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INFORME TÉCNICO

Código de Documento: P014434-2-GE-INF-00003

Cliente: **Prime Energía Spa**

Proyecto: **Determinación de Mínimos Técnicos – Central Pajonales**

Asunto: **Informe de Mínimo Técnico – Central Pajonales**

Comentarios: Revisado conforme a "Observaciones al Informe de Mínimo Técnico de la Central Pajonales", documento código: CEN-GO-DCO-MT-Pajonales V1. Actualizado con datos operacionales.

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1	01/12/2020	Revisión Final	Diego Larraín	Ismael Rodríguez	Eduardo Andrzejewski	Eduardo Andrzejewski
0	11/02/2020	Revisión Coordinador	Ismael Rodríguez	Ismael Rodríguez	Eduardo Andrzejewski	Eduardo Andrzejewski
B	22/11/2019	Revisión Cliente	Ismael Rodríguez	Ismael Rodríguez	Eduardo Andrzejewski	Eduardo Andrzejewski
A	12/11/2019	Revisión Interna	Ismael Rodríguez	Ismael Rodríguez	Eduardo Andrzejewski	Eduardo Andrzejewski
REV.	**DD/MM/AAAA**	**ESTATUS**	**ESCRITO**	**VERIFICADO**	**APROBADO**	**VALIDADO**

TABLA DE CONTENIDO

RESUMEN EJECUTIVO

La central Pajonales está ubicada en la comuna de Vallenar, Provincia del Huasco, región de Atacama. La central se compone de 4 naves, o casas de fuerza, que contienen 14 grupos electrógenos diésel cada una, totalizando una capacidad instalada de 100 MW. La central tiene como punto de conexión al SI la S/E Pajonales.

Conforme a la resolución dispuesta por la CNE, las empresas generadoras deberán determinar e informar al Coordinador Eléctrico Nacional, el Mínimo Técnico de sus unidades generadoras en conformidad a las disposiciones del Anexo Técnico "Determinación de Mínimos Técnicos en Unidades Generadoras" de la Norma Técnica de Seguridad y Calidad de Servicio (NTSyCS) – Resolución exenta N°375.

En este contexto, se ha determinado para las 56 unidades generadoras diésel idénticas, el siguiente valor de Mínimo Técnico:

- **Mínimo Técnico de 468 kW_e por unidad generadora**, cuyo valor está fundamentado bajos las recomendaciones del fabricante de las unidades generadoras y los registros operacionales obtenidos en sitio y en las pruebas FAT.

1. OBJETIVO

El presente informe tiene como objetivo determinar, informar y respaldar los valores de Mínimo Técnico de las unidades generadoras de la Central Pajonales, conforme a las disposiciones establecidas en el Anexo Técnico “Determinación de Mínimos Técnicos en Unidades Generadoras” de la NTSyCS.

2. DEFINICIONES Y ABREVIACIONES

Definiciones

Mínimo Técnico	Se entenderá por Mínimo Técnico la potencia activa bruta mínima con la cual una unidad puede operar en forma permanente, segura y estable inyectando energía al SI en forma continua.
Unidad	Unidad Generadora (Motor de combustión Interna acoplado a su respectivo generador eléctrico)

Tabla 1. Definiciones

Abreviaciones

CNE	Comisión Nacional de Energía
CEN	Consumo Especifico Neto
MT	Mínimo Técnico
PMAX	Potencia Máxima
FP	Factor de Potencia
NTSyCS	Norma Técnica de Seguridad y Calidad de Servicio
S/E	Subestación Eléctrica
SI	Sistema Interconectado
N-1,2,3...	Nave 1,2,3…N
U_N	Unidad N
FAT	Factory Acceptance Test

Tabla 2. Abreviaciones

3. DOCUMENTOS Y NORMAS APLICADAS

Los documentos aplicables para la determinación de Mínimos Técnicos en Unidades Generadoras son los siguientes:

1.	Anexo Técnico: Determinación de Mínimos Técnicos en Unidades Generadoras
2.	Recomendaciones del Fabricante MTU: Grupo Electrógeno Diésel MTU 16V DS2500
3.	Registros Operacionales: Pruebas FAT efectuadas a unidades generadoras MTU 16V DS2500, y registros operacionales de la central con fecha 26/11/2020.
4.	ISO 8528-1: Reciprocating internal combustion engine driven alternating current generating sets -- part 1: application, ratings and performance

Tabla 3. Documentos de Referencia

4. DESCRIPCIÓN DE LA CENTRAL

La central Pajonales, propiedad de Prime Energía Spa, se compone de 56 grupos electrógenos diésel idénticos divididos en 4 naves. En la Tabla 4 se indican los parámetros principales de cada unidad generadora:

Central Pajonales	**Información**	**Referencia**
Modelo Grupo Electrógeno	MTU 16V DS2500	Hoja de datos Motor-Generador
Modelo Motor	16V4000G24F – 4 Ciclos	Hoja de datos Motor-Generador
Potencia Nominal Prime	1.872 kW	Hoja de datos Motor-Generador
Consumo Especifico *Prime Power*	223 [g/kWh]	Hoja de datos Motor-Generador
Velocidad Nominal	1.500 [rpm]	Hoja de datos Motor-Generador
Modelo Generador	LSA 52.3 L12-4 50 [Hz]	Hoja de datos Motor-Generador
Factor de Potencia Nominal	0,8	Hoja de datos Motor-Generador

Tabla 4. Información principal grupos electrógenos.

Nave	Unidades	Marca – Modelo	Potencia Neta Conjunta [MW]
N-1	U_1 - U_{14}	MTU 16V DS2500	25
N-2	U_{15} – U_{28}		25
N-3	U_{29} – U_{42}		25
N-4	U_{43} – U_{56}		25

Tabla 5. Distribución y Potencia Conjunta Grupos Electrógenos

Todos los motores de la central utilizar combustible Diésel y se encuentran configurados para operar en modo *Prime Power*[1] (ver Anexo A), cuya definición se presenta a continuación:

13.3.2 Prime Power (PRP)

Prime power is defined as being the maximum power which a generating set is capable of delivering continuously whilst supplying a variable electrical load when operated for an unlimited number of hours per year under the agreed operating conditions with the maintenance intervals and procedures being carried out as prescribed by the manufacturer (see Figure 2).

The permissible average power output (P_{pp}) over 24 h of operation shall not exceed 70 % of the PRP unless otherwise agreed by the RIC engine manufacturer.

Figura 1. Definición Potencia Prime, Norma ISO 8528

En los Anexos A y B se incluye documentación técnica de la central y sus unidades generadoras.

Puntos de Medición

Los puntos de medición de potencia neta, bruta y de servicios auxiliares se indican en los diagramas unilineales de la central adjuntos en Anexos D y E.

5. MÍNIMO TÉCNICO

Se requiere determinar y respaldar el Mínimo Técnico de las unidades generadoras de la central Pajonales. En los siguientes capítulos se indican y desarrollan las justificativas basadas de acuerdo con los siguientes criterios:

- Recomendaciones del fabricante de las unidades generadoras
- Registros operacionales de las unidades generadoras
- Referencias nacionales de unidades similares

[1] Aplicable para suministros de energía de carga variable por una cantidad ilimitada de horas, acorde a la norma ISO 8528. Se permite una sobrecarga del 10% según normas ISO3046, AS2789, DIN6271 Y BS5514.

5.1. Recomendaciones de Fabricantes

5.1.1. Fabricante de las Unidades Generadoras - MTU

El fabricante de los grupos electrógenos diésel recomienda operar la unidad a cargas mecánicas mayores o iguales 480 kW_m (recomendación adjunta en Anexo C) la cual corresponde a una potencia eléctrica de 457 kW_e (considerando la eficiencia de 95,2% del generador eléctrico).

La operación del motor a un valor menor al indicado anteriormente lleva a una disminución de la temperatura en el motor y por tanto a un modo de operación inadecuado para su operación en el largo plazo.

De manera adicional, se indica que el motor operando a bajas cargas puede mostrar el fenómeno denominado como ""Wet Stacking" (ducto de escape húmedo). A continuación de muestra un extracto de la carta enviada por el fabricante MTU:

Continuous Engine operation at loads between 115 kWm and 480 kWm should be avoided:
The Cylinder Cutout function is inactive at loads higher than approx. 115 kWm, the engine operates then in full engine mode. This leads to a temperature decrease in the engine and therefore to an inappropriate operation mode for long time operation. At loads higher than 480 kWm, the load is sufficient to ensure an acceptable level of engine temperature.

Please take in account that the engine will show "Wet Stacking". This means that at low load, oil traces may appear on the outside of the engine caused by oil accumulation in the exhaust pipe. These oil leakages will have no effect on reliability, load acceptance, maintenance schedule or any other technical data of the engine. For further information please refer to our White Paper "Information about Wet Stacking on Diesel Engines".

Figura 2. Extracto de carta de recomendación para operación a bajas cargas.

Mayor detalle del fenómeno mencionado anteriormente puede ser visto en la infografía del proveedor *Clifford Power* (ver Anexo C).

5.1.2. Recomendaciones de otros Fabricantes

NFPA

La Asociación Nacional de Protección contra el Fuego (NFPA por sus siglas en inglés), advierte en su estándar número 110, de generadores de emergencia y standby, sobre el fenómeno "*Wet Stacking*". Esto se previene operando el motor con cargas sobre el 30% de la potencia nominal.

Aurora Generators

El fabricante de motores Aurora indica en su artículo "*What Happens To Engines Running Without Sufficient Loads*" (ver Anexo C) diversos problemas y riesgos asociados a la operación de motores diésel en bajas cargas.

Caterpillar

El fabricante de motores Caterpillar indica en su artículo "*The Impact Of Generator Set Underloading*" (ver Anexo C) los riesgos de operar motores diésel en cargas inferiores al 30% de su potencia nominal. Principalmente señala el riesgo acumulación de depósitos y humedecimiento del ducto de escape.

Cummins

El fabricante de motores Cummins también recomienda en sus manuales de operación una carga mínima del 30% para evitar la acumulación de depósitos de carbón producidos por la combustión incompleta del combustible; y reducir el riesgo de dilución de combustible en el aceite de lubricación del motor.

Precaución: *Evitar funcionamientos sin carga que no sean por periodos cortos. Se recomienda una carga mínima del 30%. Esta carga ayudará a evitar la acumulación de depósitos de carbón en los inyectores, a causa del combustible sin quemar, y reduce el riesgo de dilución en combustible del aceite de lubricación del motor. El motor debe pararse lo antes posible después de que se hayan comprobado las funciones adecuadas.*

Figura 3.Carga mínima del 30% (Manual de operación Cummins)

Además, se advierte respecto a la temperatura del refrigerante, que al descender alrededor de los 60°C promueve estos efectos indeseados:

Precaución: *Si la temperatura del refrigerante del motor baja demasiado, 60° C (140° F), el combustible crudo por la combustión incompleta lavará el aceite de lubricación de las paredes del cilindro y diluirá el aceite del cárter. En estas condiciones, no todas las piezas móviles del motor recibirán la cantidad correcta de lubricación.*

Figura 4. Precaución de operación con baja temperatura de refrigerante (60°C; Manual de operación Cummins)

5.2. Antecedentes Operacionales

La central Pajonales dispone de los registros operacionales de una unidad generadora en los cuales se puede apreciar el Mínimo Técnico y Potencia Máxima conforme a lo declarado en las pruebas FAT (ver Anexo G).

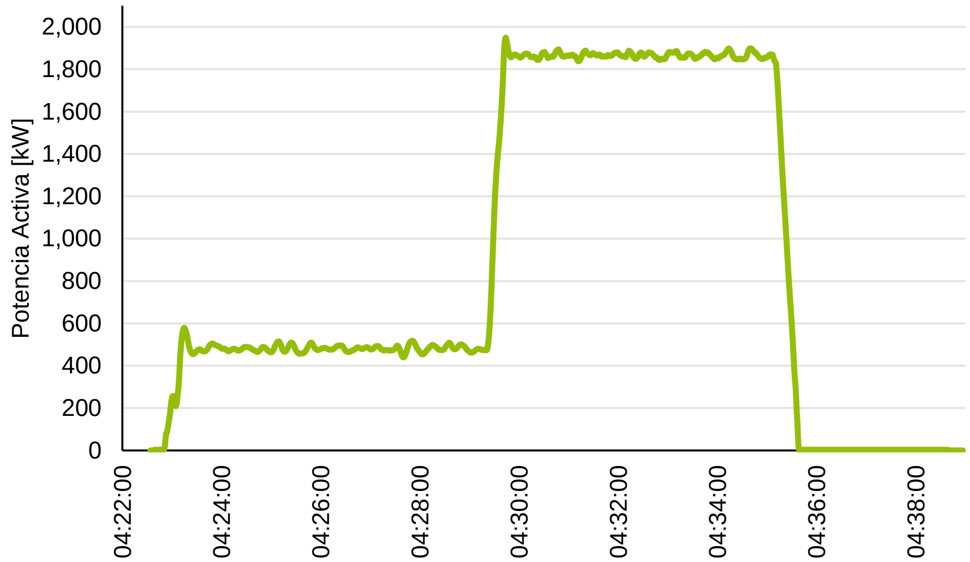


Figura 5. Registro de datos operacionales con fecha 26-11-2020.

De acuerdo con la Figura 5, el grupo electrógeno presenta una operación estable en ambos niveles de carga.

5.3. Fuentes de Inestabilidad

No se tienen registros de alarmas que representen fuentes de inestabilidad en la operación de los grupos electrógenos a bajas cargas.

5.4. Restricciones Ambientales u Operacionales

La Central Pajonales no está sujeta a restricciones ambientales u operacionales que pudiesen influir en la determinación del Mínimo Técnico de sus unidades.

5.5. Antecedentes Nacionales

Como referencia, se han recogido valores de Mínimos Técnicos de unidades con características similares que operan a nivel nacional (ver Tabla 6).

Central	Potencia Nominal [kW]	Mínimo Técnico [kW]	Mínimo Técnico [% P_{nom}]	Fabricante
Degan 1– U_1 – U_{22}	1.637	490	30%	MTU
Degan 2– U_{23} – U_{28}	1.600	480	30%	Cummins
Genpac– U_1 – U_{60}	1.600	480	30%	FG Wilson
Quellón II– U_1 - U_{10}	1.800	540	30%	Cummins
Quintay– U_1 y U_2	1.200	360	30%	Cummins
Placilla– U_1 y U_2	1.200	360	30%	Cummins
El Totoral– U_1 y U_2	1.200	360	30%	Cummins
Las Vegas– U_1 y U_2	1.050	360	30%	Cummins
La Portada– U_1-U_3-U_6	1.000	250	25%	Cummins
Chiloé– U_1 – U_9	1.200	600	50%	Caterpillar
Maule– U_3 – U_5	750	375	50%	Caterpillar

Tabla 6. Mínimos Técnicos de unidades similares características a nivel nacional

6. CONCLUSIONES

Expuestos los antecedentes del Capítulo 5 del presente informe, es posible determinar y respaldar el valor de Mínimo Técnico de las unidades generadoras de la central Pajonales.

Conforme a la sección 5.1.1, el fabricante de los grupos electrógenos MTU, recomienda operar las unidades a una potencia mecánica igual o mayor al 24,4% de carga.

Luego, en la sección 5.2, se presentan datos operacionales que respaldan la información entregada en las pruebas FAT, donde la potencia mínima declarada es de 468 kW_e (25% carga)

En vista de las justificativas anteriores, se ha determinado como Mínimo Técnico de las unidades generadoras, un valor de **468 kW_e**, el cual es aplicable a los 56 grupos electrógenos idénticos de la central.

7. ANEXOS

ANEXO A – INFORMACIÓN TÉCNICA DE LAS UNIDADES

ANEXO B – INFORMACIÓN TÉCNICA DEL GENERADOR

ANEXO C – RECOMENDACIONES DE FABRICANTES

ANEXO D – DIAGRAMA UNILINEAL ELÉCTRICO DE LA CENTRAL

ANEXO E – DIAGRAMA UNILINEAL ELÉCTRICO DE LA SUBESTACIÓN

ANEXO F – LAYOUT CENTRAL GENERADORA

ANEXO G – REGISTROS DE PRUEBAS FAT

ANEXO A – INFORMACIÓN TÉCNICA DE LAS UNIDADES

4 Datos técnicos

4.1 DG16V4000A2E (3G, optimizado en emisiones de gas de escape según NEA paraORDE)

Datos de potencia del grupo electrógeno

Potencia con aire de aspiración de 34 °C y altura de empleo de 100 m sobre el nivel del mar.

