The Powerdim program is a simple and fundamental tool that serves to calculate the right power plant to power the facilities of a particular home, business, company or electrical equipment.

POWERDIM

Technical criteria and mathematical calculations of power plants for the Powerdim Application.

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CONTENT

TECHNICAL CRITERIA AND MATHEMATICAL CALCULATIONS OF POWER PLANTS - FOR THE POWERDIM APPLICATION - V1. 2.0.0.

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1. BASES TO USE THE APPLICATION.

1.1 Overview:

The Powerdim application makes the calculation of the diesel power plant required to feed or support the power supply of an Electrical Installation, being applicable for all alternating current installations at 50 or 60 Hertz. Any type of project or Installation can be studied here, as listed below:

- ✓ A house, apartment, building or residential unit basically composed of appliances and small engines.
- ✓ Small businesses, commercial premises, offices, office buildings and shopping centers.
- ✓ Events or public show as involving fixed or portable equipment with lights, sound, video projectors, giant screens, inflatable dummies.
- ✓ Hypermarkets, Industry, warehouses and business centers that have electrical loads of all kinds.
- ✓ Civil construction works that basically involve portable equipment such as electric welders and motors of all sizes.
- ✓ Exploration projects and mining and oil exploitation, within which there are combined loads of camps and production and involve the frequent use of variable speed equipment.

Note: are exceptued for places that may require special sizing for their power plants, included in the technical regulations, such as hospitals, skyscrapers, data centers, etc., for which these calculations should be taken only as a reference.

1.2 Results:

The solution is based on alternating current diesel power plants for a frequency of 50Hz or 60 Hz.
Two options are provided as a solution:

- ✓ ***<u>Option 1:</u>*** Application of a three-phase power plant, with electrical outputs of 4 cables: L-L-L-N.
- ✓ ***<u>Option 2:</u>*** Application of a single-phase power plant, with electrical outputs of 3 L-L-N cables.

Nominal parameters *shown*: For each option, the main nominal electrical parameters are presented with which the commercial search for the required power plants can be initiated, and which should be present in the plate data of the equipment. These are:

- P: Power of the power plant required, in kilowatts.
- pf: Nominal power factor.
- V: Rated voltage [suggested], in volts.
- IL: Nominal current, in amps.

According to the commercial possibilities for the acquisition of equipment, with the available physical spaces or with the electrical conditions of the installation, it is possible that the use of several power plants must be resorted to cover the energy requirement; in this case, the powers of the plants used must add up to the same power specified in these results and these must be connected in parallel to feed the electrical installation.

PLEASE NOTE: ***Single-phase power plants*** are commercially available for powers below 15kW, therefore, although the results are valid, option 2 of the solution will not be applicable for single-phase power plants greater than this power.

1.3 Technical response of the selected power plant:

As a criterion of this application, the expected response, based on the voltage and frequency parameters of the diesel power plant against engine starts and sudden load inputs, is considered to always be within the normal ranges of operación and manufacturing; this is assumed because within the calculations, an additional provision of capacity is assigned for the diesel power plant,which allows to foresee that there will be no falls or large fluctuations of these two electrical parameters.

Despite the above, the voltage and frequency fluctuations of diesel power plants are generally greater than those presented by public power supply networks.

1.4 Power plant factory tests:

The manufacturers of diesel power plants are obliged to guarantee, with factory tests, the power stablished values that the diesel power plant can withstand in the face of sudden increases in load, in kW; that is, it must guarantee the load steps that the diesel plant can withstand.

1.5 End User Knowledge about the electrical installation and the solution scope:

Theend user must basically know the following:

- What are the load steps presented by your electrical installation, caused by the entry and exit of equipment and electric motors?
- What are the values of load steps (kW), which the power plant can support, and which are tested and guaranteed by the manufacturer?
- What is the level of sensitivity of the equipment of your installation to the voltage and frequency fluctuations of diesel power plants?
- Keep in mind that if the size of the diesel power plant is very high with respect to the value of the load of its electrical system, the smaller the voltage and

frequency fluctuations that it presents, but greater the fuel consumption and lower your efficiency.

2. CALCULATION PROCESS.

2.1 General description of the calculation process:

To measure the required diesel power plant, to feed an electrical system or a specific electrical load, electrical parameters in steady state of the system calculations are made, that is based on the type of electrical installation and the characteristics of all connected electrical equipment. From this calculation, five technical conditions are applied, which the power plant must meet in terms of its power supply capacity, which are:

- *Condition 1.* Have a power (in kW), such that none of the electrical currents of each of the cables of the installation, exceeds the conduction capacity of any of the lines of the generator.
- *Condition 2.* Have a capacity such that it allows it to operate at a percentage load recommended by standards and manufacturers; the above, in accordance with the maximum power consumed by the equipment of the load in its normal operation.
- *Condition 3.* Have the capacity to supply the maximum power, in kW, consumed by the charging equipment in its normal operation, plus the amount of power that is required for the start of all electric motors.
- *Condition 4*. The electric generator must have sufficient power (in KVA), to ensure that the voltage generated is stable; the above, in accordance with the capacitive reactive power required by the load.
- *Condition 5*. The electric generator must have sufficient power (in KVA), to prevent overheating or internal damage to its rotor; the above, in accordance with the inductive reactive power required by the load.

For the power plant to meet each of these conditions, it is required to have the nominal power of the load and add a power quantity within the calculations, whose value is different for each of the conditions evaluated. The result or selection criterion applied for the sizing of the diesel power plant shall correspond to the highest calculated power, in kW, which allows these five technical conditions to be simultaneously enforced.

2.2 Process structure:

The process required for the sizing of the diesel power plant is structured asfollows:

2.2.1 Input data.

Provide the data of the requirement (input data):

- What is the daily operating regime of the electrical system?
- What is the type of Electrical Installation that the system has?
- What are the electrical load equipment?
- What is the cost per gallon of diesel fuel? (optional).

2.2.2 Process of calculation.

To perform the Electrical Installation parameters calculations.

