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INFORME TÉCNICO

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Cliente: Prime Energía Spa

Proyecto: Determinación de Mínimos Técnicos – Central San Javier I

Asunto: Informe de Mínimo Técnico – Central San Javier I

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

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2	01/12/2021	Revisión Final	Diego Larraín	Luis Garrido	Luis Garrido	Eduardo Andrzejewski
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0	11/02/2020	Revisión Coordinador	Ismael Rodríguez	Ismael Rodríguez	Eduardo Andrzejewski	Eduardo Andrzejewski
B	03/12/2019	Revisión Cliente	Ismael Rodríguez	Ismael Rodríguez	Eduardo Andrzejewski	Eduardo Andrzejewski
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Informe de Mínimo Técnico – Central San Javier I

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RESUMEN EJECUTIVO

La central San Javier I está ubicada en la comuna de Constitución, Provincia de Talca, Región del Maule. La central se compone de 1 nave, o casa de fuerza, que contiene 14 grupos electrógenos diésel, totalizando una capacidad instalada de 26 MW. La central tiene como punto de conexión al SI la S/E San Javier.

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 14 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 San Javier I, 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 Electrónico Diésel MTU 16V DS2500
3.	Registros Operacionales: Pruebas FAT efectuadas a unidades generadoras MTU 16V DS2500
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 San Javier I, propiedad de Prime Energía Spa, se compone de 14 grupos electrógenos diésel idénticos 1 nave. En la Tabla 4 se indican los parámetros principales de cada unidad generadora.

Central San Javier I	Información	Referencia
Modelo Grupo Electrónico	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 Específico a 100% Carga	222,4 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

Tabla 5. Distribución y Potencia Conjunta Grupos Electrónicos

Todos los motores de la central utilizan 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 la sección 7 (Anexos) 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 San Javier I. 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

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.

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.

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 B) 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 B) 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 San Javier I dispone con los registros operacionales en sitio de una unidad generadora, en los cuales se puede apreciar el Mínimo Técnico y la Potencia Máxima (ver Figura 5). Estos valores van en línea con lo declarado por las pruebas FAT.

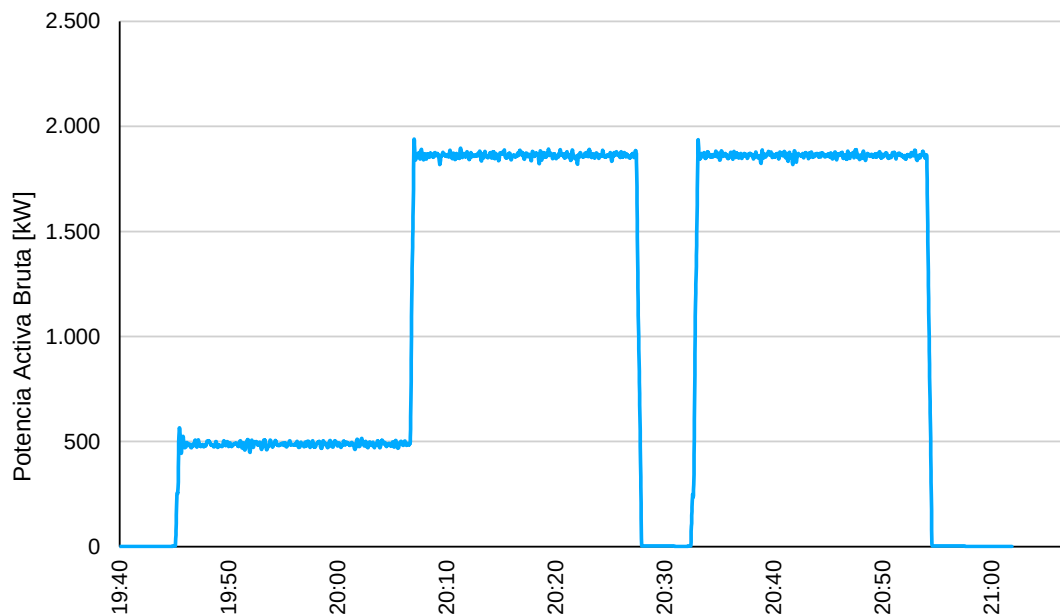


Figura 5. Pruebas de datos operacionales con fecha 09/11/2021

De acuerdo con la Figura 5, el grupo electrógeno presenta una operación estable tanto en Potencia Máxima como en Mínimo Técnico, siendo este último correspondiente al 25% de la potencia nominal, cuyo valor es 468 kW.