Generador modelo: Leroy Somer LSA 52.3 L12 / 4p	
Tensión (V)	415
Frecuencia (Hz)	50
Potencia (kWel)	1872
Potencia (kVA)*	2340
Intensidad (A)	3255
*cos phi = 0,8	

Datos del motor

Todos los datos se refieren al motor y se basan en las condiciones estándar ISO con un aire de aspiración de 25 °C y una altura de empleo de 100 m sobre el nivel del mar.

Motor		
Fabricante		MTU
Tipo		16V4000G24F
Ciclo de trabajo		Cuatro tiempos
Número de cilindros		16
Disposición de los cilindros: ángulo en V	°	90
Cilindrada unitaria	l	4,77
Cilindrada total	l	76,3
Orificio	mm	170
Carrera	mm	210
Relación de compresión		16,4
Revoluciones nominales	rpm	1500
Potencia mecánica máx.	kW_m	1965

Sistema de combustible		
Altura máx. de aspiración de combustible	m	5
Caudal de admisión máx. de combustible	l/min	20

Consumo de combustible**	l/h	g/kWh
Al 100 % de potencia	471,1	199
Al 75 % de potencia	358,7	202
Al 50 % de potencia	247,4	209
**valores conforme a ISO 3046-1. Para la conversión se ha asumido una densidad de combustible de 0,83 g/ml. El consumo de combustible se refiere a la potencia nominal del motor.		

TIM-ID: 0000083999 - 001

Volumen de llenado / contenido		
Total aceite de motor	l	300
Líquido refrigerante del motor en el lado del motor	l	175
Líquido refrigerante del aire de sobrealimentación en el lado del motor	l	50

Sistema de aire de sobrealimentación		
Caudal volumétrico del aire de combustión	m^3/s	2,5
Depresión máx. de aspiración	mbares	50

Sistema de refrigeración		
Caudal volumétrico del líquido refrigerante del motor	m^3/h	68,5
Caudal volumétrico del líquido refrigerante del aire de sobrealimentación	m^3/h	30
Calor evacuado por el líquido refrigerante del motor	kW	660
Calor evacuado del aire de sobrealimentación	kW	430
Calor de radiación y por convección del motor	kW	90

Sistema de escape		
Temperatura del gas de escape (después del turbosobrealimentador)	°C	480
Caudal volumétrico del gas de escape	m^3/s	6,6
Sobrepresión máx. del gas de escape	mbares	85
Sobrepresión mín. del gas de escape	mbares	30

Emisión de sonido (grupo de aplicación 3G)		
Ruidos en la superficie del grupo, nivel sonoro, al 75 % de carga y 1 m de distancia (tolerancia +2 dB(A))	dB(A)	99
Ruidos en la superficie del grupo, nivel de intensidad sonora, a 75 % de carga (tolerancia +2 dB(A))	dB(A)	122

Dimensiones y pesos

Grupo electrógeno	
Peso (seco)	Véase el plano de montaje MTUA-001076-00-MEC-PM-0001-xx
Longitud	
Anchura	
Altura	

TIM-ID: 0000083999 - 001

3.2 Grupo electrógeno

3.2.1 Grupo electrógeno – Grupo de aplicación 3G

El grupo electrógeno está formado por un motor diesel montado con un generador en un mismo bastidor. El motor arranca y acciona el generador para producir energía eléctrica sobre demanda.

Grupos electrógenos para el suministro eléctrico continuo

Grupo de aplicación 3G – Servicio continuo, duración limitada, ICXN (Grid Stability Power)

Para compensar las puntas de carga se utiliza el grupo electrógeno paralelamente a una red eléctrica. En el servicio de corta duración con carga constante se utilizan los grupos electrógenos transitoriamente. Se utilizan en los campos de aplicación siguientes:

- Estabilización de la red pública (compensación de puntas de carga) cuando se alimentan energías (solar, eólica) renovables
- En programas de red tales como STOR y Emergency Capacity Program

Servicio continuo	Grupo de aplicación 3G
Modo de servicio	Servicio continuo, duración limitada
Base de cálculo	10 % sobrecargable (ICXN)
Factor de carga	< 100 %
Horas de servicio	1000 h, de ellas 500 h con el 100 % de carga sin interrupción

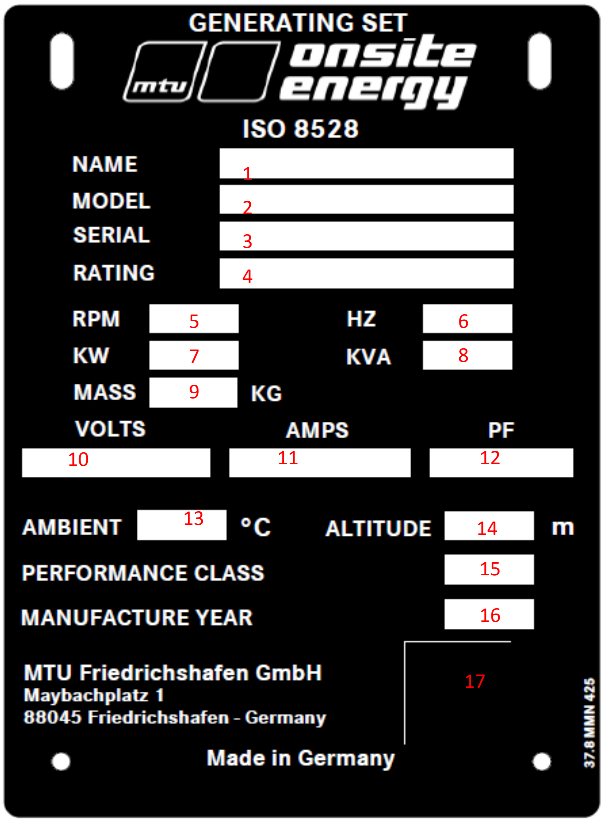
Ventajas

- Amplia gama de grupos electrógenos estandarizados para responder a las necesidades del cliente en cuanto a potencia, emisiones y otras prestaciones
- Posibilidad de selección entre diversos componentes (p. ej. filtro previo de combustible) y opciones (p. ej. refrigerador de combustible)
- La tecnología más moderna de motores diesel
- Los componentes principales más innovadores para un mayor rendimiento y una larga vida útil

TIM-ID: 0000083986 - 001

QUICKSTART CHILE GENSET NAME PLATE DRAWING

FIELD	DESCRIPTION	DATA
1	NAME	MTU 16V4000 DS2500
2	MODEL	DG16V4000A2E
3	SERIAL	0
4	RATING	3G_LTP
5	RPM	1500
6	HZ	50 Hz
7	KW	1872
8	KVA	2340
9	MASS KG	14.000
10	VOLTS	415
11	AMPS	3255
12	PF	0,8
13	AMBIENT °C	40°C
14	ALTITUDE m	
15	PERFORMANCE CLASS	G3
16	MANUFACTURE YEAR	00.01.1900
17	CE-Patch	-



ANEXO B – INFORMACIÓN TÉCNICA DEL GENERADOR

Nidec
All for dreams

LEROY-SOMER™ | 1

ALTERNATOR TECHNICAL DESCRIPTION 1
LSA 52.3 L12 / 4p

LS Reference: MB448-12-2017-1 1

Date: 07.12.2017

V4.06a - 11/2017

Project Manager : mb 1

Leroy Somer Marbaise GmbH
Electric Power Generation
Eschborner Landstrasse 166 - 60489 Frankfurt am Main

Mario.BRANDSTAETTER@mail.nidec.com
+49 (0) 69 780708-28
MB

Main data M 1

Generator type:	**LSA 52.3 L12 / 4p**				1
Power:	2 394	kVA	1 915 kWe	1 987 kWm	1
Voltage:	415	V	Star serial		1
Rated voltage range:	+5/-5%				1
Power factor - Lagging:	0,8				1
Frequency:	50	Hz			1
Speed:	1500	rpm			1
Nominal current:	3 331	A			1
Winding type:	p2/3				1
Classes (Insulation / Temperature Rise):	H / F				1
Ambient Temperature:	40	°C			1
Altitude:	1000	m			1

-

Installation 1

Client:	MTU Friedrichshafen GmbH	CRM	1
Project:	Chile		1
Site:	Chile		1
Prime mover:	Reciprocating engine		1
Manufacturer:	MTU		1
Type:	16V 4000		1
Duty:	Base Rating		1
Industry:	Construction		1

-

Mechanical Construction **IM1201** 1

Type of construction:	Single bearing	1
Mounting arrangement:	Horizontal Axis	1
Direction of rotation:	Clockwise (seen when facing the drive end - DE)	1
Bearing type:	Anti-friction	1
Bearing Lubrication:	Regreasable	1
Bearing insulation:	Not insulated	1
Flector type:	SAE 21	1
Balancing - Class (ISO 1940/1):	Without key - G2,5 (std)	1
Flange:	SAE 00	1
Shaft height:	500 mm	1
Width:	750 mm	1

-

Additional specificities 1

Stabilized Runaway speed:	2250 rpm - 2 min.	1

Nidec — All for dreams

LEROY-SOMER 1

ALTERNATOR TECHNICAL DESCRIPTION 1
LSA 52.3 L12 / 4p

LS Reference: MB448-12-2017-1 1

-

Cooling Method — IC01 1

Degree of protection:	IP23	1
Coolant:	Air / Temperature: 40 °C	1
Air quality:	Clean	1
Ventilation (internal):	Self-ventilated	1
Filters:	Without	1
Ducting for air inlet:	No	1
Ducting for air outlet:	No	1

-

Connection, Excitation & Regulation 1

Parallel operation:	With mains (3F)	1
Excitation:	Self-excited - Brushless - Type: PMG	1
Sustained 3-phase Isc:	> 3 x FLC for 10s.	1
AVR type:	D510C - Digital	1
AVR location:	In terminal box	1
Alternator Voltage sensing:	In terminal box	1
Additional features:		
	Three-phase sensing	1
	Diode failure detector	1

-

Terminal box

Power connection:	4 connectors (brought out neutral)	1
Main Terminal box location:	On Top	1
Line side outlet:	Right hand side (seen when facing the drive end - D)	1
Gland plate:	Standard - Cable gland plate not drilled	1

-

Protection and measurement accessories 1

1

Temperature detection 1

Stator windings:	6 x 3-wire Pt100 RTDs	1
Guide bearing - NDE:	1 x 3-wire Pt100 RTD	1

1

Anti-condensation heating 1

Voltage: 230 V - 1Ph / Power: 500 W 1

-

Transformers (Client use)

LS Supply 1

Set of 3 x CTs (measuring and/or protection):			I Primary / I Secondary / Power / Class	
Preliminary	Neutral side	S1	4000 / 1A / 10VA / Cl. 0,5 FS5	1
		S2	4000 / 1A / 10VA / Cl. 5P10	1

1

-

Various items — 171206YV03_B

Paint:	C3M-P - Polyurethane - RAL acc. to MTU request	1
Documentation:	PDF manual	1
Documentation Language:	English	1

-

Controls

QUAL/INES/006 001	Measurement of winding resistance	1
QUAL/INES/006 021	Insulation check on sensors (when fitted)	1
QUAL/INES/006 002	Voltage balance and phase order check	1
QUAL/INES/006 007	Overspeed test (according to test bench limitation)	1
QUAL/INES/006 009	High potential test	1
QUAL/INES/006 010	Insulation resistance measurement	1

-

ALTERNATOR ELECTRICAL DATA
LSA 52.3 L12 / 4P

LS Reference: MB448-12-2017-1

Date: 07.12.2017 | V4.06a - 11/2017

Main data: M

Power:	**2 394**	kVA	**1 915** kWe	**1 987**	kWm	1
Voltage:	**415**	V	Frequency:	**50**	Hz	1
Rated voltage range:	+5% / -5%		Speed:	1500	rpm	1
Power factor - Lagging:	0,8					1
Nominal current:	3 331	A	Phases	3		
Insulation / Temperature rise:	H / F		Connexion	Star serial		1
Cooling:	**IC01**		Winding type:	p2/3		1
			Winding:	- 6 Wires		1
Ambient Temperature:	40	°C				1
Altitude:	1000	m	Overspeed (rpm)	2250		1
Duty: Base Rating			Total Harmonic Distortion (THD) < 5%			1

Efficiency (Base 1915,2 kWe) IEC

	25%	50%	75%	**100%**	110%	
Power factor - Lagging: 0,8	94,6	96,3	96,5	**96,4**	96,3	1
Power factor - Lagging: 1	95,2	97,0	97,4	**97,4**	97,4	1

Reactances (%) - (Base 2394 kVA)

	Direct axis	*Unsaturated*	*Saturated*	Quadrature axis	*Unsaturated*	*Saturated*	
Synchronous reactance	Xd	271	189	Xq	138	96	1
Transient reactance	X'd	24,3	20,7	X'q	138	96	1
Subtransient reactance	X"d	11,9	10,1	X"q	12,3	10,5	1
Negative sequence reactance	X2	12,1	10,3				

X0	2,4	Zero sequence reactance	1
Xl	6,0	Stator leakage reactance	
Xr	19,7	Rotor leakage reactance	
Kc	**0,53**	Short-circuit ratio	1

Time constants (s)

	Direct axis		Quadrature axis		
Open circuit transient time constant	T'do	2,79	T'qo	NA	1
Short-circuit transient time constant	T'd	0,250	T'q	NA	1
Open circuit subtransient time constant	T"do	0,027	T"qo	0,131	1
Subtransient time constant	T"d	0,013	T"q	0,012	1

Ta	0,028	Armature time constant	1

Resistances (%)

Ra	1,4	Armature resistance	R0	0,8	Zero sequence resistance	1
X/R	7,4	X/R ratio (without unit)	R2	2,4	Negative sequence resistance	

Voltage accuracy: 0,25%
Maximum inrush current for a voltage dip of 15%: 1932 kVA
when starting an AC motor having a starting power factor between 0 and 0.4

