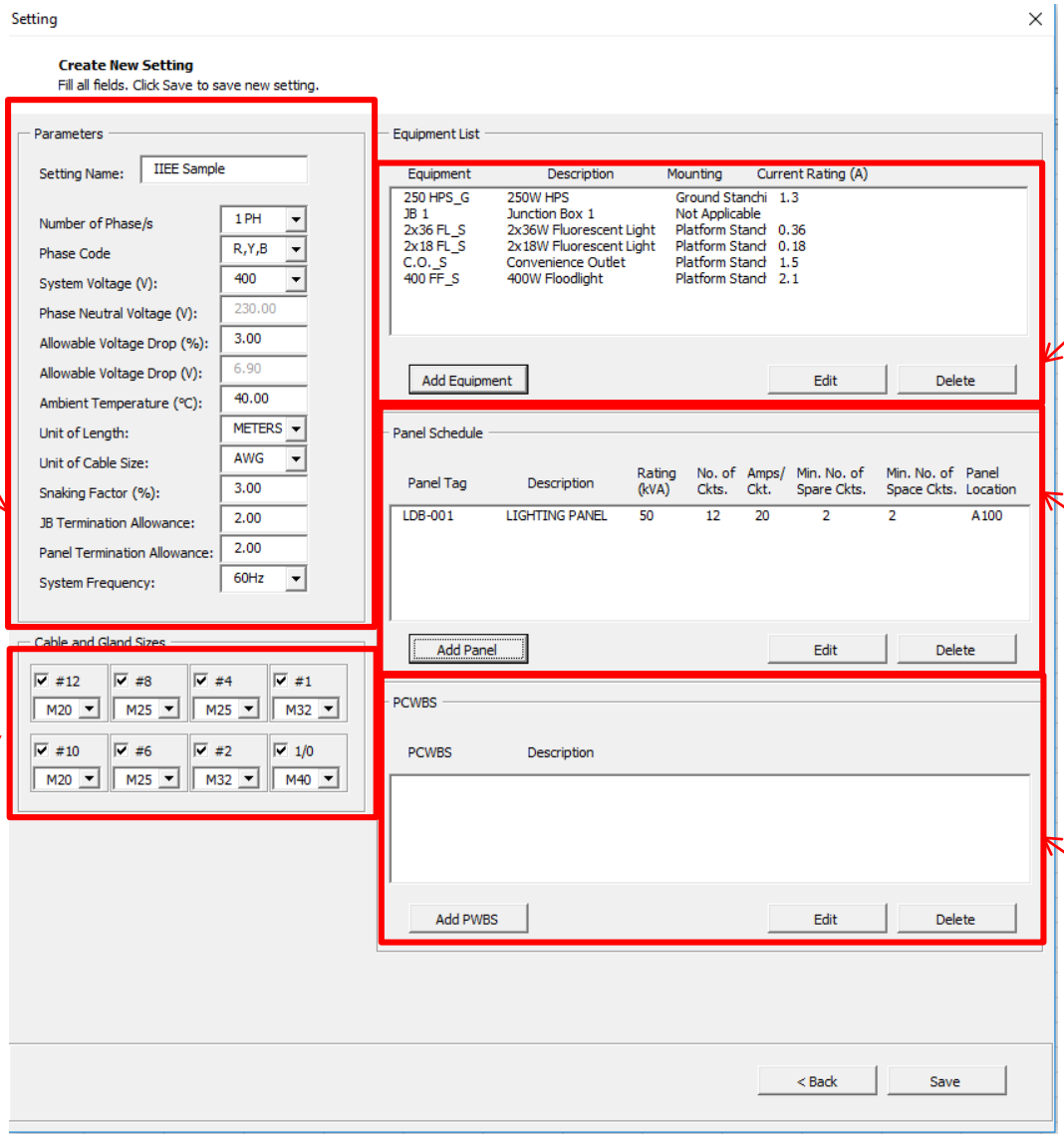
VPCM (JGC'S IN-HOUSE SOFTWARE)