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 San Javier I no está sujeta a restricciones ambientales ni 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
Combarbalá	1.872	468	25%	MTU
Pajonales	1.872	468	25%	MTU
Los Cóndores	1.872	468	25%	MTU
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 San Javier I.

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 a 480 kW_m, la cual corresponde a una potencia eléctrica de 457 kW_e (considerando la eficiencia de 95,2% del generador eléctrico).

Luego, en la sección 5.2, se presentan datos operacionales que respaldan la información entregada en las pruebas, donde la potencia mínima declarada es de 468 kW_e (25% de 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 14 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

ANEXO E – LAYOUT CENTRAL GENERADORA

ANEXO F – 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 para ORDE)

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 (kW _e)		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.		

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
Longitud	MTUA-001076-00-MEC-PM-0001-xx
Anchura	
Altura	

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

8.3.2 Motor – Hacer girar con equipo de arranque

PELIGRO



Piezas del motor en rotación y moviéndose.

¡Peligro de contusión, peligro de introducción o agarre de partes del cuerpo!

- Antes de hacer girar el motor, cerciorarse de que nadie se encuentre en la zona de peligro del mismo.
- Una vez realizados los trabajos, asegurarse de que estén montados de nuevo todos los equipos protectores y que se hayan retirado del motor las herramientas.

Nota: Hacer girar el motor con el equipo de arranque solamente en los casos siguientes:

- Prelubricación del motor: procedimiento solamente para los motores sin bomba de prelubricación. Los motores con bomba de prelubricación siempre se deben prelubricar con ésta(→ Página 120).
- Para seguir operando un refrigerador de aire de sobrealimentación con fugas, sólo en el marco de una medida de emergencia antes de arrancar del motor (→ Página 234).

Hacer girar el motor con equipo de arranque

Nota: • Al hacer girar el motor, éste no debe arrancar ni inyectar combustible.
• Para el giro del motor, el ECU debe estar energizado.

1. Seleccionar uno de los procedimientos siguientes:

- a) Ciclo de arranque externo: En el ECU está aplicada la señal de parada. Los arrancadores se energizan a través del control de la planta.
- b) Ciclo de arranque interno: El motor se puede hacer girar a través de CAN-J1939, SPN 1206 a través de los arrancadores sin inyección de combustible.

Nota: Se deben respetar las pausas entre los giros para proteger el arrancador contra un sobrecalentamiento.

2. Realizar los pasos siguientes tres veces seguidas:

- a) Hacer girar el motor durante 15 segundos.
- b) Atenerse a una pausa de 60 segundos.