- Calculate the power consumption for each Electrical Installation load.
- Distribute the connection of electrical loads between the lines of the Installation (to distribute kW and kvar).
- Calculate Total kW.
- Calculate Total kVA.
- Calculate Total kvar.
- Calculate Total p.f.
- Determine electrical current and power factor for each line of the Installation.
- Perform the calculations of the 5 technical conditions that the power plant must meet.

2.2.3 Results delivery.

- ✓ Deliver the three-phase "Standby" plant power value.
- ✓ Deliver the three-phase "Prime" plant power value.
- ✓ Deliver the three-phase "Continuous" plant power value.
- ✓ Deliver the single-phase plant power value (if applicable).
- ✓ Deliver the diesel fuel consumptions and costs result.

3. GENERAL ASSUMED ASPECTS.

The following general technical criteria are assumed for this application.

1. *The power of the load equipment:* this power is considered constant, regardless of the value assigned to the voltage of the Electrical Installation; that is, only the respective variations in the electric current will be considered and calculated against the modifications of the voltage of the Installation.
2. *Electrical charge states:* Two types of charge state are included for the Electrical Installation:

- The first is the stable condition of power consumption when the load has stabilized and reaches its normal operating conditions,
- The second is the transient starting condition of electric motors, which demands high power consumption to overcome inertia and bring them to their stable operating values.

3. *Sequencing of electric motor starts:* Motor starts that can be programmed and controlled by the user of the installation shall be assumed to be carried out sequentially to avoid a possible diesel power plant shut down or a significant decrease in their useful life; this criterion is applied in the calculations with a view to properly sizing the capacity of the plant and ensuring its operation at an efficient point of operation.
4. *The type of electrical motors:* within the Electrical installation, both three-phase and single-phase motors, will be taken as induction motors with NEMA code G, with a consumption value of 6 KVA / hp at the starting time.
5. *Diesel fuel consumption calculations:* these calculations will be made based on an equation formulated from workshop tests and field data, applied for both technologies electronic injection as well as mechanical injection diesel plants, and for different commercial brands. It is then assumed that this equation applies to all types of diesel power plants, without presenting appreciable variations in consumption between different technologies and different brands.
6. *Fuel savings:* the genset power group is a unit with a very low efficiency that emits a large amount of heat, which must be dissipated by means of peripheral accessories of the power plant (basically by the cooling system, and ventilation); these heat dissipating systems can be of two types, according to the design of each power plant and its surrounding cabin; namely: 1) of constant fixed action or 2) of adjustable and moderate analog action according to the thermal conditions of the group. Normally the appreciable fuel savings between the different technologies are differentiated by use of one or another heat dissipation system. On the other hand, we have not found, according to our field monitoring reports, that there are differences in diesel fuel consumption attributable to the constructive engineering of the diesel engine or its fuel injection system. For this App purposes, it assumes that the fuel consumption of diesel power plants, working in no load condition, are 10% with respect to their consumption at nominal power and are considered negligible fuelsavings, for any value of loads, with respect to the consumptions calculated here.
7. *The basic results:* It has been determined that the type of power plant to be implemented in the solution will be a power plant with 4-stroke internal

combustion engine, with synchronous generator at 50 or 60 Hz. and deliver here two main results derived of the calculations developed and correspond basically to: 1) the "Standby" power, given in kW, of the three-phase diesel power plant and 2) the power of the applicable single-phase power plant, given in kW.

8. *Environmental conditions and location of the plant at Altitude Above Sea Level (masl): it is* generally assumed that the standard environmental conditions within which the power plant must operate are as follows:
   Ambient temperature = 4°C generator minimum condition.
   10°C batteries minimum condition.
   25°C standard default.
   40°C. maximum condition.
   Altitude= 152 masl. standard default.
   Power derating is normally applied for different environmental conditions (3% for every 500m above 1000 masl and 3% for every 5 ° C above 40 ° C). These deratings will not be explicitly considered within the Powerdim application calculations.
   However, the power plant calculated here will be considered applicable up to an altitude of about 3,500 meters above sea level, which is based on the provision of additional power included in its calculations.
   Important Note: At an operational level, solutions are applied to compensate for critical environmental conditions (especially useful when the power plant remains off, in standby mode), such as the following:
   - Use power plants with turbocharged diesel engines to improve the power response of the equipment and compensate for oxygen deficiencies when raising altitude above sea level; It is presumed here that the equipment used at altitudes equal to or greater than 2,000 meters above sea level must be turbo-charged equipment.
   - To facilitate the starting of the diesel engine, elements such as engine preheaters are used; this in turn compensates to a certain degree for the occurrence of low ambient temperatures.
   - Batteries heaters are also used to compensate for low temperatures.
   - To avoid the drop in the electrical insulation level of the windings, caused by the relative humidity of the air, resistive heating plates are used located on the heads of the generator windings.
9. *Additional Prime and Continuous power results:* The Powerdim application additionally delivers the suggested values of "Prime" and "Continuous" powers in kW, which correspond to hypothetical values for which the selected "Standby" power plant would be in a position to operate to deliver electrical power under the "Prime" or "Continuous" modalities;

however,this must be properly verified with the manufacturers of each particular diesel power plant.

10. *About ISO8528-1:*
The ISO-8528-1 standard is applicable for diesel power plants, consisting of a reciprocating internal combustion engine and an alternating current generator, these operating as a unit.
This standard defines, among others, the powers "Standy", "Prime" and "Continuous" as power values that the manufacturer of the plant guarantees that it will deliver to the customer's electrical installation, for certain load values, according to the behavior of the load and the number of hours of daily work. The foregoing is limited, in some cases, to the supply of power for a specific maximum period of working hours per ***year.***
This standard does not refer to the possibility that a power plant may be rated simultaneously for use with the modalities of the Standy, "Prime" and "Continuous" powers; nor does it stablish any condition, mathematical or constructive, that allows to relate the definitions of these powers.
Itis up to manufacturers to define whether a power plant can be used for several of the applications defined in the standard, and to present its nominal power values, or to clarify whether the plant can only be used for a single specific application of those mentioned in the standard.
The requirements that the manufacturer must meet in terms of defining and guaranteeing the duration (per hours of use), or useful life cycle of the power plants, for each of the applications defined in the standard, are not established.
11. *Power Plant Feature Plate:* The manufacturer has to record on this board one, two or all three power values: "Standby", "Prime" or "Continuous"; this allows the user of the installation to make the selection of the appropriate power plant, according to their specific needs.