According to: I.E.C. 60034.1 - 60034.2 - NEMA MG 1-32

ALTERNATOR MAIN CURVES
LSA 52.3 L12 / 4P

LS Reference: MB448-12-2017-1

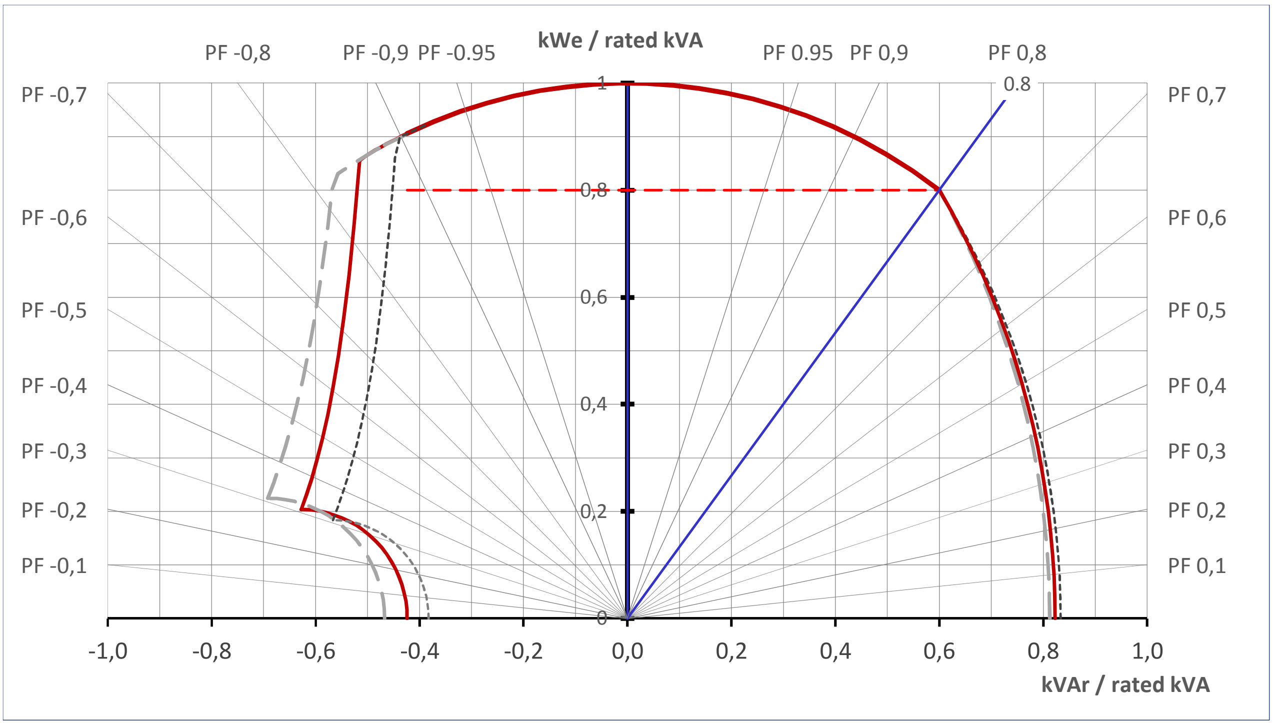
Date: 07.12.2017

2394kVA - 415V - 50 Hz

V4.06a - 11/2017

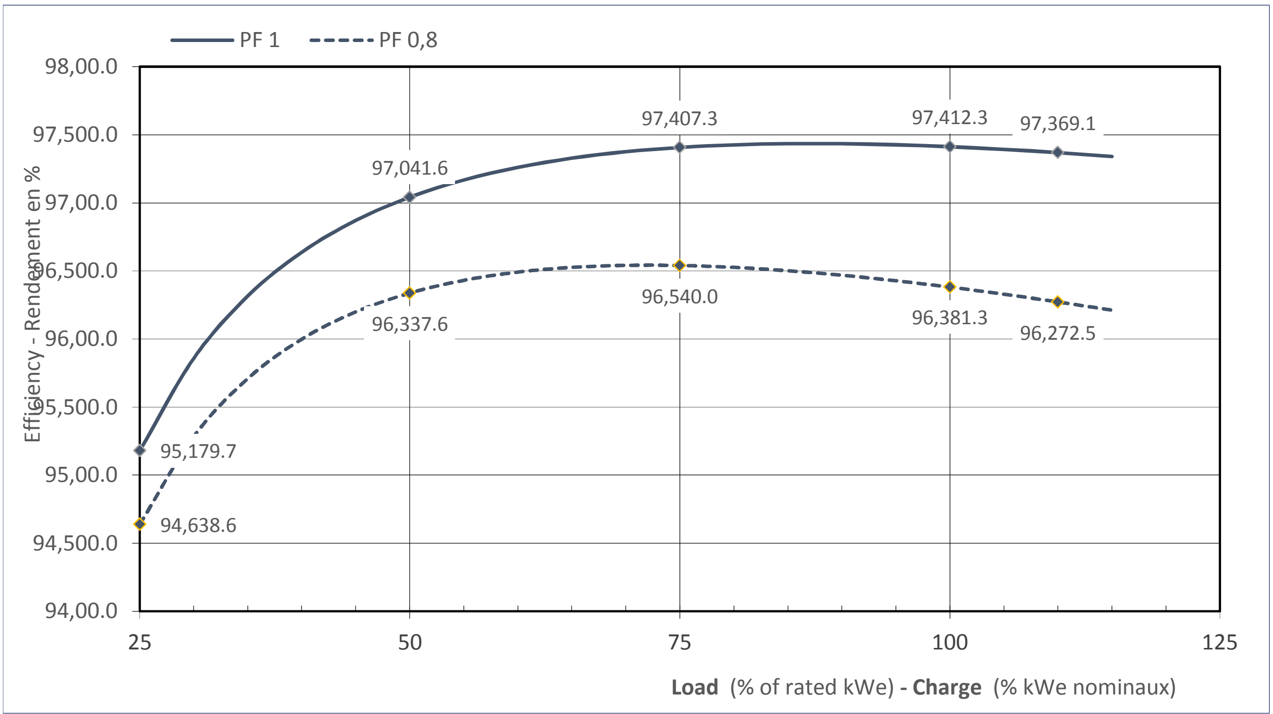
Capability Curve

— —	Umax	+ 5%	436	V
——	Un		**415**	V
- - - - -	Umin	- 5%	394	V



Efficiency Curves

According to: IEC

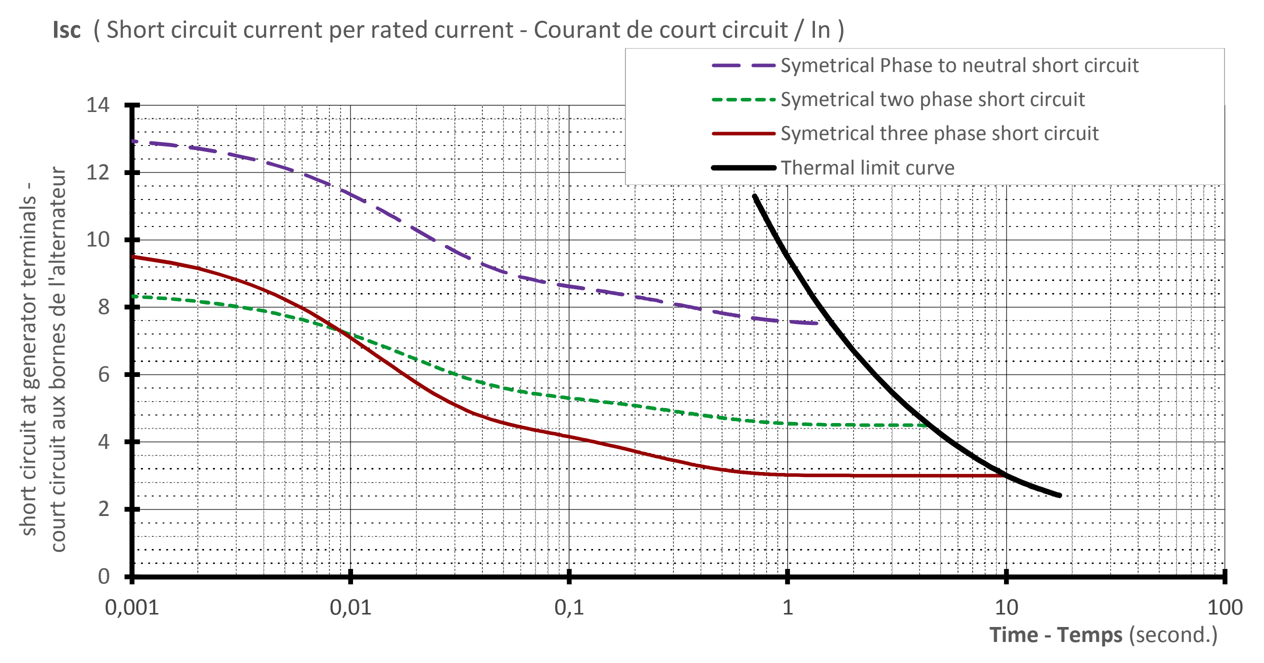


ALTERNATOR MAIN CURVES
LSA 52.3 L12 / 4P

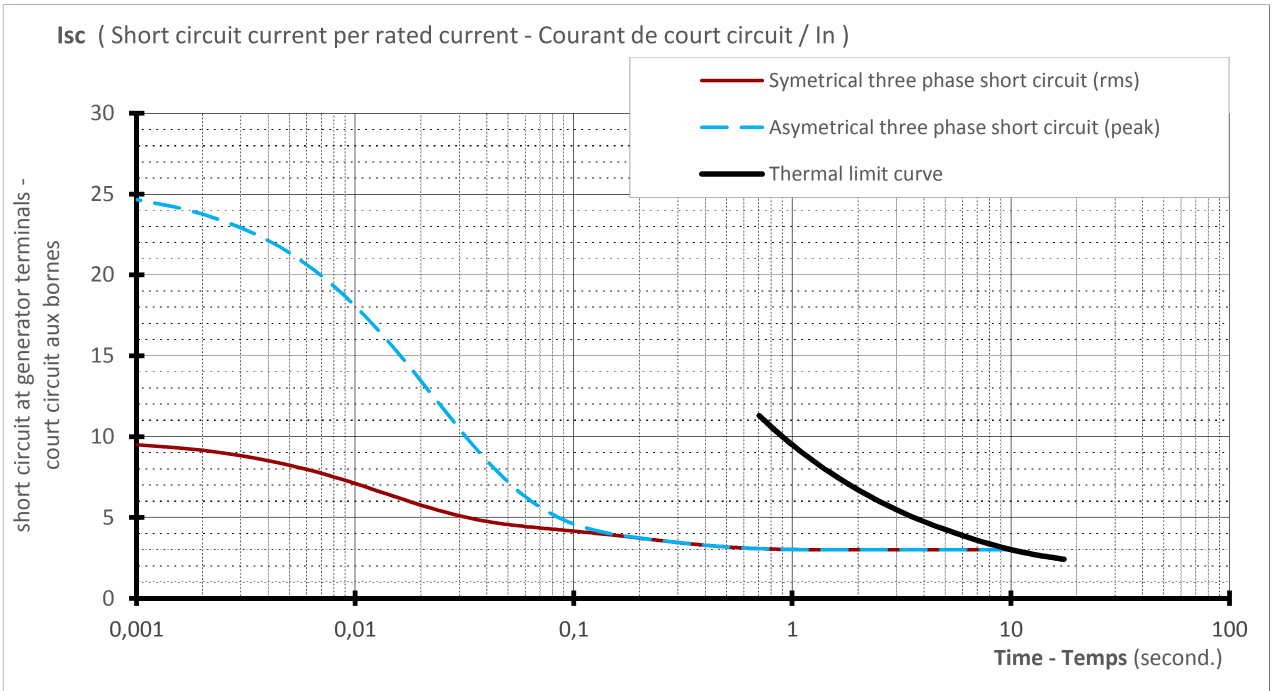
LS Reference: MB448-12-2017-1

Stator Current decrement curves

Symmetrical phase to neutral short-circ	initial max value	43 071	A	12,9 x In	
Symmetrical two phase short-circuit		27 735	A	8,3 x In	In = **3331** A
Symmetrical three phase short-circuit		31 658	A	9,5 x In	
Thermal Limit					



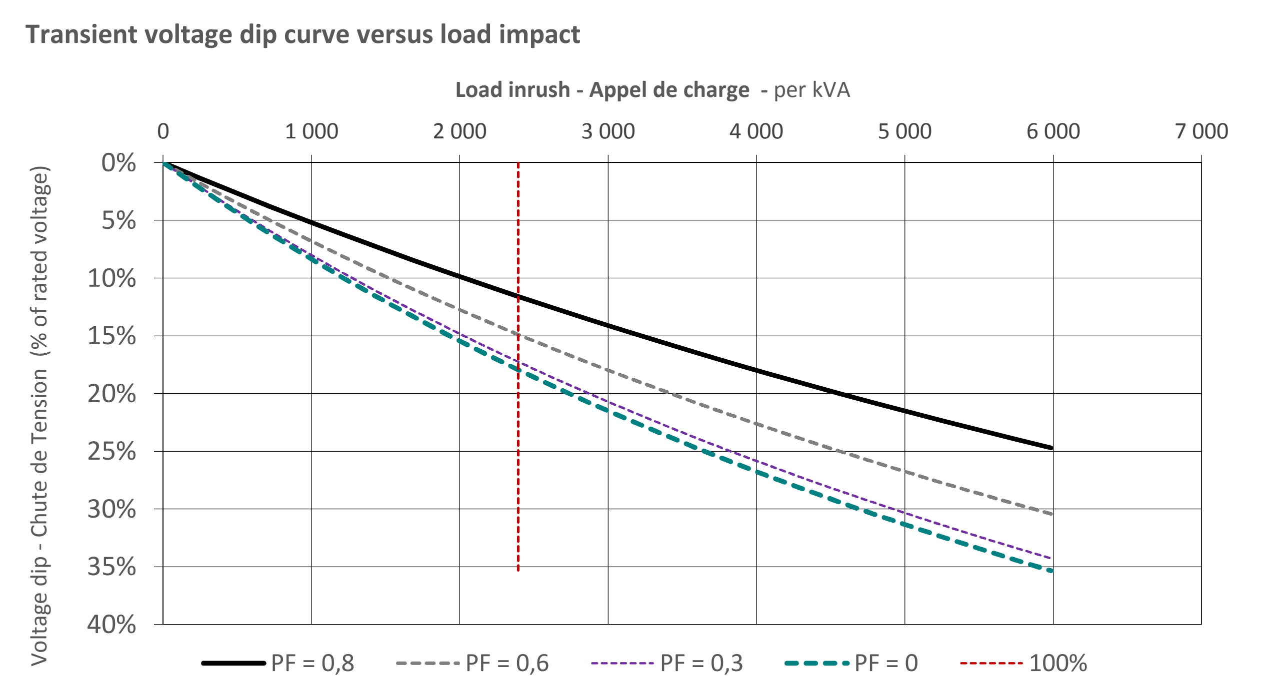
Asymmetrical three phase short-circuit	IP	81 525	A	24,5 x In