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	-

GENERATING SET

mtu onsite energy

ISO 8528

NAME

MODEL

SERIAL

RATING

RPM HZ

KW KVA

MASS KG

VOLTS AMPS PF

AMBIENT °C ALTITUDE m

PERFORMANCE CLASS

MANUFACTURE YEAR

MTU Friedrichshafen GmbH
Maybachplatz 1
88045 Friedrichshafen - Germany

Made in Germany

37.8 MMX 425

**MTU Friedrichshafen GmbH**

Maybachplatz 1
88045 Friedrichshafen
Germany
T +49 7541 90-0

Attachment "Fuel Consumption increase for 16V4000G24F 3G NEA in g/kWe"**

Engine air intake [°C]	Los Condores 160m	Llanos Blancos 200m	San Javier 325m	Combarbala 970m	Pajonales 1100m
10	219,9	221,9	222,4	227,3	223,6
11	219,9	221,9	222,4	227,3	223,6
12	219,9	221,9	222,4	227,3	223,6
13	219,9	221,9	222,4	227,3	223,6
14	219,9	221,9	222,4	227,3	223,6
15	219,9	221,9	222,4	227,3	223,6
16	219,9	221,9	222,4	227,3	223,6
17	219,9	221,9	222,4	227,3	223,6
18	219,9	221,9	222,4	227,3	223,6
19	219,9	221,9	222,4	227,3	223,6
20	219,9	221,9	222,4	227,3	223,6
21	219,9	221,9	222,4	227,3	223,6
22	219,9	221,9	222,4	227,3	223,6
23	219,9	221,9	222,4	227,3	223,6
24	219,9	221,9	222,4	227,3	223,6
25	219,9	221,9	222,4	227,3	223,6
26	219,9	221,9	222,4	227,3	223,6
27	219,9	221,9	222,4	227,3	223,6
28	219,9	221,9	222,4	227,3	223,6
29	219,9	221,9	222,4	227,3	223,6
30	219,9	221,9	222,4	227,3	223,6
31	219,9	221,9	222,4	227,3	223,6
32	219,9	221,9	222,4	227,3	223,6
33	219,9	221,9	222,4	227,3	223,6
34	219,9	221,9	222,4	227,3	223,6
35	219,9	221,9	222,4	227,3	223,6
36	219,9	221,9	222,4	227,3	223,6
37	219,9	221,9	222,4	227,3	223,6
38	219,9	221,9	222,4	227,3	223,6
39	219,9	221,9	222,4	227,3	223,6
40	219,9	221,9	222,4	227,3	223,6
41	219,9	221,9	222,4	227,3	223,6
42	219,9	221,9	222,4	227,3	223,6
43	219,9	221,9	222,4	227,3	223,6
44	219,9	221,9	222,4	227,3	223,6
45	220,8	221,9	222,4	227,3	224,5
46	221,7	221,9	222,4	227,3	225,4
47	222,5	221,9	222,4	227,3	226,3
48	223,4	221,9	222,4	227,3	227,2
49	224,3	221,9	222,4	227,3	228,1
49	225,2	221,9	222,4	227,3	229,0
50	226,1	222,8	223,3	228,2	229,9
51	227,0	223,7	224,2	229,1	230,9
52	227,9	224,6	225,1	230,0	231,8

Board of Management: Andreas Schell (President and CEO), Louise Öfverström, Dr. Otto Preiss.
Chairman of the Supervisory Board: Axel Arendt. Domicile: Friedrichshafen. Register Court: Ulm, Nr. I No. HRB 630 227.
Bank Details: Deutsche Bank AG Stuttgart: (all currencies) SWIFT/BIC DEUTDE33XXX, IBAN DE35 6007 0070 0162 9039 00.
Commerzbank AG Friedrichshafen: (EUR) SWIFT/BIC COBADEFF651, IBAN DE68 6514 0072 0170 0038 00.
V.A.T. No. DE 811121844

ANEXO B – INFORMACIÓN TÉCNICA DEL GENERADOR

ALTERNATOR TECHNICAL DESCRIPTION

LSA 52.3 L12 / 4p

LS Reference: MB448-12-2017-1

Date: 07.12.2017

V4.06a - 11/2017

Leroy Somer Marbaise GmbH

Project Manager : mb

Electric Power Generation

Mario.BRANDSTAETTER@mail.nidec.com

Eschborner Landstrasse 166 - 60489 Frankfurt am Main

+49 (0) 69 780708-28

MB

Main data

M

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

Installation

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

Mechanical Construction

IM1201

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

Additional specificities

Stabilized Runaway speed:	2250 rpm - 2 min.
---------------------------	-------------------

ALTERNATOR TECHNICAL DESCRIPTION

LSA 52.3 L12 / 4p

LS Reference: MB448-12-2017-1

Cooling Method

IC01

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

Connection, Excitation & Regulation

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

Terminal box

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

Protection and measurement accessories

Temperature detection

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

Anti-condensation heating

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

Transformers (Client use)

LS Supply	
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
S2	4000 / 1A / 10VA / Cl. 5P10

Various items

171206YV03_B

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

Controls

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

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)								
		Unsaturated		Saturated				
		Direct axis		Quadrature axis				
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

Products and materials shown in this catalogue may, at any time, be modified in order to follow the latest technological developments, improve the design or change conditions of utilization