4. DATA OF ELECTRICAL INSTALLATIONS AND LOADS.

4.1 Installation electrical frequency = 50Hz / 60Hz.

In In this application, the frequency of electrical installations is assumed indistinctly as 50 or 60Hz, in accordance with the frequencies of public power supply systems, for alternating current. Likewise, the power value of the selected power plant applies indistinctly for any of the two frequencies that the installation may have (50Hz or 60Hz). However, for the instances of acquisition and commissioning of the power plant, the user has to clearly specify before their supplier, the value of the frequency with which their Electrical Installation operates, since the power plant must operate adjusted to said value.

4.2 Electrical installation types.

The Electrical Installation cables are called as follows:

- Live or active line cable: L.
- Neutral cable: N.

Note: the ground conductive cable (GND), the Electrical Installation grounding system and the diesel power plant grounding system aren't included in this application. This must be dealt with by the user when mounting and connecting the power plant.

The application considers three types of electrical installation, structured according to the lines or cables that feed it, as follows:

- Single-phase 2-thread l-N. (Its default assumed voltage is 110V).
- Single-phase 3 wires L-L-N. (Its default assumed voltage is 220V/110V).
- Three-phase 4 wires L-L-L-N. (Its default assumed voltage is 220V/127V).

The user must select his installation verifying that the composition of wires or Lines (L-L-… .N), selected in the application, exactly reflects the type of installation of his project.

4.3 Voltages of the installation.

In the power plant, the voltage is an adjustable parameter that typically has a range of ±10% above the face value that appears on your feature plate. This means that the power plant can be adapted to operate at the exact voltage value required by the installation. If this voltage range does not conform to the values required for installation, power transformers must be used to couple the power plant to the installation.

The user must change the voltages assigned by default in the application, for the actual operating voltages (VLN and VLL) of the Electrical Installation.

4.4 Electrical current or amperage.

The application calculates the currents that circulate through the cables of the Electrical Installation, based on:

a. The type of electrical installation.
b. The value of the power of each equipment of the load.
c. An assumed balanced distribution of loads between the lines of the installation.
d. El voltage value of the installation.
e. The use of phasor operation mathematical calculations.

CAUTION : Once the generating plant has been selected and given the fact that the electric current or amperage, generated by it, has a nominal value determined in its characteristic plate, it must be verified in practice that the current measured through the cables, which feed the Electrical Installation, does not exceed the value specified in the plate; otherwise it must acquire a power plant of greater power, in such a way that its current is equal to or greater than that demanded by the installation.

Sizing of cables: *The sizing and selection of the cables that must be connected between the diesel power plant and the electrical installation can be carried out based on the value of the nominal current of the power plant or based on the current calculated for the Electrical Installation; in any of the cases, this must be based on compliance with the technical standards and /or their exceptions.*

4.5 The power value of the electrical load equipment.

The electrical load term refers, in this application, to those devices through which electrical current circulates when connected to a voltage source; This includes equipment that converts electrical energy into other types of energy such as lights, sound, heat, cold, movement, and those that fulfill any specific function within an electrical system, although its function is not that of transforming electrical energy in other forms of energy.

Regardless of Electrical Installation type and their voltage, this application consider that **electrical power of the load equipment remains constant,** that minds, that the product Voltage x Current remains constant.

4.6 Load Groups, Group Multiplier and Utilization Factor.

Application loads are classified into five **Load Groups,** as follows:

- Group 1: Residential,
- Group 2: Events,
- Group 3: Welders,
- Group 4: Engines,
- Group 5: Other Equipment.

This classification of electrical loads within Load Groups is a way to organize the entry of application data to user facilitate installation understanding and visualization.

When a Load Group already has load equipments entered in the application and said group is repeated within a facility, this can be recorded using the **Group Multiplier** factor (this is useful, for example, in cases such as the entry of loads of several apartments in a building). On the other hand, to indicate the percentage of load that is normally on in a Load Group, the **Utilization Factor** is used. It should be noted that the load of a Group with Group Multiplier = 1, being unique in the installation, must be considered in its maximum power consumption, because when the group is operating at its maximum load, the power plant must have full capacity to sustain it in operation, which indicates that it has a Utilization Factor of 100% of the group load. However, when there is a repetitive load group in the installation (with Group Multiplier > 1), it becomes multiple load groups whose Utilization Factor may be different from 100%, because normally these load groups they do not present maximum use consumption simultaneously. In these cases, it becomes a critical success factor, in the sizing of the appropriate electrical plant, that the user applies a known or proven Utilization Factor, in accordance with pre-established tables or with the experience and knowledge of the Electrical Installation entered or other similar ones.

4.7 Load connection within the electrical installation.

In the application calculation structure, within the installation, the load equipment can be connected in one of three ways:

- Single-phase equipment that connects between a line cable and the neutral cable (L-N).
- Single-phase equipment that connects between two actives lines(L-L).
- Single-phase equipment that can be considered as ***Reconnectable;*** that is, that can be connected between a line cable and the neutral cable (L-N), or that can be connected between two lines cable (L-L).
- Three-phase equipment connecting between the three active lines (L-L-L).

Within the application five load group dialog boxes, single-phase loads are marked with equipment name, equipment power and the connection type; example: [Computer 150w L-N].
Each equipment connection, in the application, automatically is assumed according to the user selected Electrical Installation type; for example, a loading equipment that is marked with L-N / L-L connection option, will be assumed line to neutral connected if the installation is single-phase (L-N) or will be assumed as line to line connected if the selected installation the single-phase (L-L).
These considerations on the hypothetical electrical charges connection facilitates the mathematical calculations structuring and don’t significantly affect the final obtained results on the required power plant sizing.