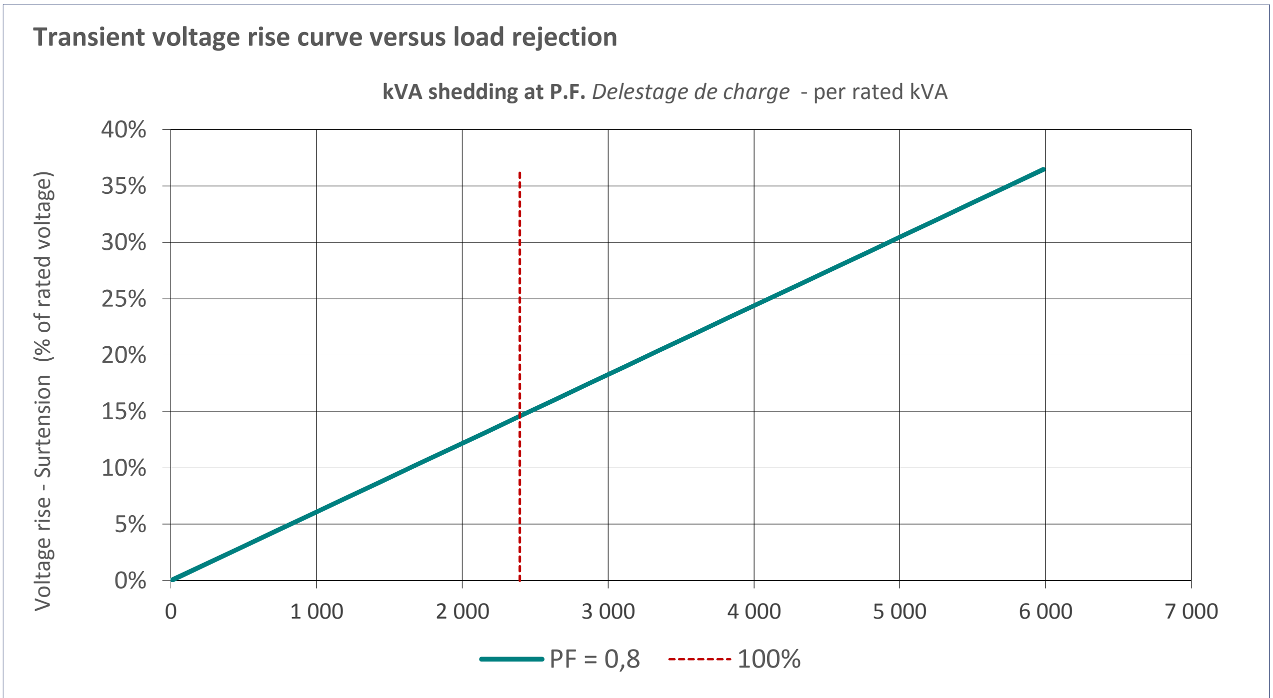


ALTERNATOR MAIN CURVES
LSA 52.3 L12 / 4P

LS Reference: MB448-12-2017-1

Transient Voltage Variation

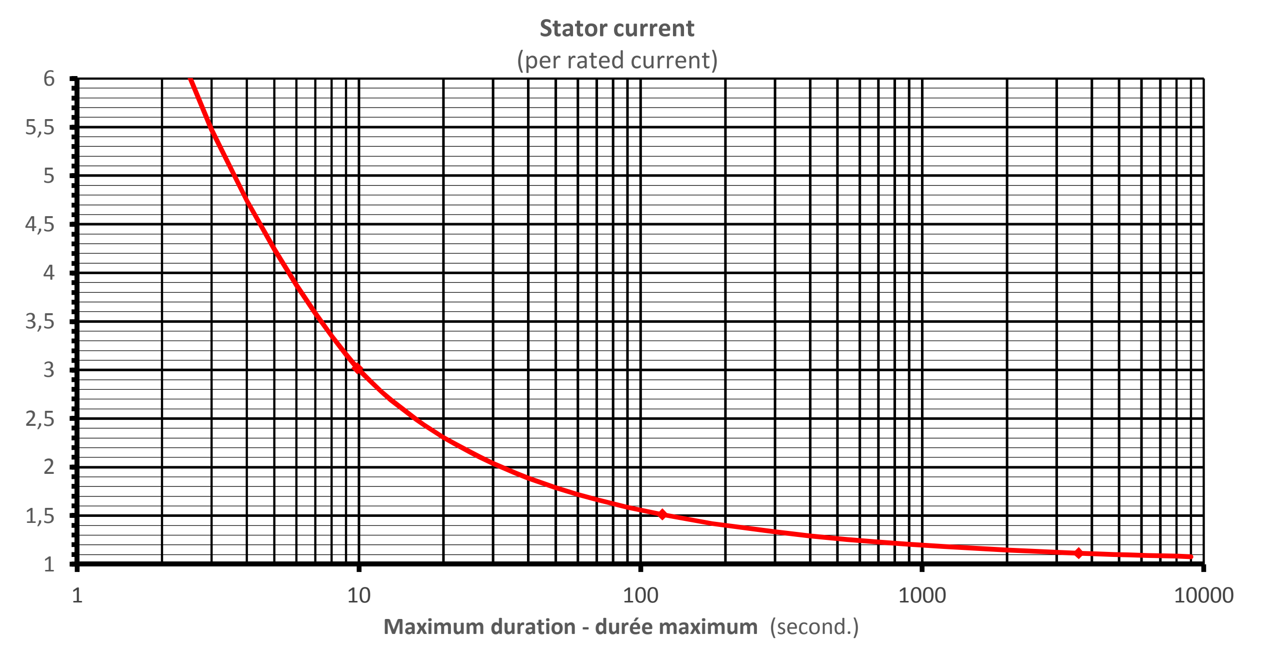




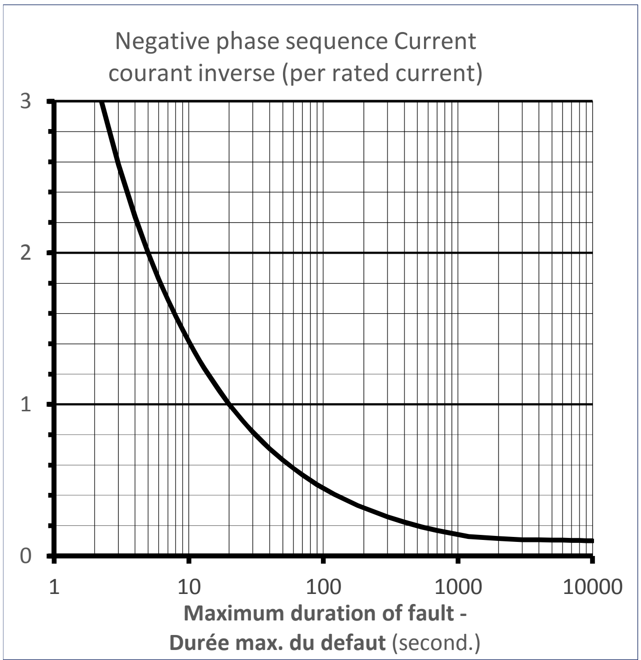
ALTERNATOR MAIN CURVES
LSA 52.3 L12 / 4P

LS Reference: MB448-12-2017-1

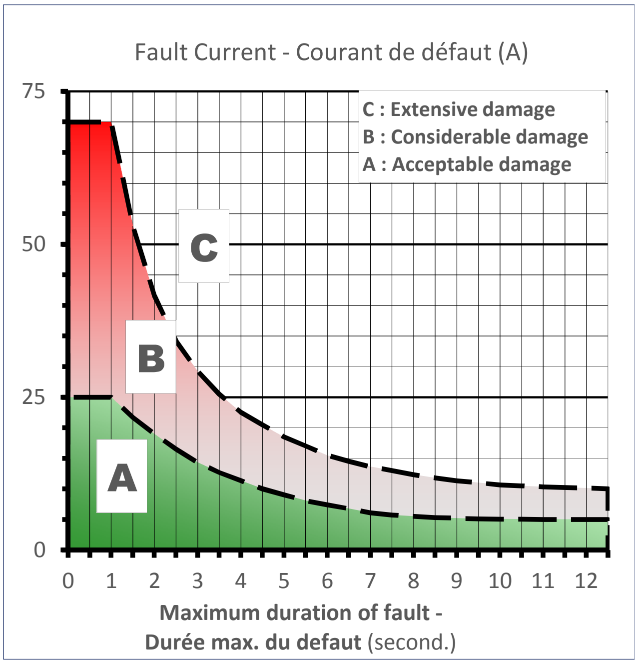
Thermal Damage Curve



Unbalance Load Curve



Stator Earth Fault Current



ANEXO C – RECOMENDACIONES DE FABRICANTES

To	To whom it may concern	Sender	MTU Friedrichshafen GmbH Maybachplatz 1 88045 Friedrichshafen Germany
Date	08.06.2018		

Subject: Quickstart 475 MW Project Chile

Dear Sirs,

For your Project Quickstart 475 MW Chile you asked about the Low Load operation capability for an

- Engine type 16V4000G24F
- Emission optimization NEA
- Application Group "Grid Stability" 3B

For this specific project only, we can provide the following approval:

Step	Period [h]	Load
1	≤12	70 kWm* – 115 kW m*
2	≥1	≥1370 kW m*

*all given loads refer to kW mechanical engine power output at 1500 rpm

Number of cycles: unlimited

Continuous Engine operation at loads between 115 kWm and 480 kWm should be avoided:
The Cylinder Cutout function is inactive at loads higher than approx. 115 kWm, the engine operates then in full engine mode. This leads to a temperature decrease in the engine and therefore to an inappropriate operation mode for long time operation. At loads higher than 480 kWm, the load is sufficient to ensure an acceptable level of engine temperature.

Please take in account that the engine will show "Wet Stacking". This means that at low load, oil traces may appear on the outside of the engine caused by oil accumulation in the exhaust pipe. These oil leakages will have no effect on reliability, load acceptance, maintenance schedule or any other technical data of the engine. For further information please refer to our White Paper "Information about Wet Stacking on Diesel Engines".

Digital signature, original version can be seen
at MTU / Dept. EDF

MTU Friedrichshafen GmbH
i.A. Robert Welz

CLIFFORD POWER

The power of dependability™

Information Sheet # 09

Your Reliable Guide for Power Solutions

Wet Stacking of Generator Sets and How to Avoid It

1.0 Introduction

Most standby generator systems up to five megawatts use the reciprocating internal combustion engine as the power source to drive the generator that produces the electrical power. The engines of choice are either diesel, natural gas or LPG fueled. A large percentage of standby power systems use the diesel engine. Diesel is a convenient independent fuel source and the compression ignition systems of diesel engines have a much higher thermal efficiency than the spark ignition system used by gas engines. However, one factor to be considered when selecting a diesel power source is the potential for “wet stacking.”

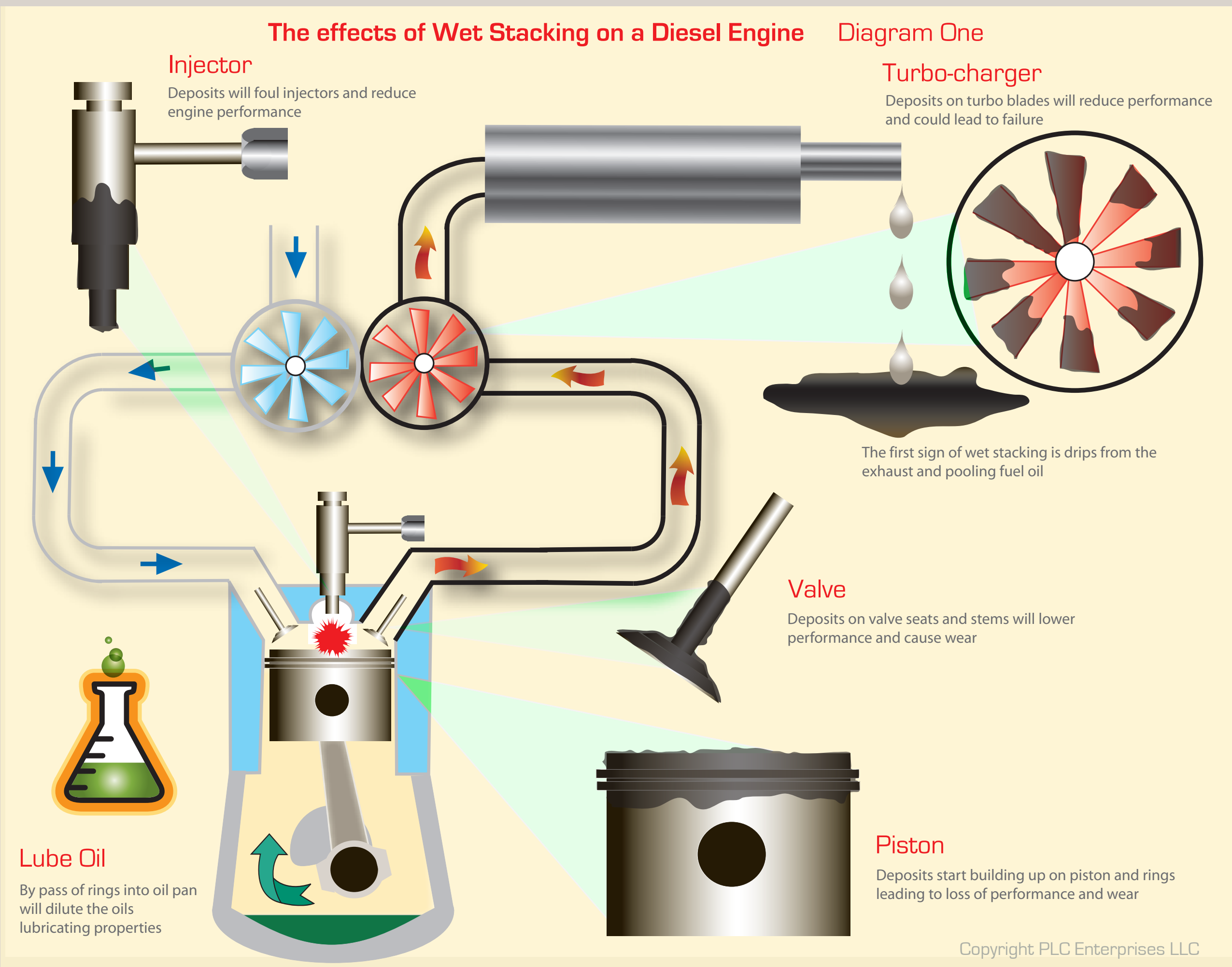
The National Fire Protection Agency (NFPA), in their NFPA 110 Code for Emergency and Standby Power Systems section 6 - 4.2 (1996 edition) refer to wet stacking as a field term indicating the presence of unburned fuel or carbon in the exhaust system. The later 1999 edition suggests a more quantitative method for determining the presence of wet stacking by measuring the exhaust gas temperature, explained later in this information sheet.

This information sheet discusses the causes of wet stacking, its effect on the engine, why it should be avoided and methods for eliminating the condition.

The designer of a generator system must take into account the potential for wet stacking when determining equipment for the system, load calculations and maintenance and service programs. The system designer should consider the following.

2.0 Causes of Wet Stacking:

Like all internal combustion engines, to operate at maximum efficiency a diesel engine has to have exactly the right air-to-fuel ratio and be able to sustain its designed operational temperature for a complete burn of fuel. When a diesel engine is operated on light loads, it will not attain its correct operating temperature. When the diesel engine runs below its designed operating temperature for extended periods, unburned fuel is exhausted and noticed as wetness in the exhaust system, hence the phrase wet stacking. (Continued over)



To fulfill our commitment to be the leading supplier and preferred service provider in the Power Generation Industry, the Clifford Power Systems, Inc. team maintains up-to-date technology and information standards on Power Industry changes, regulations and trends. As a service, our **Information Sheets** are circulated on a regular basis, to existing and potential Power Customers to maintain awareness of changes and developments in engineering standards, electrical codes, and technology impacting the Power Generation Industry.

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817.640.5544

Longview
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White Oak, TX 75693
903.291.8305

San Antonio
5803 Rocky Point
San Antonio, TX 78249
210.333.0377

3.0 Engine Effect

When unburned fuel is exhausted out of the combustion chamber, it starts to build up in the exhaust side of the engine, resulting in fouled injectors and a buildup of carbon on the exhaust valves, turbo charger and exhaust.

Excessive deposits can result in a loss of engine performance as gases bypass valve seatings, exhaust buildup produces back pressure, and deposits on the turbo blades reduces turbo efficiency.

Permanent damage will not be incurred over short periods, but over longer periods, deposits will scar and erode key engine surfaces. (Diagram One) Also, when engines run below the designed operational temperature, the piston rings do not expand sufficiently to adequately seal the space between the pistons and the cylinder walls. This results in unburned fuel and gases escaping into the oil pan and diluting the lubricating properties of the oil, leading to premature engine wear.

3.0 Why To Avoid Wet Stacking

In addition to the adverse engine effect, the designer and user of a system have to consider:

- Expense - Excessive wet stacking will shorten engine life by many years and before planned replacement.
- Pollution - Many urban areas restrict the level of smoke emissions wet stacking produces.
- Power - Even before an engine is damaged, deposits will reduce maximum power. A prematurely worn engine will have a lower maximum power than it was designed to develop.
- Maintenance - An engine experiencing wet stacking will require considerable more maintenance than an engine that is adequately loaded.

4.0 NFPA Guidelines

Wet stacking is a recognized condition with organizations that write codes for standby generator set systems, such as the National Fire Protection Association (NFPA) which has issued several guide lines for controlling the effects.

The NFPA guidelines in Level 1 and 2 applications require exercising the unit at least monthly for 30 minutes under either of two methods:

1. Under operating temperature conditions and not less than 30 percent of the EPS name plate kW rating, or
2. Loading to maintain the minimum exhaust gas temperature as recommended by the manufacturer. (See NFPA 8.4.2.) Exhaust gas temperature specifications are available from the manufacturer of the unit.

5.0 Additional Conditions

The Joint Commission on Accreditation of Health Care Organizations (JCAHO), the organization that accredits health care institutions, has taken this testing to a level beyond the NFPA. They require testing of 12 times per year with testing intervals between 20-40 days. Testing generators for at least 30 minutes under a dynamic load of 30% or greater of the name plate rating.

Systems that do not meet the 30% load capacity have three options.

1. Increase the load to meet or exceed 30% of the name plate rating,
2. Maintain the minimum exhaust temperature as recommended by the engine manufacturer, or
3. Undertake load bank testing for a total of 2 hours continuous loading as follows: a) Load at 25% of name plate for 30 minutes b) 50% for 30 minutes c) 75% for 60 minutes.

JCAHO also recommends that all automatic transfer switches (ATS) are tested 12 times per year at 20 and 40 day intervals. The provider of the power system through planned maintenance programs can undertake load testing when testing the ATS.

6.0 Solutions to wet stacking:

The obvious solution is to always run the generator set with an electrical load that reaches the designed operational temperature of the diesel, or approximately 75% of full load. Built-up fuel deposits and carbon can be removed by running the diesel engine at the required operational temperature for several hours if wet stacking has not yet reached the level where carbon buildup can only be removed by a major engine overhaul. The following load bank solutions should prevent a reoccurrence of wet stacking.

Automatic auxiliary loading:

When the generator set is the only source of power and the connected load for periods is very light a auxiliary load bank. The auxiliary automatically switches on when it detects the facility load is too low to adequately load the generator. When the facility load increases the load bank will switch off.

Facility manual load bank:

Operated as described for the automatic load bank, but a manually operated system for use with light loads and when the larger load is also manually initiated. The load bank can also be used for load testing a system primarily used for standby power.

Portable load bank: The distributor for the diesel generator set is often the best qualified to undertake the maintenance of the system. Today it is very common for the owner of a standby generator system to outsource complete maintenance of the system and have a planned maintenance (PM) contract with a full service generator-set supplier.

During a regularly scheduled planned maintenance call, the distributor will bring in a portable load bank to run the generator at a load that maintains the designed operational temperature. Portable load banks range from a few 10kW thru 2MW units mounted on large trailers as pictured.

5.0 Note regarding - Joint Commission of Accreditation for Hospital Organizations (JCAHO)

We feel it of interest to note that many hospitals are now being accredited by the Joint Commission. This organization addresses emergency management of hospitals (such as occurs with loss of utility power, water, etc). They provide standards covering: provisioning of care, treatment and services, patients rights and responsibilities in hospitals, and this includes a reliable EPSS in most cases. There has to be a written emergency plan in place with clearly defined responsibilities and assignation of adequate staff, including multiple back-up personnel.