ALTERNATOR MAIN CURVES LSA 52.3 L12 / 4P

LS Reference: MB448-12-2017-1

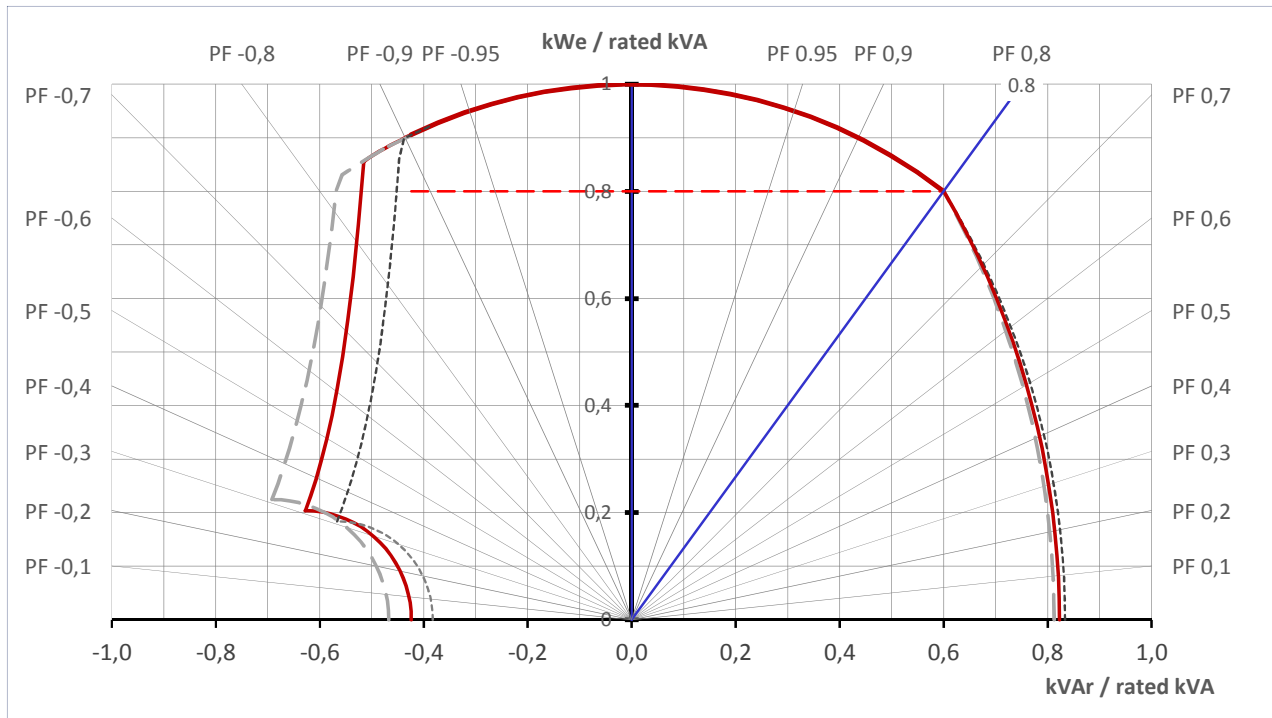
Date: 07.12.2017

2394kVA - 415V - 50 Hz

V4.06a - 11/2017

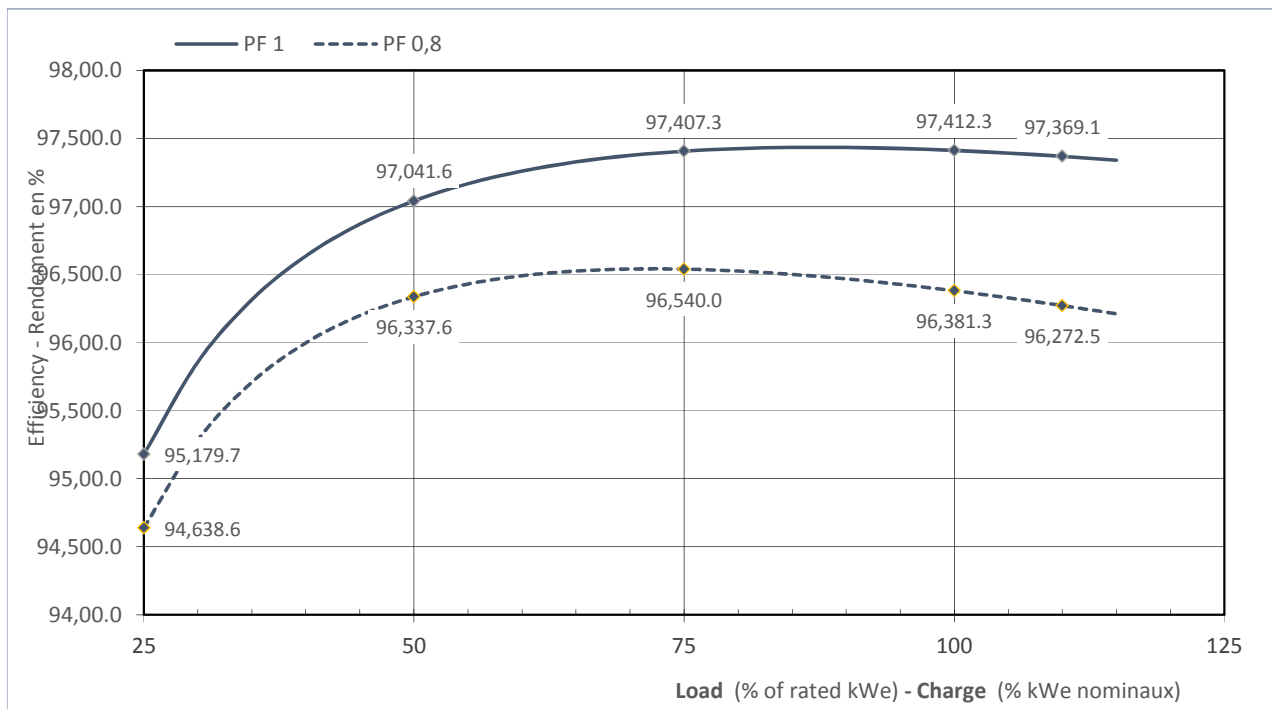