4.8 Load Group 1- Residential and Commercial.

Led Lamp	10w	L-N	Frying pot 3 L	2100w	L-N/L-L
Wall electrical Outlet	100w	L-N	1-seat stove	1200w	L-N
Led-TV up to 50"	150w	L-N	Stove Oven	4800w	L-N/L-L
Computer	150w	L-N	Dishwasher 12 set	1500w	L-N/L-L
Printer	60w	L-N	Washing machine 0-22kg	1400w	L-N
Sound equipment	45w	L-N	Personal hot shower	4000w	L-N/L-L
Water dispenser	510w	L-N	Clothes ironer	1400w	L-N
Coffee maker-1.5 L	1000w	L-N	Freezer Horiz. showcase-312 L	434w	L-N
Microwave-23 L	1300w	L-N	Freezer Vert. showcase -425 L	520w	L-N
Table top oven-20 L	1500w	L-N	Air conditioning.(12,000 BTU)	1560w	L-N/L-L
Fridge- 500 L	600w	L-N	Air fan/extractor	270w	L-N
Blender -1 L	600w	L-N	Indoor heater(+fan)	1850w	L-N/L-L
Rice Cooker -1.8 L	500w	L-N	Outdoor heater(Without fan)	1300w	L-N

4.9 Load Group 2- Events and shows.

Luminaries	Sound Equipment	Led screens	Event inflatables
20 w L-N	---- 100w rms L-N	44" (0.5m2) 107w L -N	Blower: 1/4hp L-N
30 w L-N	---- 200w rms L-N	70"(1.35m2) 289w L-N	Blower: 1/2hp L-N
50 w L-N	---- 300w rms L-N	88" (2m2) 428w L-N	Blower: 3/4hp L-N
100 w L-N	---- 500w rms L-N	132" (4.5m2) 963w L-N	Blower: 1 hp L-N
200 w L-N	-- 1.000w rms L-N	176" (8m2) 1.712w L-N/L-L	Blower: 2 hp L-N/L-L
300 w L-N/L-L	-- 2.000w rms L-N/L-L	199"(12.5m2) 2.675w L-N/L-L	
500 w L-N/L-L	-- 3.000w rms L-N/L-L	264" (18m2) 3.852w L-N/L-L	
1.000 w L-N/L-L	-- 4.000w rms L-N/L-L	308"(24.5m2) 5.243w L-N/L-L	
2.000 w L-N/L-L	-- 5.000w rms L-N/L-L	Video projectors	
3.000 w L-N/L-L		--- (4mx7m) 310w L-N	
4.000 w L-N/L-L			

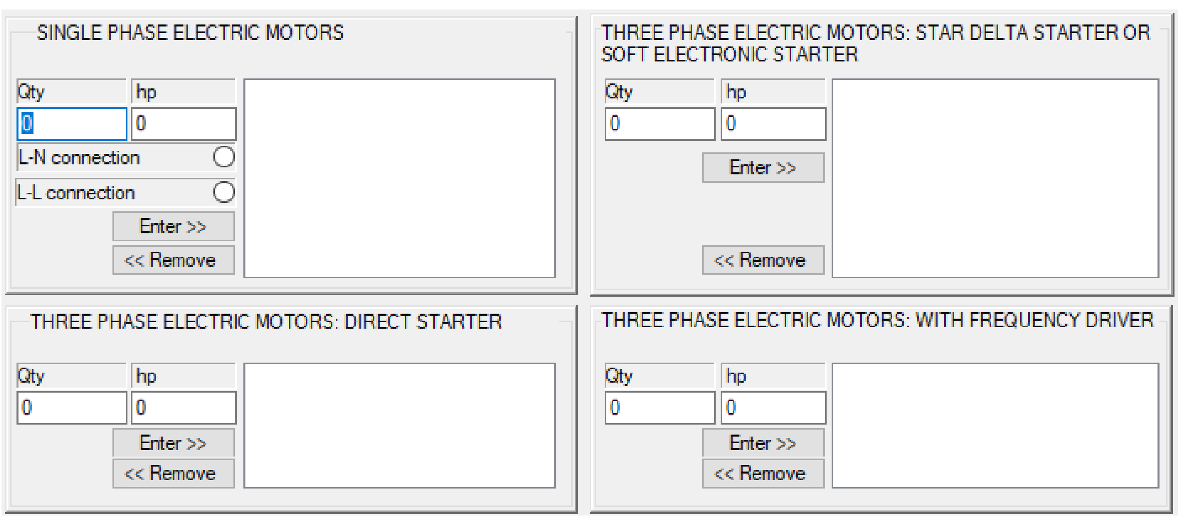
4.10 Load Group 3- Electric welders.

For this Load Group, all single-phase welders are considered as reconnectable equipment; that is, they can be Line to Neutral connected L-N or can be line to line connected L-L.

Electrode welders		MIG-type welders		TIG-type welders	
Single phase with output:	100 A	Single phase with output:	70 A	Single phase with output:	170 A
Single phase with output:	180 A	Single phase with output:	180 A	Single phase with output:	220 A
Single phase with output:	225 A	Three phase with output:	255 A	Three phase with output:	300 A
Single phase with output:	270 A	Three phase with output:	300 A	Three phase with output:	400 A
Single phase with output:	300 A	Three phase with output:	420 A		
Three phase with output:	450 A	Three phase with output:	500 A		
Three phase with output:	520 A				
Three phase with output:	600 A				

4.11 Load Group 4- Electric motors.

It has been assumed that all electric motors have a power factor equal to 0.8. and an efficiency of 85%.



Within the Load Group of electric motors, according to the number of phases and the type of start, the motors were classified as follows:

1. Single-phase motors.
2. Three-phase motors: Direct starter.
3. Three-phase motors: Star-Delta starter or soft electronic starter.

For calculation purposes, within this classification the following types of electric motors have been grouped:

- Motors with star-delta starter.
- Motors with electronic soft starter.
- Motors with auto-transformer starter.
- Wound rotor motors with resistance starter.

4. Three-phase motors: with frequency driver.

   Regarding the "Electric motors with frequency driver" it has been assumed that the power consumption of the variator-motor assembly increases by 10% due to the energy losses of the variator and the auxiliary equipment required.