FILL UP THE SETTINGS

- System Information
- Criteria

- Cable information
- Cable gland information



- Set up load information

- Panel Board Information

- Location information

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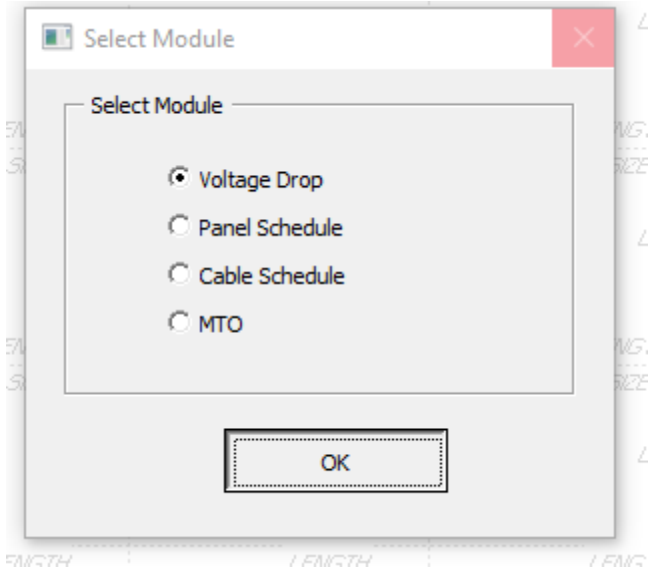
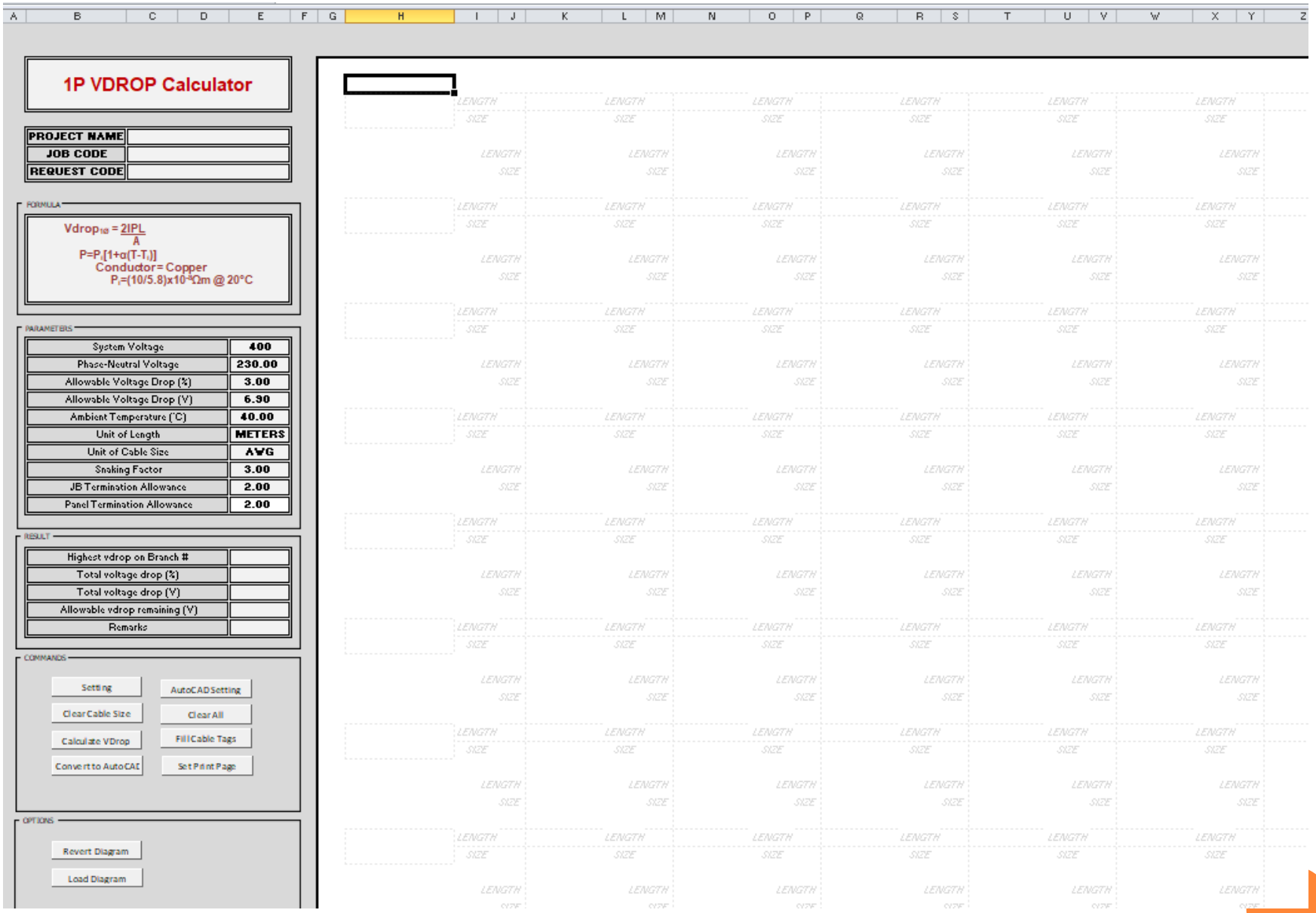
SELECT THE MODULE