All such persons must be trained and their attendance should be taken into account by the EPSS supplier when arranging such courses. The EPSS maintenance requirements must conform to NFPA 110 for testing purposes, but in addition, calls for monthly testing of generator and automatic transfer switches.

More details can be found on JCAHO web site:

www.jointcommission.org

Typical Portable Load Bank

WHAT HAPPENS TO ENGINES RUNNING WITHOUT SUFFICIENT LOADS

Posted by **Aurora Generators** on **May 19, 2016**

Diesel engines can suffer damage as a result of misapplication or misuse - namely **internal glazing and carbon buildup**. This is a common problem in generator sets caused by failure to follow application and operating guidelines - ideally diesel engines should run at least around 60-75% of their maximum rated load. Short periods of low load running are permissible providing the set is brought up to full load, or close to full load on a regular basis. Internal glazing and carbon buildup is due to prolonged periods of running at low speeds and/or **low loads**. Such conditions may occur when an engine is left idling in a 'standby' generator unit, ready to run up when needed, (misuse); if the engine powering the set is over powered (misapplication) for the load applied to it, causing the diesel unit to be under loaded, or as is very often the case, when sets are started and run off load as a test (misuse). Running an engine under low loads causes lower cylinder pressures and consequent poor piston ring sealing since this relies on the gas pressure to force them against the oil film on the bores to form the seal. Low cylinder pressures cause poor combustion and resultant lower combustion pressures and temperatures.

This poor combustion leads to soot formation and unburned fuel residues which clogs and gums piston rings. This causes a further drop in sealing efficiency and exacerbates the initial low pressure. Glazing occurs when hot combustion gases blow past the now poorly sealing piston rings, causing the lubricating oil on the cylinder walls to 'flash burn', creating an enamel-like glaze, which smooth's the bore and removes the effect of the intricate pattern of honing marks machined into the bore surface. Which are there to hold oil and return it to the crankcase via the scraper ring.

Hard carbon also forms from poor combustion and this is highly abrasive and scrapes the honing marks on the bores leading to bore polishing, which then leads to increased oil consumption (blue smoking) and yet further loss of pressure, since the oil film trapped in the honing marks is intended to maintain the piston seal and pressures. Un-burnt fuel leaks past the piston rings and contaminates the lubricating oil. Poor combustion causes the injectors to become clogged with soot, causing further deterioration in combustion and black smoking.

The problem is increased further the formation of acids in the engine oil caused by condensed water and combustion by-products which would normally boil off at higher temperatures. This acidic buildup in the lubricating oil causes slow but ultimately damaging wear to bearing surfaces.

This cycle of degradation means that the engine soon becomes irreversibly damaged and may not start at all and will no longer be able to reach full power when required. Under loaded running inevitably causes not only white smoke from unburnt fuel but over time is joined by the blue smoke of burnt lubricating oil leaking past the damaged piston rings and the black smoke caused by the damaged injectors. This pollution is unacceptable to the authorities and any neighbors.

Once glazing or carbon buildup has occurred, it can only be cured by stripping down the engine and re-boring the cylinder bores, machining new honing marks and stripping, cleaning and de-coking combustion chambers, fuel injector nozzles and valves. If detected in the early stages, running an engine at maximum load to raise the internal pressures and temperatures, allows the piston rings to scrape glaze off the bores and allow carbon buildup to be burnt off. However, if glazing has progressed to the stage where the piston rings have seized into their grooves, this will not have any effect.

The situation can be prevented by carefully selecting the generator set in accordance with manufacturers printed guidelines.

For emergency only sets, which are islands, the emergency load is often only about 1/4 of the sets standby rating, this apparent oversize being necessitated to be able to meet starting loads and minimizing starting voltage drop. Hence, the available load is not usually enough for load testing and again engine damage will result if this is used as the weekly or monthly load test. This situation can be dealt with by hiring in a load bank for regular testing or, installing a permanent load bank. Both these options cost money in terms of engine wear and fuel use but are better than the alternative of under loading the engine.

THE IMPACT OF GENERATOR SET UNDERLOADING

Brian Jabeck
Market Development and Design Engineer Consultant
Electric Power Division

October 2014

CATERPILLAR®

INTRODUCTION

System health and reliability are critical to backup and prime power solutions for every facility, from mission critical data centers to neighborhood grocery stores. A generator set is a key piece of the power system, and proper operation and maintenance are essential to long-term system reliability that ensures availability and uptime.

While power systems vary in operation, application and load profile depending on the purpose and complexity, all power systems are designed with common goals: providing reliable power and maximizing system efficiency. To achieve these design goals, it is important to understand system operation, load profile and schemes, and required maintenance. This paper will focus on the operation of generator sets in low-load scenarios and what can result if they are used outside of these parameters.

GENERATOR SET RATED LOADS

First, it is important to understand that generator sets are designed to run and, to be specific, they are designed to run with load. This may seem trivial, but loading a generator set properly is essential to availability, healthy engine operation and long engine life.

The ideal operation targets of each generator set will depend on the application and rating. Generally speaking, standby- and prime-rated diesel generator sets are designed to operate between 50 and 85 percent of the full nameplate, while continuous-rated diesel generator sets are optimized between 70 and 100 percent load. Natural gas and biogas generator sets, independent of application and rating, are designed for operation between 70 and 100 percent of the nameplate rating.

Manufacturer service intervals and projected component life are based on operation in these ranges to deliver an ideal mix of product performance, power density and long-term operational life. This makes the design phase critical to ensure that the power generation system is sized to operate within the manufacturer's recommended load levels while meeting the facility requirements. Misapplying generator sets by underloading them for extended runs will impact product health, operation and uptime while increasing the opportunity for unplanned events and shutdowns.

DIESEL GENERATOR SETS

Operating a diesel generator set at load levels less than 30 percent of rated output for extended time periods impacts the unit negatively. The most prevalent consequence is engine exhaust slobber, which is also known as exhaust manifold slobber or wet stacking. Engine slobber is a black, oily liquid that can leak from exhaust manifold joints due to extended low- or no-load scenarios. Running at high idle with little or no load reduces the heat in the cylinder, allowing unburned fuel and oil deposits to leak through the exhaust slip joints.

Visible slobber does not necessarily indicate a problem with an engine, but it signals possible underloading concerns, low ambient temperatures or low jacket water temperature. In most circumstances, engine slobber alone, while unsightly, will not immediately harm an engine. However, slobber is a sign of underloading and could be an indication of other underloading effects. Long periods of light loading can lead to deposit build-up behind the piston rings, deposits developing inside the cylinders and, in extreme cases, cylinder liner polishing can occur. These conditions can lead to power losses, poor performance and accelerated wear of components, which can cause increased maintenance costs and unplanned downtime or failure.

GAS GENERATOR SETS

Gas generator sets above 1000 kW are typically used in prime power and non-emergency standby applications where the load profile is steady and at higher load levels. Optimal operating conditions for gas generator sets can range from 50 percent to 100 percent of the rated load. Caterpillar recommends not loading natural gas generator sets in any application below 50 percent of their rated load for any duration, and the ideal range for operation is at 70 percent load and above.

Gas engines do not typically slobber, but there are other effects of low-load operations. At low load, gas engines do not have enough cylinder pressure to maintain oil control in the cylinder. This allows the oil to work its way past the rings into the combustion chambers, leading to ash deposits. These deposits change the compression ratio, which can reduce the detonation margin. If the detonation margin is reduced sufficiently, detonation can occur. Detonation will decrease the life of the engine, damage components and lead to unplanned shutdowns or failures.

Similar to diesel generator sets, the extended operation of gas generator sets at low loads can lead to deposit build-up on the valves, spark plugs and behind the piston rings. In extreme cases deposits in the cylinder can develop, causing cylinder liner polishing.

Additionally, natural gas engines run rich at low loads to maintain combustion and ensure that the engine does not misfire. A rich air-to-fuel ratio causes the engine to deviate from the expected emissions levels, potentially leading to non-compliance with required emissions regulations. Also, a rich air-to-fuel ratio increases temperatures and can accelerate component wear.

As is the case with diesel generator sets, all of these conditions can result in power losses, poor performance and accelerated wear of components, resulting in increased maintenance costs and unplanned downtime or failure.

AFTERTREATMENT

Aftertreatment components such as diesel oxidation catalysts (DOC), selective catalytic reduction (SCR) components and diesel particulate filters (DPF) are commonplace in many locations and applications, and they are all impacted by low-load operation. Without proper design and planning, low-load operation will have an impact on all aftertreatment components, causing emissions targets to be missed and ultimately leading to engine shutdown.

A DOC or DPF that is operating below the minimum exhaust temperature can cause back pressure limits to reach critical levels in a short period of time and lead to generator set shutdown. This issue becomes more critical in distributed or modular systems where there is no paralleling capability to share load between multiple units and ensure that a generator set is not operating at low loads for extended periods of time.

Meeting the minimum temperature is also critical in applications with an SCR system. If the SCR system does not reach the minimum operating temperature, the system will not begin dosing diesel exhaust fluid (DEF) into the exhaust stream, causing higher than expected emissions levels and impacting federal or local site permits.

Some SRC systems may need to be equipped with an additional exhaust heater to help meet minimum exhaust temperature requirements. While this may help maintain temperature needs, it also requires additional load to operate, which increases system complexity, cost and maintenance, and it does not address the impact of underloading on the engine. A more effective approach is to ensure that each generator set meets its minimum load targets for improved long-term system reliability and durability.

LOW LOAD MANAGEMENT

If maintained properly, diesel and gas generator sets can operate at light loads for long periods of time with no harmful effects. After operation at low load levels, each impacted generator set should operate under increased load to raise the cylinder temperature and pressure, which cleans the deposits from the combustion chamber. In addition, if low load operation is expected to occur regularly, a more aggressive maintenance plan will help to ensure that there is no excessive component wear and the chances for unplanned downtime are minimized.

The first major consideration in managing low load is how to add load to a system if the building load is not enough, or if the customer does not want to use critical loads for generator set maintenance. This issue can be resolved by having access to installed system load banks or a quick connect system that will allow for load banks to be easily tied into the power system for testing or maintenance purposes. Accounting for these requirements during the design phase allows for seamless integration into the system, which can be more cost effective than having to retrofit a site after construction and installation are complete.

Caterpillar recommends a testing process for diesel and natural gas generator sets. For diesel generator sets, Caterpillar recommends loading the generator set to a minimum of 30 percent load for approximately 30 minutes for every four hours of light load operation. Exhaust temperature measurements should be taken at the exhaust manifold prior to the turbo or in the exhaust stack just after the turbo to confirm that the recommended exhaust temperatures are met during operation.

The requirements for natural gas generator sets are slightly different. First, Caterpillar recommends aggressively working to limit underloading natural gas generator sets. See Table 1 below for time limits on low load operation for natural gas engines. After the time limit for reduced load operation has expired, the engine should be operated for a minimum of two hours at a load factor of at least 70 percent. Following these guidelines will keep engine maintenance to a minimum and improve long-term product health and durability.

For more information on generator set maintenance and testing, please contact your local Cat dealer or reference the operation and maintenance manual.

Engine Load	**Time Limit**
0 to 30 percent	1/2 hour
31 to 50 percent	2 hours
51 to 100 percent	Continuous [1]

[1] For continuous operation, the manifold air pressure must be greater than the atmospheric pressure.

Table 1: Time limits for low load operation of natural gas generator sets.

CONCLUSION

Underloading your power system impacts many individual components as well as overall system performance. While the simple solution is ensuring that your operational load is above 50 percent of the generator set nameplate, actual site conditions, site requirements and site expansion do not always line up with initial system design plans. This makes system underloading prevalent in the power generation market, specifically in the standby market. To help minimize the effects of underloading, it is critical to have operation and maintenance plans in place to maintain the health and reliability of the complete system and your generator set.

ABOUT

About Caterpillar

For nearly 90 years, Caterpillar Inc. has been making sustainable progress possible and driving positive change on every continent. Customers turn to Caterpillar to help them develop infrastructure, energy and natural resource assets. With 2013 sales and revenues of $55.656 billion, Caterpillar is the world's leading manufacturer of construction and mining equipment, diesel and natural gas engines, industrial gas turbines and diesel-electric locomotives. The company principally operates through its three product segments – Resource Industries, Construction Industries and Power Systems – and also provides financing and related services through its Financial Products segment. For more information, visit caterpillar.com. To connect with us on social media, visit caterpillar.com/social-media.

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Online Community: ***https://caterpillar.lithium.com/t5/Electric-Power-Generation/ct-p/EPG***

Facebook: ***http://www.facebook.com/Caterpillar.Electric.Power***

YouTube: ***http://www.youtube.com/CatPowerGeneration***

LEXE0832-00 October 2014

ANEXO D – DIAGRAMA UNILINEAL ELÉCTRICO DE LA CENTRAL

QUICKSTART PROJECT 475 MW - CHILE
PAJONALES

ESQUEMA UNIFILAR GENERADORES & CABINAS 23kV
INDICE

REV.	DESCRIPTION	DRAWN	CHECKED	APPROVED	DATE
1B	SEGUN COMENTARIOS PRIME	C.M.C.	M.P.A.	A.M.S.	11.09.18
1A	FIRST ISSUED	M.G.O.	M.P.A.	A.M.S.	25.07.18
00	FIRST ISSUED	M.G.O.	M.P.A.	A.M.S.	19.02.18

TSK mtu

FORMAT A-1

SCALE -

CLIENT: PrimeEnergía

CLIENT Nr. -

PROJECT: QUICKSTART PROJECT 475MW - CHILE PAJONALES

TSK Nr. $(GETVAR,??) [

REVISION ----

DRAWING TITLE: ESQUEMA UNIFILAR GENERADORES & CABINAS 23kV INDICE

SUBCONTRACTOR Nr. -

REVISION -

SHEET 00 TO 06

PROJECT Nr -

NOTAS-NOTES

1. EN ALGUNOS CASOS EL DIMENSIONAMIENTO DE LOS EQUIPOS ES PRELIMINAR, LOS VALORES FINALES SE DEFINIRÁN TRAS REALIZAR LOS CÁLCULOS E INGENIERÍA DE DETALLE
2. SECUENCIA DE FASES L1-L2-L3, SENTIDO HORARIO
3. LAS CARACTERÍSTICAS DE LOS EQUIPOS ESTÁN DEFINIDAS PARA UNA ALTITUD DE 160 m SOBRE EL NIVEL DEL MAR Y UNA TEMPERATURA DE 30ºC
4. EARTHING
   a. SISTEMA DE 23 KV - NEUTRO A TIERRA IMPEDANTE A TRAVÉS DE UN TRANSFORMADOR PARA LIMITAR LA CORRIENTE DE FALTA A 400 A.
   b. SISTEMA DE 415 V / 380 V. NEUTRO A TIERRA
   c. SISTEMA DE 110 VDC. AISLADO
5. TENSIONES AUXILIARES
   a. CONTROL Y SEÑALIZACIÓN : 110 VDC
   b. MOTOR DE CARGA DE MUELLES: 110 VDC
   c. RESISTENCIAS DE CALEFACCIÓN, ALUMBRADO Y ENCHUFES (SI APLICA): 220 VAC
6. TODOS LOS TRANSFORMADORES DE TENSIÓN IRÁN EQUIPADOS CON RESISTENCIAS TERCIARIAS DE FERRERESONANCIA DE VALOR APROXIMADO 100Ω CONECTADAS EN TRIÁNGULO ABIERTO
7. CADA CELDA TIENE QUE TENER ENCLAVAMIENTOS MECÁNICOS ENTRE SUS COMPONENTES DE ACUERDO A LA NORMA IEC 62271-200
8. ENCLAVAMIENTOS POR LLAVE / CANDADO:
   a. TODOS LOS SECCIONADORES DE PUESTA A TIERRA SE PODRÁN ENCLAVAR EN LA POSICIÓN ABIERTO
   b. TODOS LOS INTERRUPTORES SE PODRÁN ENCLAVAR EN LA POSICIÓN ABIERTO Y/O EXTRAÍDO
9. CADA CELDA DEBE ESTAR EQUIPADA CON UNA RESISTENCIA DE CALDEO CONTROLADA POR TERMOSTATO
10. -
11. EL GRADO DE PROTECCIÓN DEL CONJUNTO HA DE SER IP 4X
12. LA CATEGORÍA DE PÉRDIDA DE CONTINUIDAD DE SERVICIO HA DE SER AL MENOS LSC 2A Y LA CLASIFICACIÓN POR ARCO INTERNO DEBE SER AL MENOS IAC A-FL DE ACUERDO A LA NORMA IEC 62271-200
13. EL INTERCAMBIO DE SEÑALES ENTRE LAS CELDAS DE MEDIA TENSIÓN Y EL SISTEMA DE CONTROL DE LA PLANTA PODRÁ SER CALBEADO MEDIANTE CONTACTOS LIBRES DE POTENCIAL O BIEN A TRAVÉS DE UN PROTOCOLO DE COMUNICACIONES (IEC 61850, MODBUS TCP/IP O SIMILAR)
14. SE INSTALARAN LOS SWITCHES NECESARIOS EN LOS CONJUNTOS DONDE HAYA ELEMENTOS COMUNICABLES. TODOS ESTOS ELEMENTOS SE CABLERÁN INTERNAMENTE A DICHO SIWTCH.
15. -
16. -
17. -
18. LA FUNCIÓN 86 SE PODRÁ IMPLEMENTAR BIEN DESDE EL PROPIO RELÉ DE PROTECCIÓN DE LA CELDA (SI DISPONE DE ELLA) O BIEN MEDIANTE UN RELÉ BIESTABLE INDEPENDIENTE.