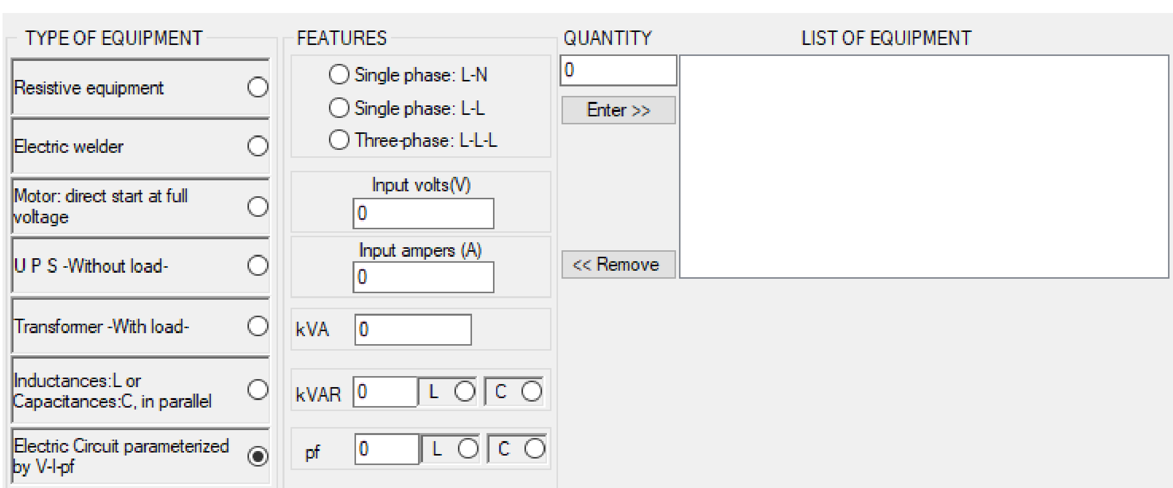
4.12 Cargo Group 5- Other Equipment.

This group corresponds to equipment that must be entered according to its plate data or by reading its electrical parameters. The following types of equipment can be entered into this Load Group:

5. Resistive equipment.
6. Electric welders.
7. Motors: direct start at full voltage.
8. UPS -Without load-.
9. Transformer -With load-.
10. Inductances L or capacitances C, in parallel.
11. Electric circuit parameterized by V, I, pf.

According to phases quantity, the above types of equipment can be registered as

- Single phase: LN.
- Single phase: LL.
- Three-phase: LLL.



***Resistive* equipment**: they are parameterized by voltage and current.
Electric welders: they are parameterized by input voltage and input current. If a welder is required to be entered by its output parameters, enter this equipment in the Load Group 3 box.
Direct start motors: they are parameterized by voltage and current.
THE UPS -without load-: they are parameterized by kVA. It has been assumed, for UPSs that their own power consumption is 10%, the above due to their energy losses. For this application, also UPS-backed equipment must be entered in the Load Groups.
Transformers-with Load-: are parameterized by kVA. The input of the transformers has been included in the application, considering them as compact equipment, composed of the transformer and its load; these are assumed as loaded at 125% and with a total power factor pf = 0.8. For each transformer, a note will appear in the Load Group 5 dialog box, asking the user to check if the transformer is powering motors with powers greater than the following:

a. Direct starter motors with hp > 12% x KVA transformer.
b. Motors with any type of start with hp > 82,42% x KVA of the transformer.

If the presence of either of these two conditions is confirmed, the user must remove the transformer from the list of equipment and its loads must be entered one by one separately within load groups 1,2,3,4,5.
Inductances and capacitances: they are parameterized by kvar.
Electric circuits: they are parameterized by voltage, current and power factor. For each Circuit entered, a note will appear in the Load Group 5 dialog box, asking the user to check if the circuit is powering motors with powers greater than the following:

a. Direct starter motors with hp > 12% x KW of the circuit.
b. Motors with any type of start with hp > 82.42% x KW of the circuit.

If the presence of any of these two conditions is confirmed, the user must remove the Circuit from the list of equipment and its loads must be entered one by one separately within the Load Groups 1,2,3,4,5.

5. ELECTRICALVARIABLES DEFINITION.

The electrical variables used for the calculations are as follows:

I_{eqp}:	An equipment or load nominal current.
V_{eqp}:	An equipment or load nominal voltage.
I_i:	Input power supply current of welder.
V_i:	Input voltage of welder.
I_{weld}:	Welder arc output current.
V_{weld}:	Welder arc output voltage.
$KW_{WeldLoss}$:	Welder losses in kW.
hp_m:	Electrical motor mechanical output power, in hp.
hp_{mg}:	The assembly largest motor power, in hp.
hp_{mt}:	All assembly electrical motors power sum, in hp.
KW_{Stm}:	Highest engine start consumed power in kW.
I_L:	Line current.
I_{LM}:	Maximum electrical installation line current.
I_N:	Electrical installation neutral cable current.
V_{LN}:	Phase voltage (Line to Neutral).
V_{LL}:	Line voltage (Line to Line).
P_R:	Residential and commercial load power in kW.
P_E:	Events and public shows' load power in kW.
P_S:	Electrical welders load power in kW.
P_M:	Electrical motors consumed power in KW.
P_O:	Other equipment load power in kW.
KW_p:	Power of diesel electrical plant, in kW.
KVA_p:	kVA of diesel electrical plant.
PF_p:	Diesel electrical plant power factor.
$KVAR_{capFM}$:	Electrical Installation's higher capacitive reactive power per line, in kvar.
$KVAR_{indFM}$:	Electrical Installation's higher inductive reactive power per line, in kvar.
$Cons_{Diesel}$:	Diesel fuel consumption in gal / h.

6. STEADY STATE LOAD POWER CONSUMPTION CALCULATIONS.

6.1 Resistive loads power consumed calculation.

If the equipment power isn't on the nameplate, the calculations are as follows.
Single-phase resistive loads PR = (V_{eqp} x I_{eqp}) / 1000
Three-phase resistive loads PR = (V_{eqp} x I_{eqp} x 1,732) / 1000.

6.2 Electrical welders power consumed Calculation.

The full load welder power factor will be considered as equal to one (pf=1).
According to data, available to application user, there are two calculation options:

- ***In the Load Group 5,*** if the voltage and supply current data of the soldering iron are known, the calculations of power consumed are as follows:
  Single-phase welders. P_S = (V_i x I_i) / 1000
  Three-phase welders. P_S = (V_i x I_i x 1,732) / 1000
- ***In the Load Group 3***, will use the welding output voltage and welding output current and will be considered losses $KW_{WeldLoss}$ = 10%, for which, the calculations are as follows:
  P_S = (I_{weld} x V_{weld} x 1,1) / 1000. Valid for single-phase and three-phase welders.