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1P VDROP Calculator

PROJECT NAME	
JOB CODE	
REQUEST CODE	

FORMULA

$$Vdrop_{1\phi} = \frac{2IPL}{A}$$

$$P = P_i[1+\alpha(T-T_i)]$$

Conductor = Copper

$P_i = (10/5.8)\times10^{-8}\Omega m$ @ 20°C

$\alpha = 3.93\times10^{-3}/°C$

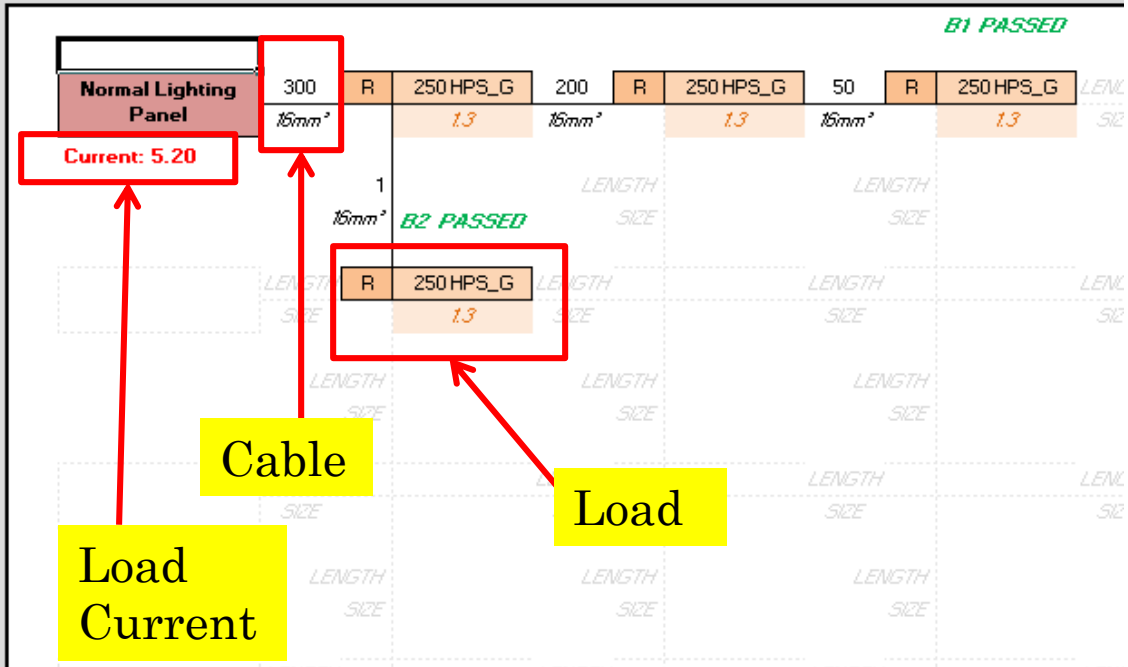
PARAMETERS

System Voltage	400
Phase-Neutral Voltage	230.00
Allowable Voltage Drop (%)	3.00
Allowable Voltage Drop (V)	6.90
Ambient Temperature (°C)	40.00
Unit of Length	METERS
Unit of Cable Size	SQMM
Snaking Factor	0.00
JB Termination Allowance	0.00
Panel Termination Allowance	0.00

RESULT

Highest vdrop on Branch #	1
Total voltage drop (%)	2.17
Total voltage drop (V)	4.99
Allowable vdrop remaining (V)	1.91
Remarks	PASSED

COMMANDS



Highest vdrop on Branch #	1
Total voltage drop (%)	2.17
Total voltage drop (V)	4.99
Allowable vdrop remaining (V)	1.91
Remarks	PASSED

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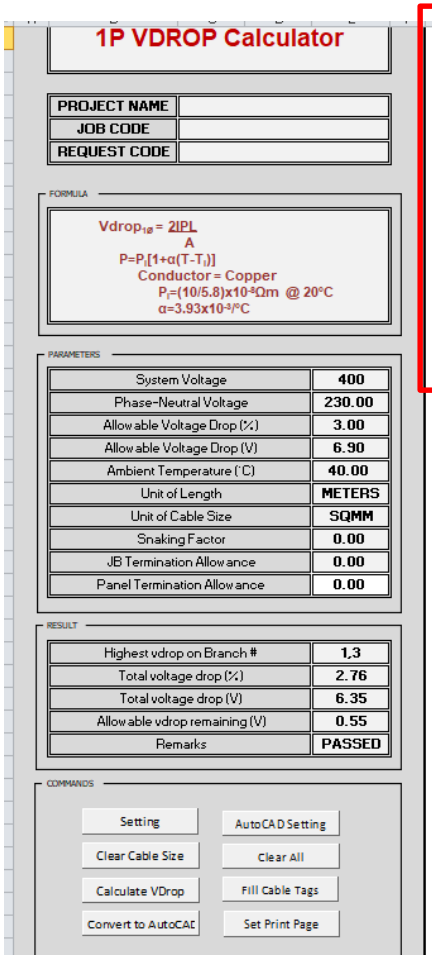