SÍMBOLOS GRÁFICOS PARA ESQUEMAS - ELECTRICAL SYMBOLOGY (IEC 60617-2013)

Símbolo	Descripción
X	LOCALIZACIÓN DE ENLACE
	PUNTO DE CONEXIÓN
	TERMINAL (BORNE)
	BORNE ENCHUFABLE
	CONEXIÓN POR CABLE
	ELEMENTO EXTRAIBLE (BASE Y CLAVIJA)
	INTERRUPTOR AUTOMÁTICO
	SECCIONADOR DE PUESTA A TIERRA
	SECCIONADOR
	INTERRUPTOR SECCIONADOR
	FUSIBLE
M	MANDO POR MOTOR ELÉCTRICO
M.I.	ENCLAVAMIENTO MECÁNICO
CV	CONMUTADOR VOLTÍMETRO
	CONDENSADOR
	DETECTOR PRESENCIA DE TENSIÓN
	TRANSFORMADOR DE TENSIÓN
	DEVANADO TRIFÁSICO EN TRIANGULO
	DEVANADO TRIFÁSICO EN ESTRELLA
	DEVANADO TRIFÁSICO EN ZIG-ZAG O EN ESTRELLAS CONECTADAS
	TRANSFORMADOR DE CORRIENTE
	TRANSFORMADOR DE CORRIENTE CON TRES CONDUCTORES PRIMARIOS PASANTES
P1 / P2	TRANSFORMADOR DE CORRIENTE DE DOS NÚCLEOS CON UN ARROLLAMIENTO SECUNDARIO EN CADA UNO
	BOBINA DE RELÉ
U<	RELÉ DE MÍNIMA TENSIÓN
	RESISTENCIA
G ~	GENERADOR
	PUNTO NEUTRO
	TIERRA DE PROTECCIÓN

LSIG / LSI — PROTECCION INTERRUPTOR
FUNCIÓN
L = SOBRECARGA
S = CORTOCIRCUITO INVERSO/ CORTOCIRCUITO CON RETARDO
I = CORTOCIRCUITO
G = FALLO A TIERRA

SCADA — DESDE SISTEMA DE CONTROL DE DISTRIBUCIÓN

(x) FUNCIONES DE MEDIDA

A = CORRIENTE
V = TENSIÓN
Hz = FRECUENCIA
W = POTENCIA
VAr = ENERGÍA REACTIVA
VA = POTENCIA APARENTE
φ = FACTOR DE POTENCIA

(x) FUNCION DE PROTECCION
(IEEE C.37.2-1991)

15 = DISPOSITIVO REGULADOR DE VELOCIDAD O FRECUENCIA
23 = DISPOSITIVO REGULADOR DE TEMPERATURA
25 = DISPOSITIVO DE SINCRONIZACIÓN O PUESTA EN PARALELO
26 = DISPOSITIVO TÉRMICO
27 = RELÉ DE MÍNIMA TENSIÓN
32 = RELÉ DIRECCIONAL DE POTENCIA
40 = RELÉ DE CAMPO
46 = RELÉ DE INTENSIDAD PARA EQUILIBRIO O INVERSIÓN DE FASES
47 = RELÉ DE TENSIÓN PARA SECUENCIA DE FASE
49 = RELÉ TÉRMICO PARA MÁQUINA, APARATO O TRANSFORMADOR
50 = RELÉ INSTANTÁNEO DE SOBRE INTENSIDAD O DE VELOCIDAD DE AUMENTO DE INTENSIDAD
51 = RELÉ DE SOBREINTENSIDAD TEMPORIZADO
59 = RELÉ DE SOBRETENSIÓN
63 = RELÉ DE PRESIÓN DE GAS, LÍQUIDO O VACÍO
64 = RELÉ DE PROTECCIÓN DE TIERRA
67 = RELÉ DIRECCIONAL DE SOBREINTENSIDAD DE C.A.
71 = RELÉ DE NIVEL LÍQUIDO O GASEOSO
74 = RELÉ DE ALARMA
81 = RELÉ DE FRECUENCIA
86 = RELÉ DE ENCLAVAMIENTO
87 = RELÉ DE PROTECCIÓN DIFERENCIAL

TWD / XXX — MARCA DE REFERENCIA A TÍPICOS

TWD = REFERENCIA A COLECCIÓN TÍPICOS
VER PLANOS: ESQUEMAS TÍPICOS ELÉCTRICOS
TSKE-001076-00-ELC-DE-1003
TSKE-001076-00-ELC-DE-1005

xxx = INDICADOR DE ESQUEMA TIPO

PLANOS DE REFERENCIA-*REFERENCE DRAWINGS*

PLANO-*DRAWING Nº*	TÍTULO-*TITLE*	PLANO-*DRAWING Nº*	TÍTULO-*TITLE*
TSKE-001076-04-ELC-PE-0113	SINGLE LINE DIAGRAM OUTDOOR EHV 220/23 kV	-	-
TSKE-001076-04-ELC-DE-0001	SIMPLIFY SINGLE LINE DIAGRAM	-	-
TSKE-001076-04-ELC-DE-0003	LV SINGLE LINE DIAGRAM		

REV.	DESCRIPTION	DRAWN	CHECKED	APPROVED	DATE
1B	SEGUN COMENTARIOS PRIME	C.M.C.	M.P.A.	A.M.S.	11.09.18
1A	FIRST ISSUED	M.G.O.	M.P.A.	A.M.S.	25.07.18
00	FIRST ISSUED	M.G.O.	M.P.A.	A.M.S.	19.02.18

TSK

FORMAT: A-1
SCALE: -

CLIENT: PrimeEnergía
CLIENT Nr.: -

PROJECT: QUICKSTART PROJECT 475MW - CHILE
PAJONALES

TSK Nr.: $(GETVAR,??) [
REVISION: ----

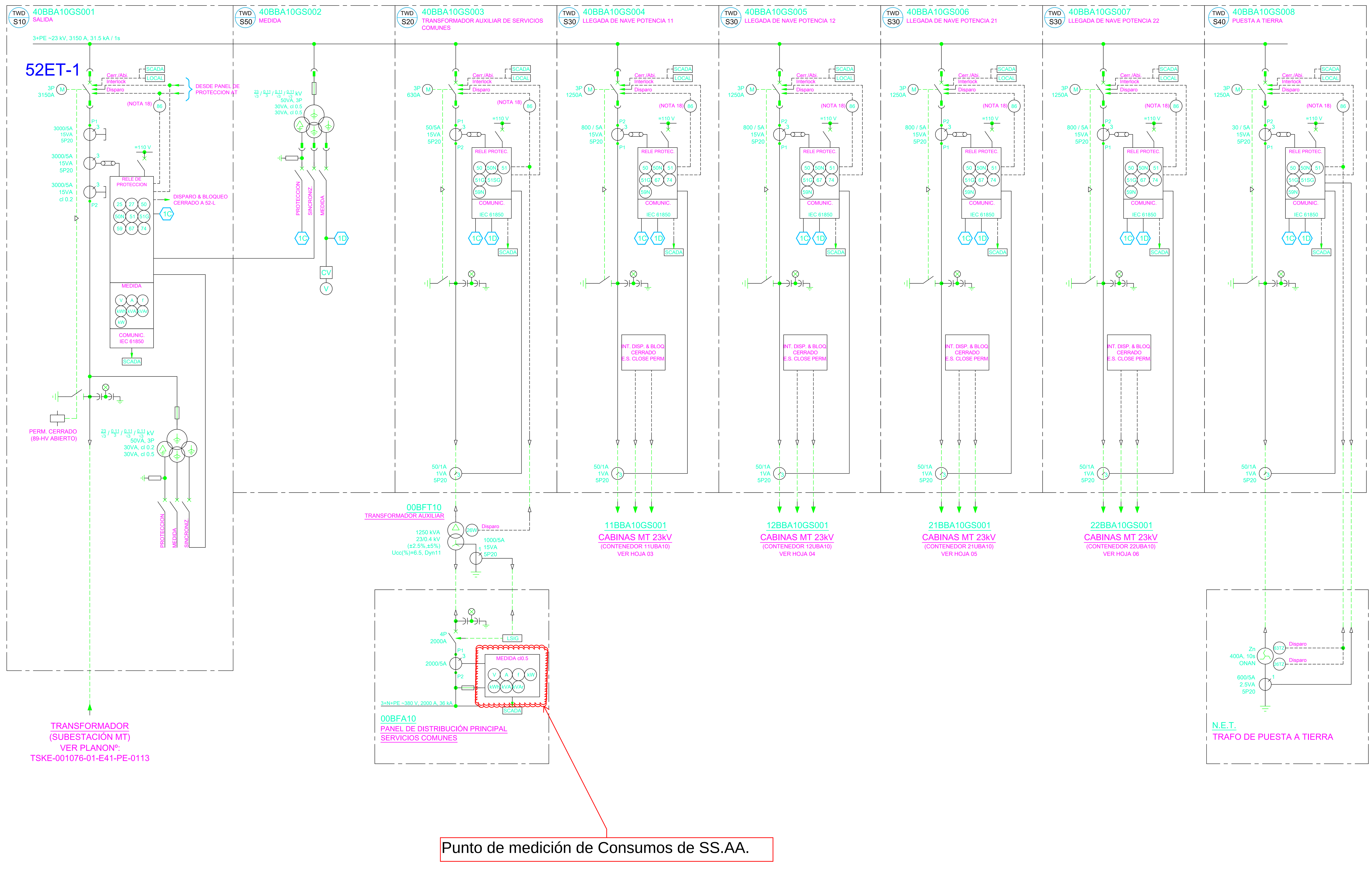
DRAWING TITLE: ESQUEMA UNIFILAR GENERADORES & CABINAS 23kV
NOTAS & SIMBOLOGIA ELECTRICA

SUBCONTRACTOR Nr.: -
REVISION: -

SHEET 01 TO 06 PROJECT Nr -

40BBA10

EDIFICIO SUBESTACIÓN DE MT, CABINAS DE MT 23 kV



1B	SEGUN COMENTARIOS PRIME	C.M.C.	M.P.A.	A.M.S.	11.09.18
1A	FIRST ISSUED	M.G.O.	M.P.A.	A.M.S.	25.07.18
00	FIRST ISSUED	M.G.O.	M.P.A.	A.M.S.	19.02.18
REV.	DESCRIPTION	DRAWN	CHECKED	APPROVED	DATE

TSK

FORMAT: A-1 | SCALE: -

CLIENT: PrimeEnergía | CLIENT Nr.: -

PROJECT: QUICKSTART PROJECT 475MW - CHILE
PAJONALES

TSK Nr.: $(GETVAR,??) [| REVISION: ----

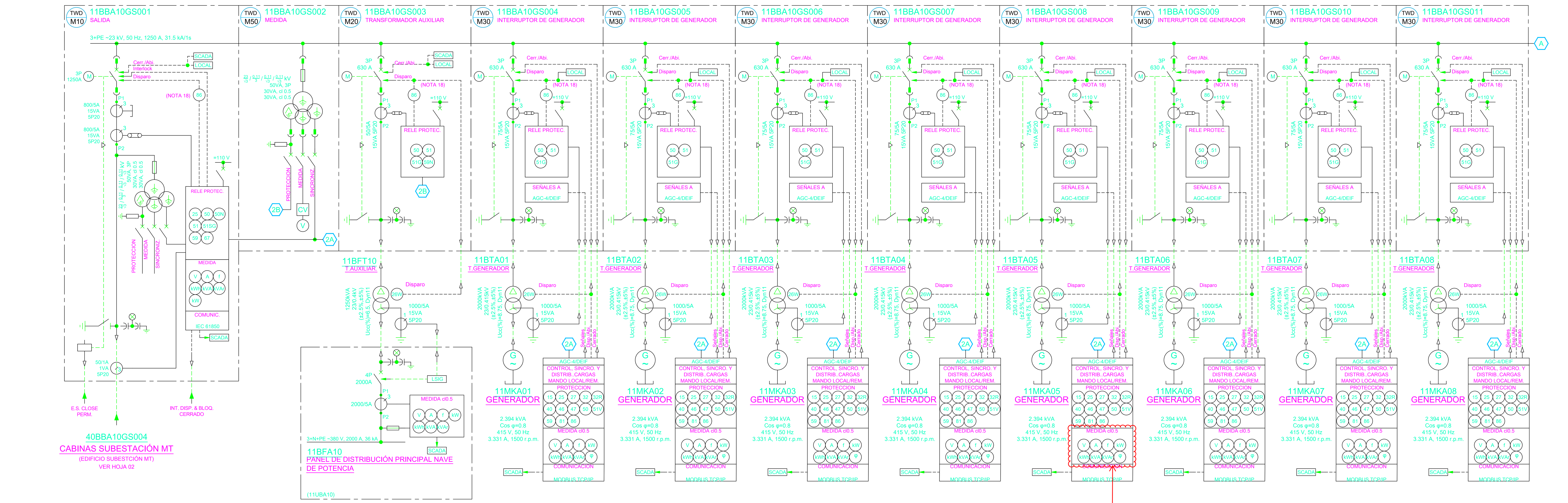
DRAWING TITLE: ESQUEMA UNIFILAR GENERADORES & CABINAS 23kV
40BBA10-SUBESTACION AT-CABINA 23kV

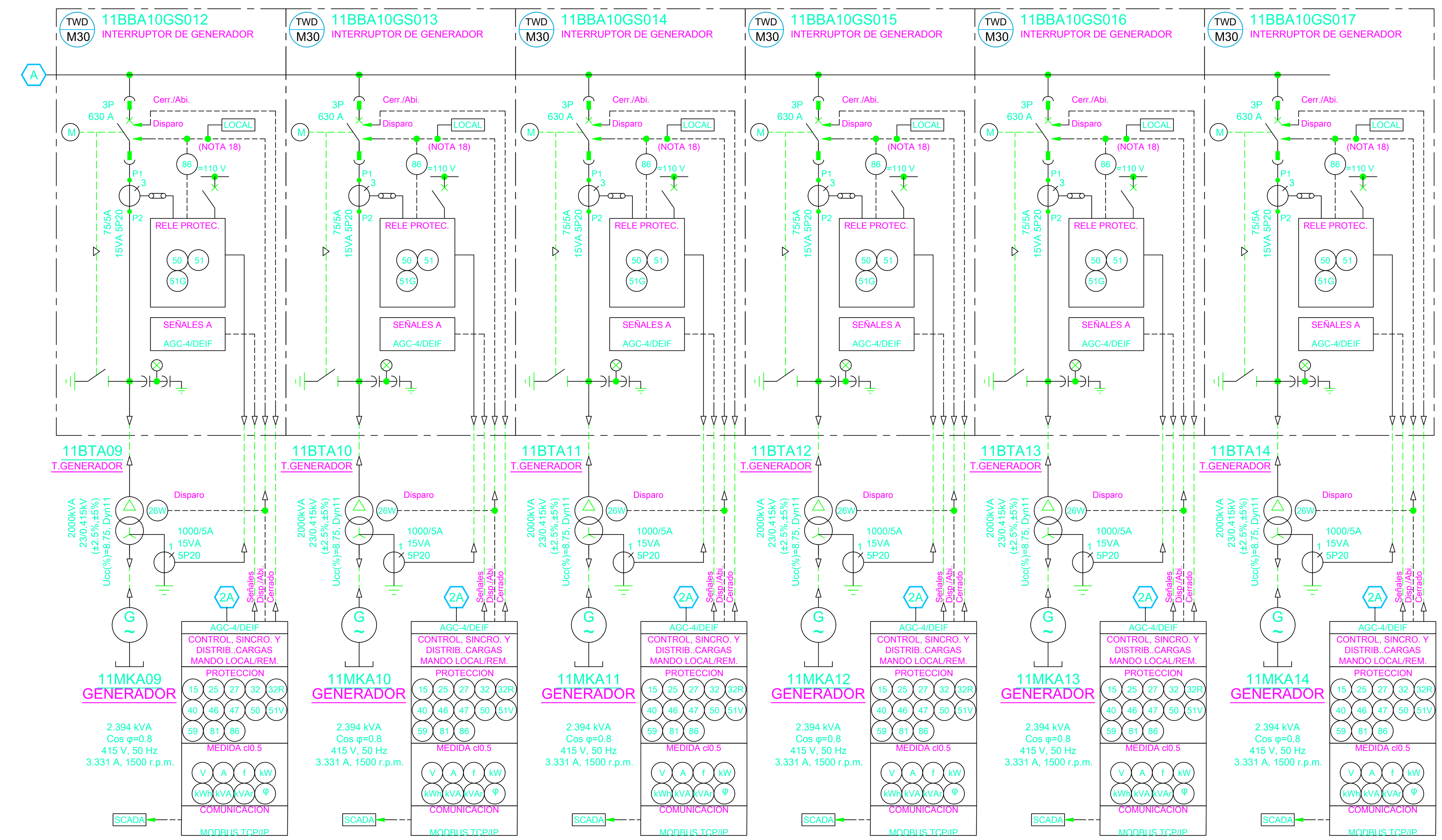
SUBCONTRACTOR Nr.: - | REVISION: -

SHEET 02 TO 06 | PROJECT Nr -

11BBA10

NAVE DE POTENCIA 11, CABINAS DE MT 23kV





Potencia bruta puede ser medida como la suma de la potencia leida por cada medidor ubicado a la salida de los grupos electrogenos (hojas 3, 4, 5 y 6)