6.3 Electrical motors power consumption.

Commonly, an electrical motor output power is given in hp.
Its value in kW is determined as 1hp = 0.746Kw; however, its electrical power consumption is affected by the motor's own efficiency. Below are the power consumption calculations considered in this application for three-phase and single-phase motors.

- **Three-phase without frequency driver motors power consumption calculation:**
  Considering a three-phase motors average efficiency equal to 0,85, you have
  Three-phase motor power consumption = hp_m x (0,746 / 0,85),
  Three-phase motor power consumption = hp_m x 0,877.
- **Three-phase with frequency driver motors power consumption calculation:**
  it has been assumed that the power consumption of the inverter-motor assembly increases by 10% due to the energy losses of the inverter and the possible auxiliary equipment required. Three-phase motor consumption with frequency converter = hpm x 0,877 x 1,1.

- **Single-phase motors power consumption calculation.**
  Considering a single-phase motors average efficiency equal to 0,659, you have:
  Single-phase motor power consumption = hp_m x (0,746 / 0,659),
  Single-phase motor power consumption = hp_m x 1,132
  Therefore, the single-phase electrical motor power consumption will be considered as 29% higher than one three-phase motor of the same power.

- **Electrical motors power consumption general calculation.**
  Henceforth, for calculation purposes, the hp_m variable will be considered corrected to the value (hp_m x 1.1) in the case of motors with a frequency driver and to the value (hp_m x 1.29) in the case of single-phase motors. According to the above, the consumption calculation formula will be as follows:
  PM = hp_m x 0,877.

  Correction Factor hpm = hpm x 1,00 for three-phase motors without frequency inverter.

  Correction Factor hpm = hpm x 1,100 for three-phase motors with frequency inverter.

  Correction Factor hpm = hpm x 1,29 for single phase motors.

7. PROPOSED LOAD DISTRIBUTION AND ELECTRICAL INSTALLATION PARAMETERS CALCULATIONS.

Because the actual modeling of Electrical Installation load circuits and, many times, the survey of field data, are long processes, the Powerdim application makes and assumes an ideal distribution of loads, following these steps:

1. To calculate all entered loads power.
2. To evaluate and find the load with highest power and the least loaded lines or phases of the Electrical Installation.
3. To assign the greater power's load connection to teh less loaded line or lines of the Electrical Installation.
4. To repeat steps 2 and 3 for the remaining loads, until they all are assigned to the installation lines.

This procedure applies to both active power and reactive power (KW distribution and kvar distribution).

The Electrical Installation owner company or user must ensure that its actual load distribution is very similar to that proposed in this application; if the phase imbalance is greater, an additional power oversizing factor must be applied to the diesel power plant.

Once the load distribution is done, phasor mathematical calculations are performed to determine current and power factor for each Electrical Installation phase and total electrical parameters; these parameters are presented in the main dialog box of the Powerdim application.

Distribution of Loads in the electrical installation		
L-1	L-2	L-3
I1:	I2:	I3:
pf1:	pf2:	pf3:

Total kW =
Total pf =
Total kVA =
Total Kvar =

NOTE: The Electrical Installation parameters are calculated including those Load Groups that have their check box activated in the application main Dialog Box; If this box is deactivated for any group, even if its loads are entered in the application, that loads aren't account for carrying out the calculations or for sizing the required power plant.

8. CONDITION 1 FOR SIZING DIESEL PLANT: SUITABLE LOAD FOR GENERATOR LINES.

Taking the Electrical Installation parameters, the highest current of the lines (I_{LM}) is determined, which must be supported by the generator and, based on this parameter, the required power plant to meet this condition is calculated.

$KW_p = V_{LL} \times I_{LM} \times 1{,}000 \times PF_p$ This is the single-phase plant power (LLN) to meet condition1

$KW_p = V_{LL} \times I_{LM} \times 1{,}732 \times PF_p$ This is the three-phase plant power to meet condition1

9. CONDITION 2 FOR SIZING DIESEL PLANT: OPERATE AT A RECOMMENDED LOAD PERCENTAGE.

The power plant must be such capacity that, when connected to the electrical installation, it operates at a load value (in kW), recommended by standards and manufacturers; In this case the load value will be considered 70% to adapt to the definitions of the Standard on Standby Power. This percentage is applied on the sum of the steady state powers of the Load Groups enabled within the electrical installation.

$KWp = (P_R + P_E + P_S + P_M + P_O)/ 0.7$ This is the plant power to meet the condition2

Valid for single-phase and three-phase plant.

10. CONDITION 3 FOR SIZING DIESEL PLANT: WITHSTAND THE ELECTRIC MOTORS START.

In addition to the maximum power, in kW, consumed by the load equipment in its normal operation, the power plant must be able to withstand the greater of the electric motor starts that are present in the Installation. Next, the considerations on starting electric motors and the calculations of the electrical power required by the diesel plant to withstand such starts are stablished.

10.1 Technical criteria assumed for motors starting.

The following considerations are stablished:

- **Start-up power factor of an electrical motor**.
  The power factor of an electric motor at the time of start-up ranges from 0,2 (most severe case of direct starts) to 0,4 (case of reduced voltage starts), which means that the kVA of the required power plant ranges between 2.5 and 5 times the value of the kW required for the diesel motor of the electrical plant.
- **Maximum current that the power plant can deliver.**
  In all cases, the maximum current delivered to the load during start-up can never exceed the overload values given for the generator, i.e., the maximum sustained Standby conditions; the criterion for calculating the power plant shall be taken based on its permissible overload capacity. This overload value will be taken from 20%.
- **Type of electric motor selected for calculations.**
  The kVA consumed by an electric motor at the time of start-up in relation to its output hp are expressed by a NEMA code letter (this letter should not be confused with the one indicating the design class), and their values are indicated in the following table; in this table each code has a range that extends to the lower limit of the following code, but does not include that value. For the calculations of the appropriate generator, we will assume that the motors to be started, both three-phase and single-phase, correspond to induction motors with G-code for a consumption value of 6 KVA / at the start-up time.