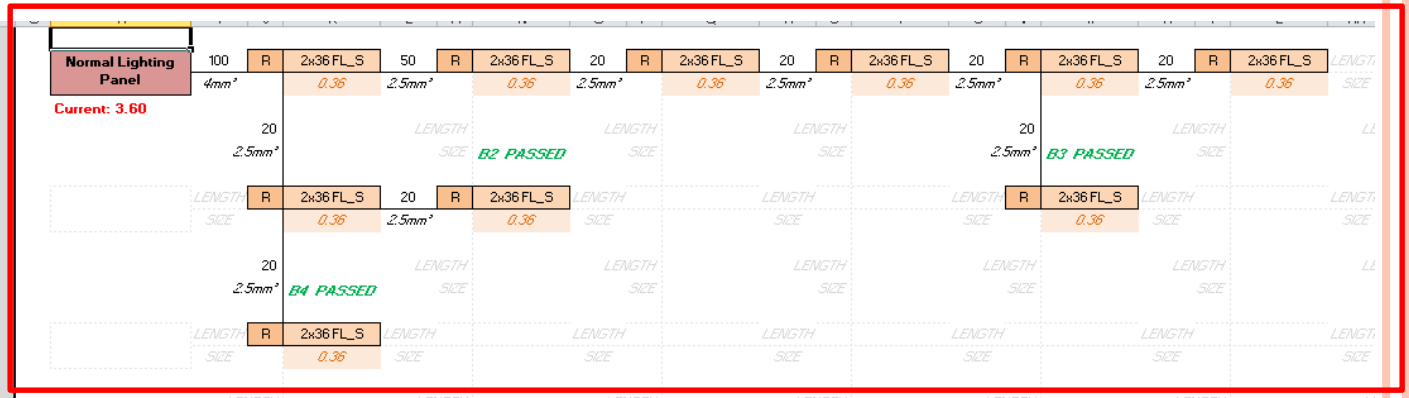

10 Fixtures

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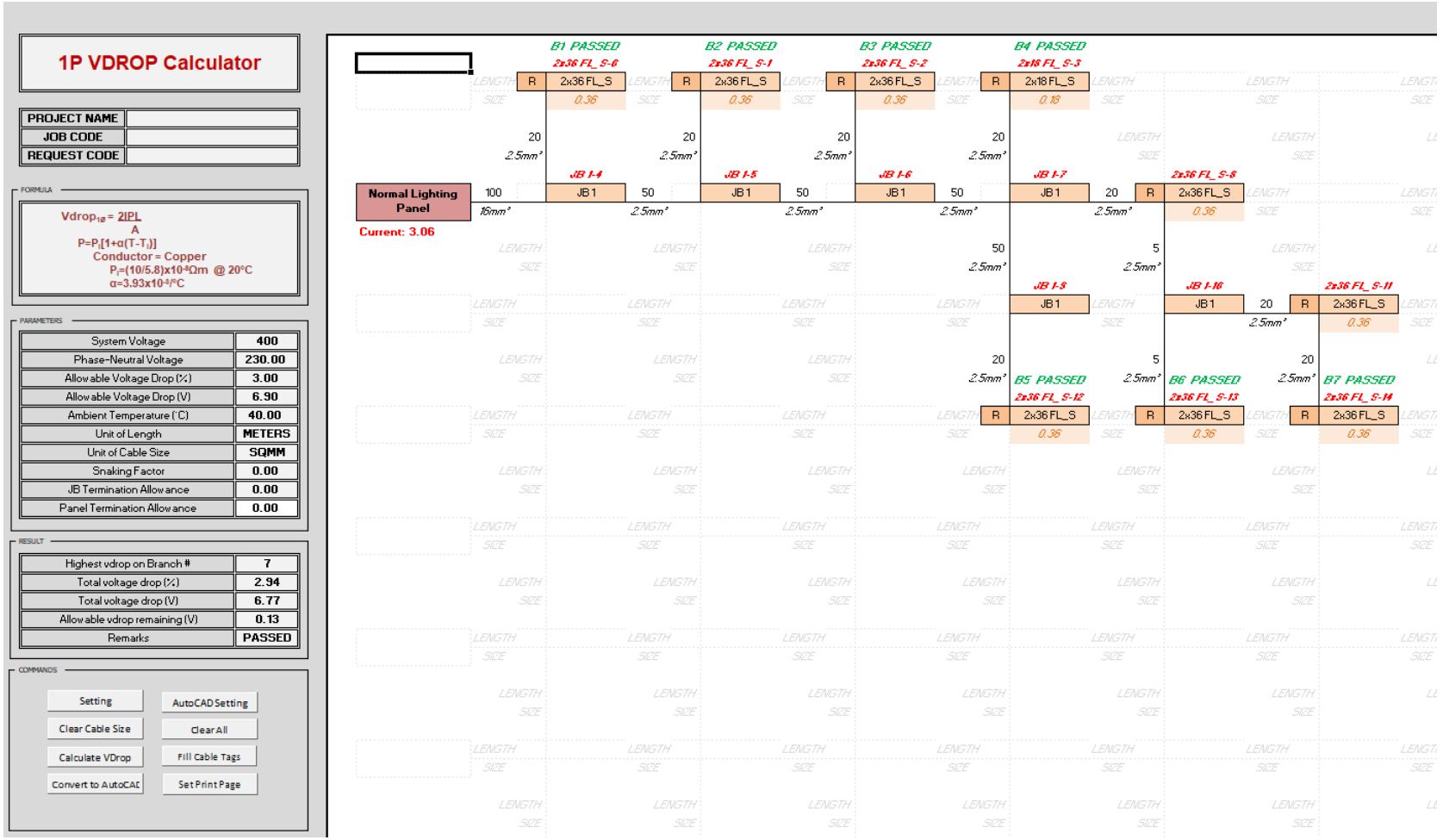