REV.	DESCRIPTION	DRAWN	CHECKED	APPROVED	DATE
1B	SEGUN COMENTARIOS PRIME	C.M.C.	M.P.A.	A.M.S.	11.09.18
1A	FIRST ISSUED	M.G.O.	M.P.A.	A.M.S.	25.07.18
00	FIRST ISSUED	M.G.O.	M.P.A.	A.M.S.	19.02.18

TSK — mtu

FORMAT: A-1 — SCALE: -

CLIENT: PrimeEnergía — CLIENT Nr.: -

PROJECT: QUICKSTART PROJECT 475MW - CHILE PAJONALES

TSK Nr.: $(GETVAR,??) [— REVISION: ----

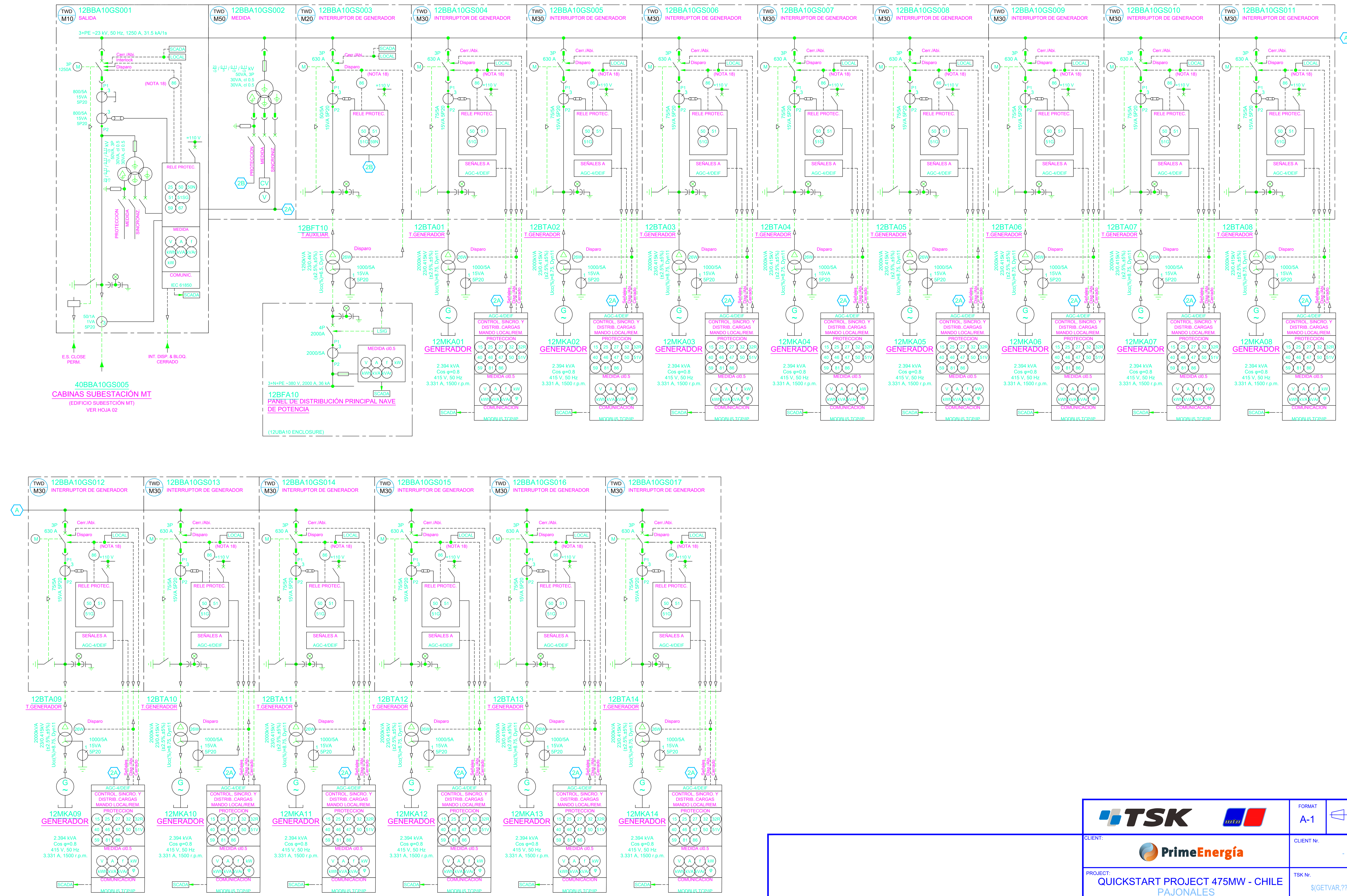
DRAWING TITLE: ESQUEMA UNIFILAR GENERADORES & CABINAS 23kV 12BBA10 - NAVE DE POTENCIA 11 - CABINA 23 kV

SUBCONTRACTOR Nr.: - — REVISION: -

SHEET 03 TO 06 — PROJECT Nr -

12BBA10

NAVE DE POTENCIA 12, CABINAS DE MT 23kV



REV.	DESCRIPTION	DRAWN	CHECKED	APPROVED	DATE
1B	SEGUN COMENTARIOS PRIME	C.M.C.	M.P.A.	A.M.S.	11.09.18
1A	FIRST ISSUED	M.G.O.	M.P.A.	A.M.S.	25.07.18
00	FIRST ISSUED	M.G.O.	M.P.A.	A.M.S.	19.02.18

FORMAT A-1 | SCALE -

CLIENT: PrimeEnergía | CLIENT Nr. -

PROJECT: QUICKSTART PROJECT 475MW - CHILE
PAJONALES

TSK Nr. $(GETVAR,??) [| REVISION ----

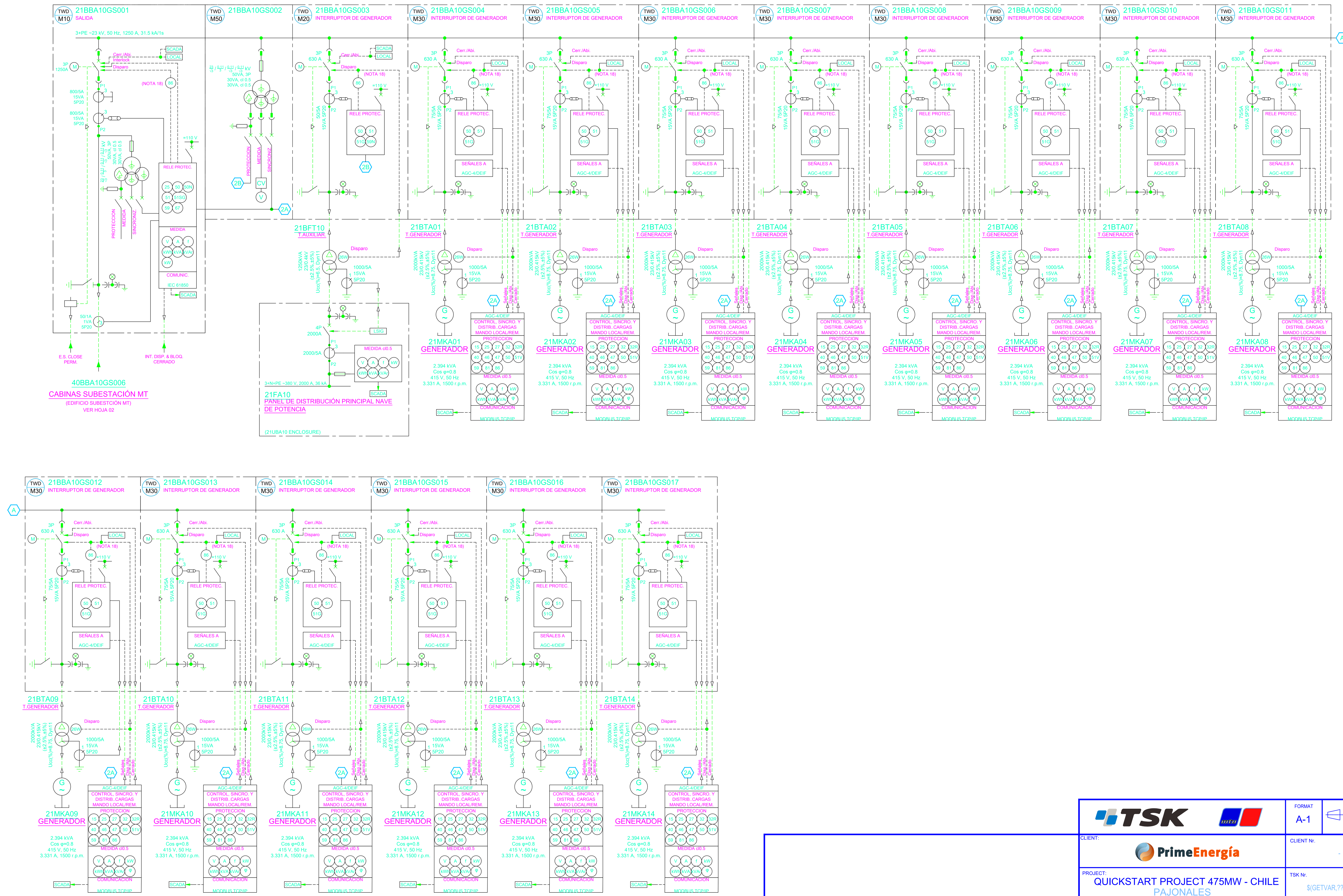
DRAWING TITLE: ESQUEMA UNIFILAR GENERADORES & CABINAS 23kV
12BBA10 - NAVE DE POTENCIA 12 - CABINA 23 kV

SUBCONTRACTOR Nr. - | REVISION -

SHEET 04 TO 06 | PROJECT Nr -

21BBA10

NAVE DE POTENCIA 21, CABINAS DE MT 23kV



REV.	DESCRIPTION	DRAWN	CHECKED	APPROVED	DATE
1B	SEGUN COMENTARIOS PRIME	C.M.C.	M.P.A.	A.M.S.	11.09.18
1A	FIRST ISSUED	M.G.O.	M.P.A.	A.M.S.	25.07.18
00	FIRST ISSUED	M.G.O.	M.P.A.	A.M.S.	19.02.18

TSK

FORMAT A-1

SCALE -

CLIENT: PrimeEnergía

CLIENT Nr. -

PROJECT: QUICKSTART PROJECT 475MW - CHILE PAJONALES

TSK Nr. $(GETVAR,??) [

REVISION ----

DRAWING TITLE: ESQUEMA UNIFILAR GENERADORES & CABINAS 23kV 21BBA10 - NAVE DE POTENCIA 21 - CABINA 23 kV

SUBCONTRACTOR Nr. -

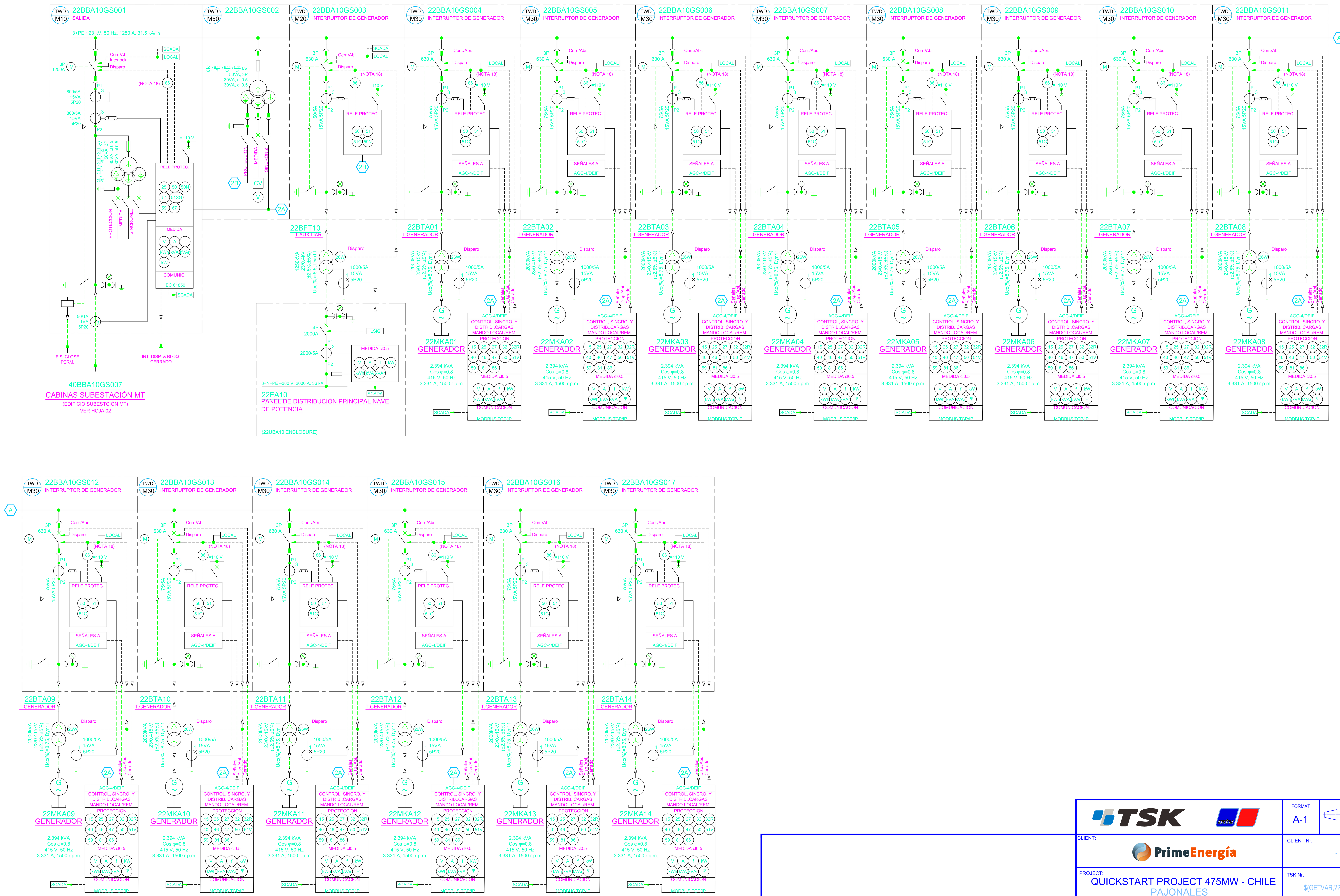
REVISION -

SHEET 05 TO 06

PROJECT Nr -

22BBA10

NAVE DE POTENCIA 22, CABINAS DE MT 23kV



REV.	DESCRIPTION	DRAWN	CHECKED	APPROVED	DATE
1B	SEGUN COMENTARIOS PRIME	C.M.C.	M.P.A.	A.M.S.	11.09.18
1A	FIRST ISSUED	M.G.O.	M.P.A.	A.M.S.	25.07.18
00	FIRST ISSUED	M.G.O.	M.P.A.	A.M.S.	19.02.18