Indicator code letters for locked rotor			
Letter Nominal code	KVA with braking rotor / hp	Letter Nominal code	KVA with braking rotor / hp
A	0 - 3.15	L	9.00 - 10.00
B	3.15 - 3.55	M	10.00 - 11.20
C	3.55 - 4.00	N	11.20 - 12.50
D	4.00 - 4.50	P	12.50-14.00
E	4.50 - 5.00	R	14.00-16.00
F	5.00 - 5.60	S	16.00-18.00
G	**5.60 - 6.30**	T	18.00-20.00
H	6.30 - 7.10	Or	20.00-22.40
J	7.10 - 8.00	V	22.40 on wards
K	8.00 - 9.00		

10.2 Power plant calculations for starting and powering direct starter motors.

The calculations are as follows:

$KVA_p = (6 \times hp_m) / 1{,}2$ where 1,2 is the generator overload factor.

$KVA_p = 5x\ hpm.$

$KW_p = KVA_p \times PF_p$ where FP=0.8 rated for three-phase plants.

(also will be assume FP=0.8 for single-phase plants).

$KW_p = 5 \times hp_m \times 0{,}8$

$KW_p = 4 \times hp_m.$

To put it another way, we have

$KW_p = (4{,}56 \times hp_m) \times 0{,}877$

If the load consists of several three-phase motors, the calculate is transformed into:

$KW_p = (3{,}56 \times hp_{mg} + hp_{mt}) \times 0{,}877.$ Where hpmg value is also included within the hpmt value.

In this case, the additional power required by the diesel power plant to start the direct start motor is:

$KW_{Stm} = 3.56 \times hp_{mg} \times 0.877$

10.3 Power plant calculations for starting and supply motors with reduced voltage starting.

In this application, all Y-D type starters, electronic soft starters and frequency driver starters for three-phase motors, are considered to be types of reduced voltage starting, that is, the motor starts at 58% of its nominal voltage. With this it is assumed that the starting current is also reduced to 58% of the direct starting current of the motor.

Returning to the type of three-phase motor selected (Nema code G), we have the following expression:

$KVA_p = (6 \text{ x } hp_{m)} / (1,2 \text{ x } 3)$

$KVA_p = 1,66\text{x } hp_m$

$KW_p = KVA_p \text{ x } PF_p$

$KW_p = 1,66 \text{ x } hp_m \text{ x } PF_p$

$KW_p = 1,66 \text{ x } hp_m \text{ x } 0,8$

$KW_p = 1,33 \text{ x } hp_m$ applies only to three-phase plants.

To express it in terms of the electrical consumption of the three-phase motor, we have

$KW_p = (1,52 \text{ x } hp_m) \text{ x } 0,877$ for three-phase power plants

If the load consists of several motors, the above expression is transformed into:

$KW_p = (0,52 \text{ x } hp_{mg} + hp_{mt}) \text{ x } 0,877.$ Where hpmg value is also included within the hpmt value.

In this case, the additional power required by the diesel power plant to start the motor with reduced voltage start is:

$KW_{Stm} = 0,52 \text{ x } hp_{mg} \text{ x } 0,877.$

10.4 Stablish the Condtion3 for sizing diesel plant: to have the capacity to withstand the start of electrical motors.

Once the additional power value required to start of each of the motor present in the Electrical Installation has been calculated, the highest of these values (KW_{Stm}) is stablished, as the additional power that the diesel power plant must have to meet the condition of starting motors within the installation. This value is added on the sum of the steady state powers of the Load Groups enabled within the Electrical Installation.

$KW_p = (P_R + P_E + P_S + P_M + P_O) + KW_{Stm}$ This is the single-phase plant power and three-phase to meet the condition3.

11. CONDITION 4 FOR SIZING DIESEL PLANT: ENSURE THE STABILITY OF THE GENERATED VOLTAGE.

This condition must be evaluated to prevent the electric generator from losing control over its excitation system for voltage generation and suffering some deterioration, because the capacitive loads present in the Electrical Installation. The electric generator must have sufficient power (in KVA), to ensure that the voltage generated is stable; the above must be in accordance with the capacitive reactive power required by the load. The operating area of the diesel power plant with steady state in voltage is given in the range of power factor between pf= 0,8 inductive and pf= 0,99 capacitive (see bibliography "APPLICATION MANUAL T-030", Cummins Power Generation, Pag64-65). The most critical condition with capacitive load, without losing stability in voltage occurs when for every 14.1 kvar (capacitive reactive power resulting from the installed load), the diesel power plant has 100kW of active power. In this application, the evaluation of this condition is made based on the maximum capacitive reactive kvar found in each phase or line of the installation ($KVAR_{capFM}$), calculated when making the ideal distribution of load; according to this, the calculation of the power plant required to meet this condition is as follows:

$KW_p = (KVAR_{capFM} \times 100 \times 2\ ) / 14.1$ This is the single-phase plant power (LLN) to meet condition 4.
$KW_p = (KVAR_{capFM} \times 100 \times 3\ ) / 14.1$ This is the three-phase plant power to meet the condition4.

12. CONDITION 5 FOR SIZING DIESEL PLANT: AVOID OVERHEATING OR INTERNAL DAMAGE OF THE ROTOR.

This condition must be evaluated to prevent the electric generator from presenting over excitations and overheating in the rotor winding, a condition that can occur when the load power factor is less than 0,8 (pf<0,8), which occurs due to the presence of highly inductive loads (see bibliography "APPLICATION MANUAL T-030", Cummins Power Generation, Pag64-65). To evaluate the condition that the diesel power plant must meet, without entering the overheating region of the rotor, the Powerdim application takes as a basis the maximum inductive reactive kvar found in each phase or line of the electrical installation ($KVAR_{indFM}$), calculated when making the ideal distribution of loads and applies the following table to calculate the power of the power plant, according to the value of the inductive power factor presented by the Electrical Installation.