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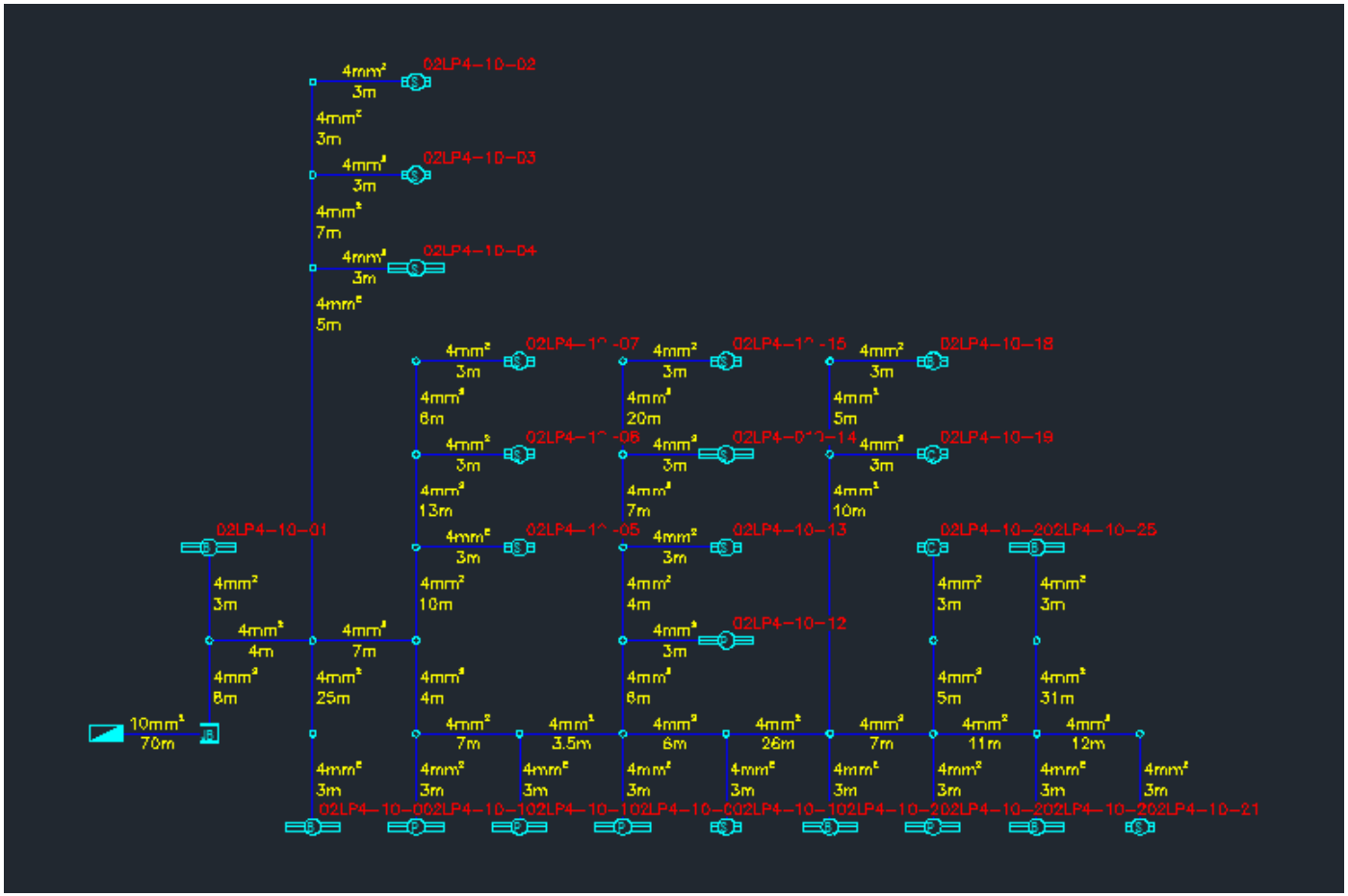
SAMPLE OUTPUT:
Lighting Block Diagram (CAD file)