TSK mtu

FORMAT A-1

SCALE -

CLIENT: PrimeEnergía

CLIENT Nr. -

PROJECT: QUICKSTART PROJECT 475MW - CHILE PAJONALES

TSK Nr. $(GETVAR,??) [

REVISION ----

DRAWING TITLE: ESQUEMA UNIFILAR GENERADORES & CABINAS 23kV 22BBA10 - NAVE DE POTENCIA 22 - CABINA 23 kV

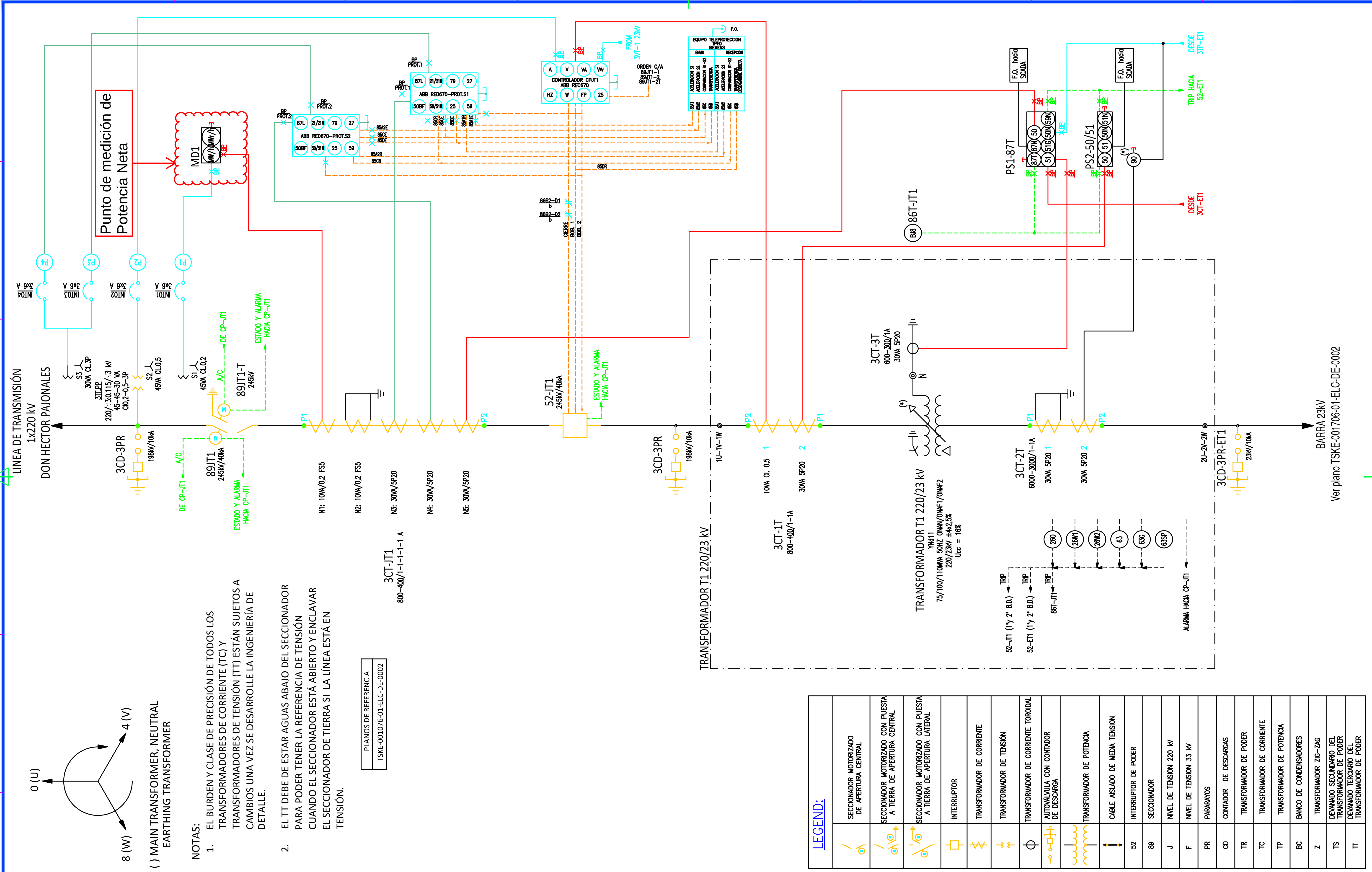
SUBCONTRACTOR Nr. -

REVISION -

SHEET 06 TO 06

PROJECT Nr -

ANEXO E – DIAGRAMA UNILINEAL ELÉCTRICO DE LA SUBESTACIÓN



REV.	DESCRIPCION	FECHA	NOMBRE
3	PRIME COMMENTS 2	05.09.18	L.P.F.
2	PRIME COMMENTS	20.08.18	M.E.P.
1	ACCORDING COMMENTS	13.07.18	A.M.D.
0	PRELIMINARY	26.02.18	A.M.D.

FECHA	26.02.18
DIBUJ.	A.M.D.
COMP.	J.L.A.
APROB.	R.A.R.

TSK

PrimeEnergía

SUBESTACION PAJONALES 220/23 kV

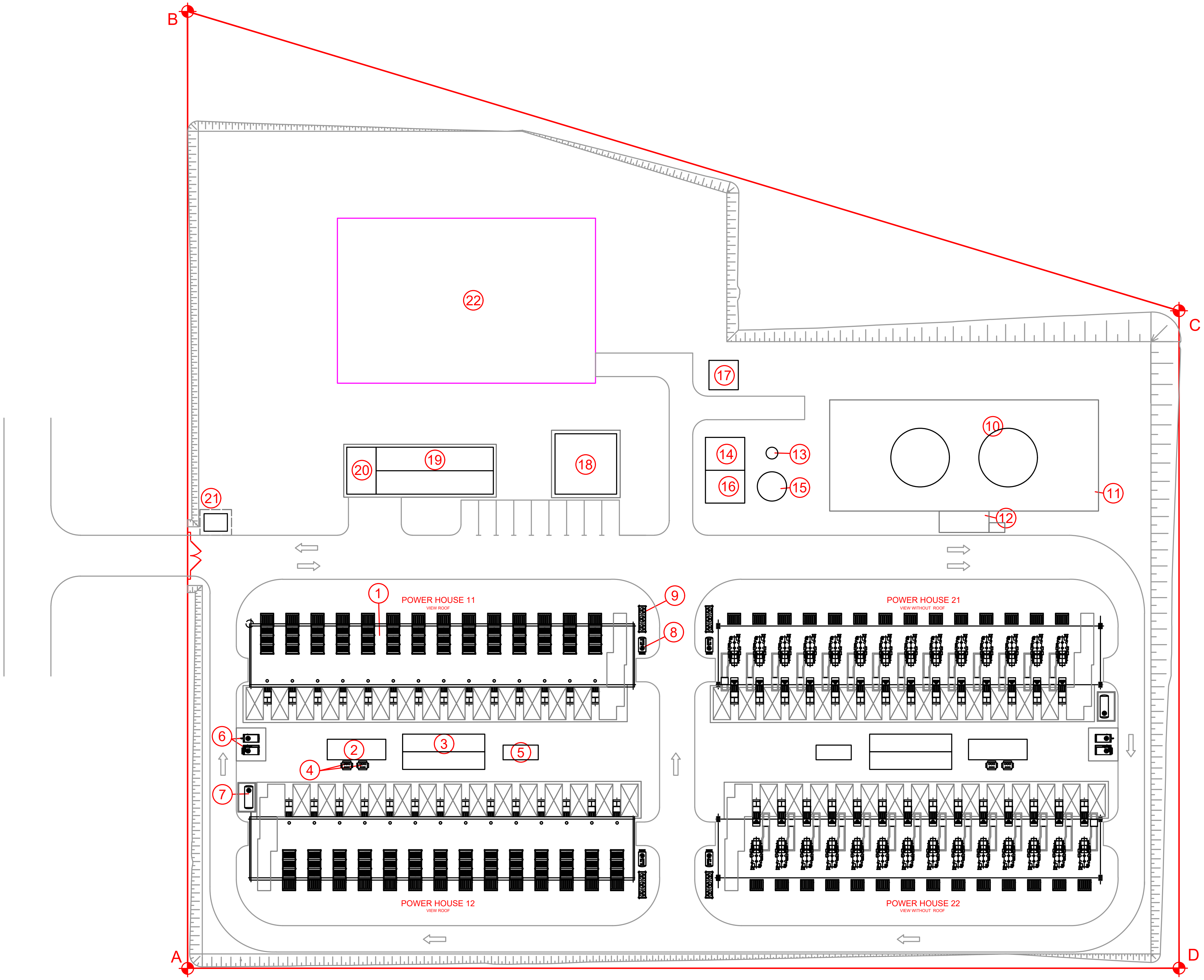
SINGLE LINE DIAGRAM OUTDOOR EHV 220/23 kV

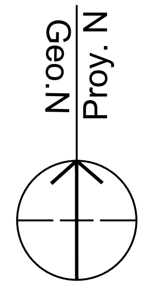
P. N° CLIENTE

P. N° TSK TSKE-001076-01-ELC-PE-0113

HOJA 1/1

ANEXO F – LAYOUT CENTRAL GENERADORA





ITEM	DESCRIPTION
	LEGEND
1	POWERHOUSE
2	LOW VOLTAGE ELECTRICAL CONTROL ROOM
3	23kW ELECTRICAL CONTROL ROOM
4	23/0,415KV AUXILIARY TRANSFORMERS
5	23kW SUMMATION SWITGEAR ENCLOSURE
6	CLEAN / DIRTY LUBE OIL TANKS
7	SPILL TANK
8	DAILY DIESEL TANK
9	FUEL OIL COOLERS
10	DIESEL STORAGE TANKS
11	FUEL TANK AREA
12	UNLOADING & PUMPING STATION
13	POTABLE WATER TANK
14	WATER PUMP STATION
15	FIRE WATER TANK
16	FIREFIGHTING HOUSE
17	WASTEWATER TREATMENT
18	ADMIN. AND CONTROL BUILDING
19	HAZARDOUS WASTE WAREHOUSE
20	WAREHOUSE & WORKSHOP BUILDING
21	GATE HOUSE
22	PLANT HV SUBSTATION

IMPORTANT NOTE:
DRAWING PRELIMINARY, CHANGES AND MODIFICATIONS MAY ARISE DURING DETAIL ENGINEERING PHASE

COORDINATE TABLE UTM

Nº Pts	North	East	Elevation	Description
1	6777839	313651	=1122.40	A
2	6778002	313651	-	B
3	6777951	313820	-	C
4	6777839	313820	-	D
Area (m2)		24245.19	(2.42 Hectares)	

TABLE OF EQUIVALENCE
PROJECT COORDINATES WITH UTM WGS84 ZONE 19J COORDINATES

	PROJECT COORDINATES		UTM WGS84 ZONE 19J	
PR	EAST (m)	NORTH (m)	X (m)	Y (m)
(0,0)	0,000	0,000	311.751,000	6.767.499,000
PP	1000,000	10000,000	312.751,000	6.777.499,000

PROJECT ELEVATIONS	UTM ELEVATIONS
100	XXX

REV.	DESCRIPTION	DRAWN	CHECKED	APPROVED	DATE
00	FIRST REVISION	NME	RAG	JQV	28-03-18

TSK onsite energy

FORMAT: A-0 | SCALE: 1:250

CLIENT: PrimeEnergía | CLIENT Nr.: -

PROJECT: QUICKSTART PROJECT 475MW - CHILE 100MW PAJONALES

TSK Nr.: 001076-01-TUB-PG-0001 | REVISION: 00

DRAWING TITLE: LAYOUT DRAWING GENERAL PLAN VIEW -

SUBCONTRACTOR Nr.: - | REVISION:

SHEET 1 TO 1 | PROJECT Nr -

ANEXO G – REGISTROS DE PRUEBAS FAT

Inspection Report
MTU-Diesel Gensets

Genset - Name:	MTU 16V4000 DS2500 ✓
Genset - Model:	DG16V4000A2E ✓
Genset - Serial No.:	95030401506 ✓
MTU-Order No.:	1325096

Power Calculation		
P = U x I x √3 x cos φ	Fuel Type	DIN EN 590 B0
	Spec. Density at 15°C	0,82-0,86 g/cm³
	Calorific Value	> 42700 kJ/kg
	Lube Oil	Shell Rimula R6 LM 10W-40

Power Definition			
PowerGen rated Power ISO 8528 Part 1:		1872 kW	50 Hz
PowerGen Overload Power	ISO 8528 Part 1:	2059 kW	50 Hz ✓

Altitude ab. Sea Level:	365 m
Intake-Air Temperature:	-3 °C
Relative Humidity:	87 %
Barometric Pressure	1029 mbar

Generator:		Engine	
Manuf.:	Leroy & Somer ✓	Manuf.:	MTU ✓
Type:	LSA 52.3 L12 - 4 ✓	Type:	16V/4000 G24F ✓
No.:	610132 / 23	No.:	548100389

Page 1 von 1	
Date:	06.02.2019
TB:	Testbench B
OP:	AN 518285

Time	Load	Frequency	Voltage	Current			Power Factor	Active Power	Fuel Consumption		Lube Oil		Coolant		Air System					Fuel		Speed/Requested Torque
									Cons.	Spec.	Pressure	Temp.	Temp.	Pres.	Temp.	Temp.	Temp.	Pres.		Temp.		
		f	U	I (L1)	I (L2)	I(L3)	φ	P	B	b	Before Engine ECU	Before Engine	After Engine ECU	After Engine ECU	Air Before Engine	Water before Inter-Cool. ECU	Air before Zyl. ECU	Air Bef.Zyl. abs. ECU		Before Engine		
min	%	Hz	V	A	A	A		kW	kg/h	g/kWh	bar	°C	°C	bar	°C	°C	°C	bar		°C		1/min. / Nm
		test ben.	test ben.	test bench	test bench	test bench	0,8-1,0	test ben.	test ben.	test ben.	1.0100.001	1.0125.001	1.0120.001	1.0101.001	test bench	1.0124.001	1.0121.001	1.0103.001		test ben.		1.2500.044 / 2.1000.049
	Start	Acceptance run																				
5 min	0-100	50,0	415	2587	2610	2623	1,00	1872	388,80	207,69	6,67	76,23	80,92	n.a.	19,40	48,33	45,54	3,21		16,0		1500 / 12184
15 min	100	50,0	415 ✓	2586	2610	2623	1,00	1872 ✓	388,80	207,69	6,51	80,55	85,31	n.a.	20,60	48,45	48,64	3,21		13,4		1500 / 12124
3 min	110	50,0	415	2847	2873	2892	1,00	2060	428,40	207,96	6,46	80,67	85,73	n.a.	24,00	50,21	51,21	3,41		13,5		1500 / 13441
	Stop																					

Step load test after start:

Switch on:	50% Load after	10	sec	ok.
	75% Load after	13	sec	ok.
	100% Load after	16	sec	ok.
Switch off:	100 - 0% Load after	31	sec	ok.

Speed shifting area from 48,0 Hz to 53,3 Hz
Run-up time from start order to 50 Hz in 6 s
Coolwater Temp. Warning 102 °C; Shutdown 104 °C
Coolwater Intercooler Temp. Warning 75 °C; Shutdown 78 °C

Overspeed - Shutdown at 1950 1/min.
Lube Oil Pressure Warning 3,5 bar, Shutdown 3,2 bar
Fuel Pressure before Filter Warning 4,3 bar, Shutdown 3,8 bar
Fuel Temp. Warning 60 °C; Shutdown 65 °C

Engine-shutdown through security equipment if lube oil pressure ≤ / bar
3 starts with electric starter: ok.

Test instruction No.:

MTUA-001076-00-MEC-PO-0003

Remarks (If more space is needed, please turn the page and use back of sheet)

SignatureTest Bench MTU Onsite Energy Systems GmbH

MTU Onsite Energy Systems GmbH
Rotthofer Straße
94099 Ruhstorf/Germany

Signature Quality Department MTU Onsite Energy Systems GmbH
i.A. Gayer Patrick

Signature buyer/customer

Lastlauf / Load Test (500ms)