pf Inductive	Single-phase plant calculation to meet condition 5
0<= pf < 0.1	$KW_p = (KVAR_{indFM} \times 100 \times 2) / 104{,}125$
0.1<= pf < 0.2	$KW_p = (KVAR_{indFM} \times 100 \times 2) / 102{,}500$
0.2<= pf < 0.3	$KW_p = (KVAR_{indFM} \times 100 \times 2) / 98{,}750$
0.3<= pf < 0.4	$KW_p = (KVAR_{indFM} \times 100 \times 2) / 95{,}825$
0.4<= pf < 0.5	$KW_p = (KVAR_{indFM} \times 100 \times 2) / 92{,}500$
0.5<= pf < 0.6	$KW_p = (KVAR_{indFM} \times 100 \times 2) / 88{,}750$
0.6<= pf < 0.7	$KW_p = (KVAR_{indFM} \times 100 \times 2) / 83{,}333$
0.7<= pf < 0.75	$KW_p = (KVAR_{indFM} \times 100 \times 2) / 80{,}000$
0.75<= pf < 0.78	$KW_p = (KVAR_{indFM} \times 100 \times 2) / 77{,}500$
0.78<= pf < 0.8	$KW_p = (KVAR_{indFM} \times 100 \times 2) / 76{,}250$

pf Inductive	Three-phase plant calculation to meet condition 5
0<= pf < 0.1	$KW_p = (KVAR_{indFM} \times 100 \times 3) / 104{,}125$
0.1<= pf < 0.2	$KW_p = (KVAR_{indFM} \times 100 \times 3) / 102{,}500$
0.2<= pf < 0.3	$KW_p = (KVAR_{indFM} \times 100 \times 3) / 98{,}750$
0.3<= pf < 0.4	$KW_p = (KVAR_{indFM} \times 100 \times 3) / 95{,}825$
0.4<= pf < 0.5	$KW_p = (KVAR_{indFM} \times 100 \times 3) / 92{,}500$
0.5<= pf < 0.6	$KW_p = (KVAR_{indFM} \times 100 \times 3) / 88{,}750$
0.6<= pf < 0.7	$KW_p = (KVAR_{indFM} \times 100 \times 3) / 83{,}333$
0.7<= pf < 0.75	$KW_p = (KVAR_{indFM} \times 100 \times 3) / 80{,}000$
0.75<= pf < 0.78	$KW_p = (KVAR_{indFM} \times 100 \times 3) / 77{,}500$
0.78<= pf < 0.8	$KW_p = (KVAR_{indFM} \times 100 \times 3) / 76{,}250$

13. DELIVERY OF RESULTS.

13.1 Dimension of the three-phase power plant.

Once the five technical conditions that the three-phase power plant must meet have been calculated, the dimension of the selected diesel power plant will be the one that corresponds to the highest power value in kW and that consequently will allow it meets the five technical conditions simultaneously. The results are as follows:

Selected plant power KW_{psel}= The highest among the following values:

- KW_p Condition 1 (Load suitable for generator lines).
- KW_p Condition 2 (Operate at a percentage load recommended by standards)
- KW_p Condition 3 (Support starting electric motors).
- KW_p Condition 4 (Ensure the stability of the generated voltage).

- KW_p Condition 5 (Avoid overheating and internal rotor damage).

Standby Power = KW_{psel} x 1,0

V_{LL} *nominal* *three-phase power plant* = V_{LN} (V of the installation) x 2.
Valid If the installation is single-phase L-N.

V_{LL} *nominal* *three-phase power plant* = VLL (V of the installation).
Valid if the installation is single-phase L-L or Three-phase.

V_{LN} *nominal* *three-phase power plant* = nominal VLL / 1,732.

Nominal power factor pf *three-phase power plant* = 0.8 Value per factory design.

I_L *nominal calculated* *three-phase power plant* = KW_{psel} x 1000 / (V_{LL} x 1,732 x 0,8).

The voltage data of the diesel power plant is obtained directly from the type of installation that the user has selected for the Study Case.

Power Prime = KW_{psel} x 0,9.
Continuous Power = KW_{psel} x 0,7.

13.2 Dimension of the single-phase power plant.

If the Electrical Installation is three-phase, the use of a single-phase power plant does not apply; otherwise, once the five technical conditions to be met by the single-phase power plant have been calculated, the dimension of the selected diesel power plant will be the one that corresponds to the highest power value in kW and that consequently will allow it to meet the five technical conditions simultaneously. The results are as follows:

Selected plant power KW_{psel} = The highest among the following values:

- KW_p Condition 1 (Load suitable for generator lines).
- KW_p Condition 2 (Operate at a percentage load recommended by standards)
- KW_p Condition 3 (Support starting electric motors).
- KW_p Condition 4 (Ensure the stability of the generated voltage).
- KW_p Condition 5 (Avoid overheating and internal rotor damage).

V_{LL} *nominal* *single-phase power plant* = V_{LN} x 2 (V of the installation).
If the installation is single-phase L-N.

V_{LL} *nominal* *single-phase power plant* = VLL (V of the installation)
If the installation is single-phase L-L.

V_{LN} nominal $_{\text{single-phase power plant}}$ = nominal VLL / 2,0.

Power plant rated pf $_{\text{single-phase power plant}}$ = 1,0 Value per factory design.

I_L nominal calculated $_{\text{single-phase power plant}}$ = KW_{psel} x 1000 / V_{LL}.

Voltage data is obtained directly from the type of installation that the user has selected for the Study Case.

14. SUGGESTIONS FOR CALCULATION OF ELECTRICAL CABLES.

In the main dialog box of the application, the user can simultaneously observe the values of Electrical Installation currents and the diesel power plant nominal currents. Based on these values, technical standards and their exceptions should be applied to support the calculation of the electrical conductors to be installed and connected between the diesel power plant and the Electrical Installation.

15. DIESEL FUEL CONSUMPTION CALCULATION.

To calculate the diesel fuel consumption of a power plant with an internal 4-stroke combustion engine, the formula determined experimentally by Motoplantas Bristol will be used, as follows:

$Cons_{Diesel}$ = { [(9 x %Load) + 100] / 1000 } x [KW_p / 14]. Value In gal / h.

Where the units are gallons / hour; 1gal = 3,785 L.

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