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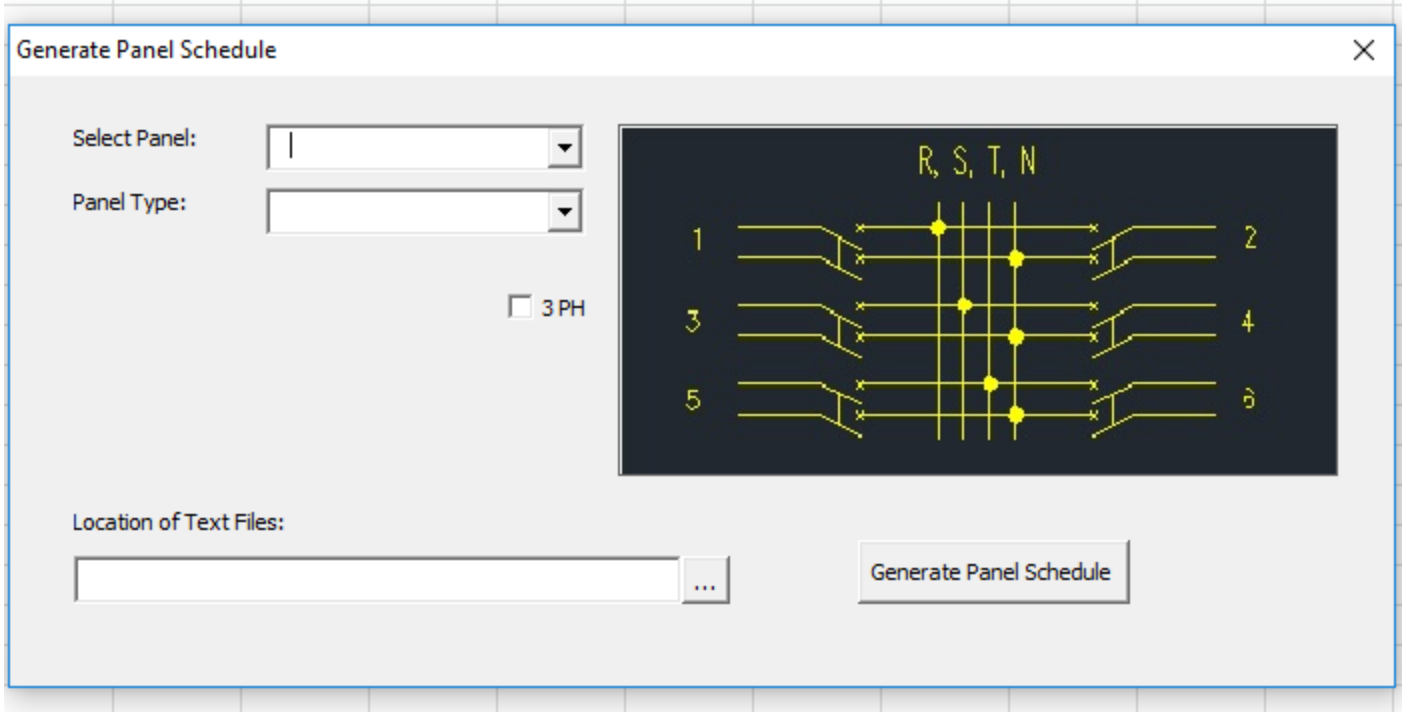
PANEL SCHEDULE MODULE:



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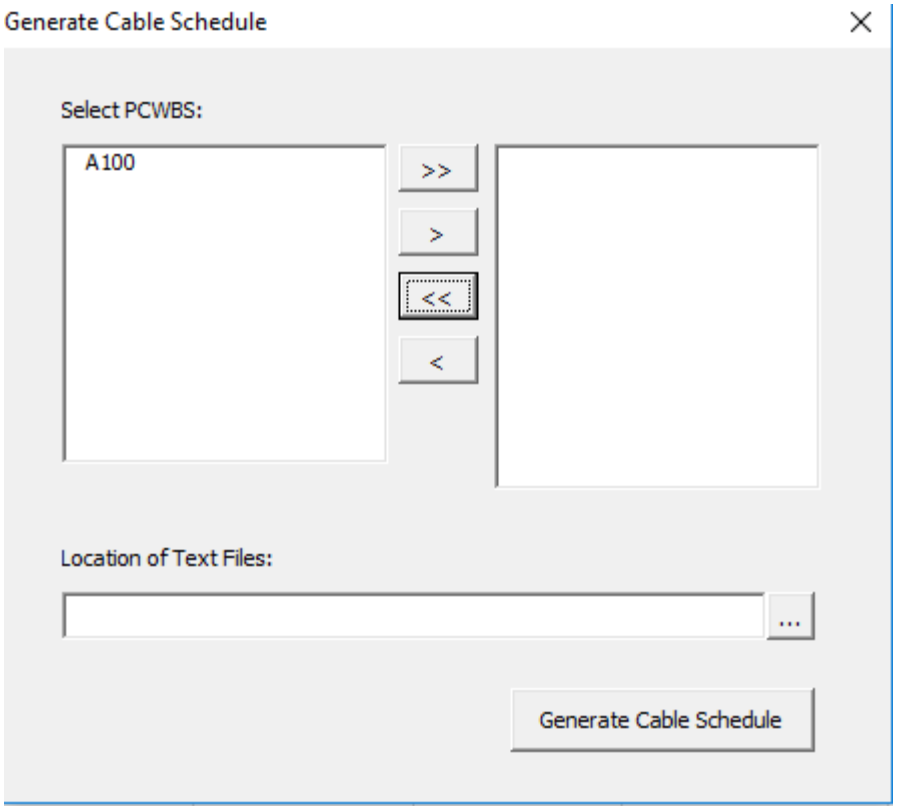
PANEL SCHEDULE MODULE:

LDB-001-1PH-Type 1

PHASE CURRENT			250 HPS_G	2x18 FL_S	2x36 FL_S	400 FF_S	C.O._S	LG ILLUM	CO	SERVICE	CKT NO.	400/230V 3ϕ, 4W, 60Hz 4P MCB, 50A R,Y,B,N	CKT NO.	SERVICE	CO	LG ILLUM	250 HPS_G	2x18 FL_S	2x36 FL_S	400 FF_S	C.O._S	PHASE CURRENT		
R	Y	B																					R	Y	B
3.06				1	8						1		2					1	8				3.06		
	3.06			1	8						3		4											0.00	
		0.00									5		6												0.00
0.00											7		8										0.00		
	0.00										9		10											0.00	
		0.00									11		12												0.00
3.06	3.06	0.00	0	2	16	0	0	0	0		SUB TOTAL		SUB TOTAL		0	0	0	1	8	0	0		3.06	0.00	0.00

OUTPUT IN EXCEL FILE

CABLE SCHEDULE MODULE:



CABLE SCHEDULE MODULE:

Project Name:

ITEM	MODULE/PCWBS	SERVICE TYPE	CABLE TAG	FROM	CABLE GLAND	ADAPTOR/REDUCER	TO	CABLE GLAND	ADAPTOR/REDUCER	CABLE SIZE	CABLE TYPE	VOLTAGE RATING	MOUNTING TYPE	LENGTH(M)
1	A100		2x36 FL_S-0-L	JB 1-4	M20	N/A	2x36 FL_S-0	M20	N/A	2C-2.5+PE				20
2	A100		JB 1-4-L	Normal Lighting Panel	M25	N/A	JB 1-4	M25	N/A	2C-16+PE				100
3	A100		2x36 FL_S-1-L	JB 1-5	M20	N/A	2x36 FL_S-1	M20	N/A	2C-2.5+PE				20
4	A100		JB 1-5-L	JB 1-4	M20	N/A	JB 1-5	M20	N/A	2C-2.5+PE				50
5	A100		2x36 FL_S-2-L	JB 1-6	M20	N/A	2x36 FL_S-2	M20	N/A	2C-2.5+PE				20
6	A100		JB 1-6-L	JB 1-5	M20	N/A	JB 1-6	M20	N/A	2C-2.5+PE				50
7	A100		2x18 FL_S-3-L	JB 1-7	M20	N/A	2x18 FL_S-3	M20	N/A	2C-2.5+PE				20
8	A100		JB 1-7-L	JB 1-6	M20	N/A	JB 1-7	M20	N/A	2C-2.5+PE				50
9	A100		2x36 FL_S-12-L	JB 1-9	M20	N/A	2x36 FL_S-12	M20	N/A	2C-2.5+PE				20
10	A100		JB 1-9-L	JB 1-7	M20	N/A	JB 1-9	M20	N/A	2C-2.5+PE				50
11	A100		2x36 FL_S-13-L	JB 1-10	M20	N/A	2x36 FL_S-13	M20	N/A	2C-2.5+PE				5
12	A100		JB 1-10-L	2x36 FL_S-8	M20	N/A	JB 1-10	M20	N/A	2C-2.5+PE				5
13	A100		2x36 FL_S-8-L	JB 1-7	M20	N/A	2x36 FL_S-8	M20	N/A	2C-2.5+PE				20
14	A100		2x36 FL_S-14-L	2x36 FL_S-11	M20	N/A	2x36 FL_S-14	M20	N/A	2C-2.5+PE				20
15	A100		2x36 FL_S-11-L	JB 1-10	M20	N/A	2x36 FL_S-11	M20	N/A	2C-2.5+PE				20
16	A100		2x36 FL_S-0-L	JB 1-4	M20	N/A	2x36 FL_S-0	M20	N/A	2C-2.5+PE				20
17	A100		JB 1-4-L	Normal Lighting Panel	M25	N/A	JB 1-4	M25	N/A	2C-16+PE				100
18	A100		2x36 FL_S-1-L	JB 1-5	M20	N/A	2x36 FL_S-1	M20	N/A	2C-2.5+PE				20
19	A100		JB 1-5-L	JB 1-4	M20	N/A	JB 1-5	M20	N/A	2C-2.5+PE				50
20	A100		2x36 FL_S-2-L	JB 1-6	M20	N/A	2x36 FL_S-2	M20	N/A	2C-2.5+PE				20
21	A100		JB 1-6-L	JB 1-5	M20	N/A	JB 1-6	M20	N/A	2C-2.5+PE				50
22	A100		2x18 FL_S-3-L	JB 1-7	M20	N/A	2x18 FL_S-3	M20	N/A	2C-2.5+PE				20
23	A100		JB 1-7-L	JB 1-6	M20	N/A	JB 1-7	M20	N/A	2C-2.5+PE				50
24	A100		2x36 FL_S-12-L	JB 1-9	M20	N/A	2x36 FL_S-12	M20	N/A	2C-2.5+PE				20

OUTPUT IN EXCEL FILE

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MATERIAL TAKE-OFF

Project Name:
Jobcode:

ITEM NO.	DESCRIPTION/SPECS	TYPE	UNIT	QTY. A100	TOTAL
1	250W HPS	250 HPS_G			0
2	2x18W Fluorescent Light	2x18 FL_S		3	3
3	2x36W Fluorescent Light	2x36 FL_S		24	24
4	400W Floodlight	400 FF_S			0
5	Convenience Outlet	C.O._S			0
6	Junction Box 1	JB 1		22	22
7	2.5mm²	2C-2.5+PE		410	410
8	4mm²	2C-4+PE			0
9	6mm²	2C-6+PE			0
10	10mm²	2C-10+PE			0
11	16mm²	2C-16+PE		100	100
12	25mm²	2C-25+PE			0
13	35mm²	2C-35+PE			0
14	50mm²	2C-50+PE			0
15	Cable Gland for 2.5mm²	M20		92	92
16	Cable Gland for 6mm²	M25		6	6
17	Cable Gland for 25mm²	M32			0
18	Normal Lighting Panel	Normal Lighting Panel		3	3
19	Receptacle Panel	Receptacle Panel			0
20	Emergency Lighting Panel	Emergency Lighting Panel			0
21	415V Switchgear (306LVW-004)	415V Switchgear (306LVW-004)			0

OUTPUT IN EXCEL FILE

ADVANTAGES OF THE VPCM:

- Easy voltage drop calculation
- Easy development of lighting block diagram
- Easy production of panel board schedule
- Create your cable schedule
- Optimize cable size (reduce cost)
- Can automatically select size of your cable
- Reduce your man-hour cost in design

QUESTIONS AND ANSWERS

JGC Philippines, Inc.

Creating Value Through Engineering

Services Offered

Project Management

Engineering

- Feasibility Study
- Front End Engineering Design
- Basic Engineering
- Detailed Engineering
- As-Built

Procurement

- Inquiry and Evaluation
- Purchasing
- Expediting
- Inspection
- Shipping and Transportation

Construction

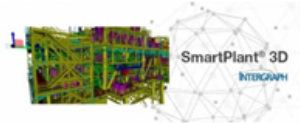
- Construction Mgt
- Safety Control
- Quality Control
- Material Control
- Subcontracting
- Field Engineering
- Testing and Commissioning

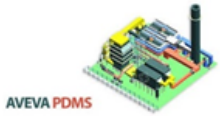
Facility Maintenance

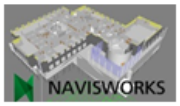
- Maintenance Planning
- CMMS Implementation
- Turn Around and Shutdown
- Warehouse Management
- Spare Parts Sourcing and Handling

JGC PHILIPPINES, INC.

Software







1. SP3D, PDS (Intergraph) and PDMS (Aveva)	3D Layout & Modeling
2. Smart Plant Review (Intergraph) Review Reality (Aveva) NavisWorks (AutoDesk)	3D Model Review
3. Auto CAD, Microstation	2D Cad Drafting
4. ETAP	Electrical system calculations
5. LUXICON, CHALMIT, DIALUX	Illumination calculation
6. Smart Plant Electrical (SPEL)	Electrical database management
7. eDPP / PDP	Electrical Load Calculation
8. PVSyst	Photovoltaic Systems Simulation

THANK YOU VERY MUCH!