Capability Curve

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



Efficiency Curves

According to: IEC

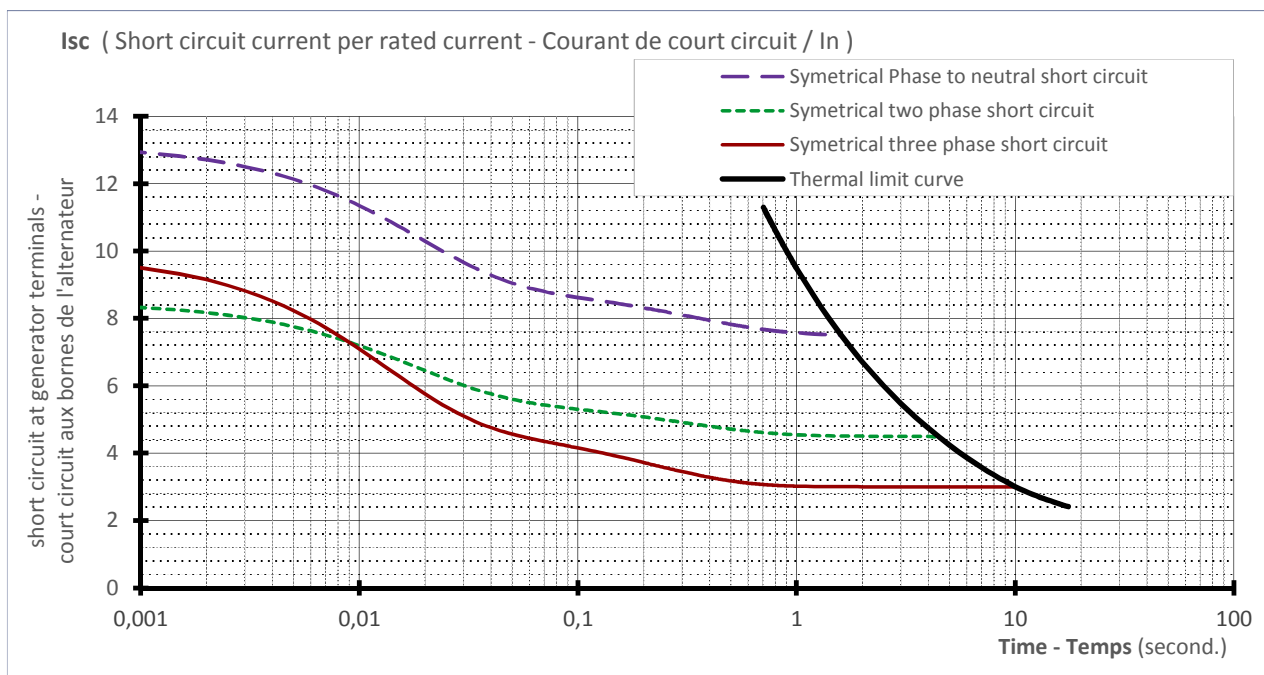


ALTERNATOR MAIN CURVES LSA 52.3 L12 / 4P

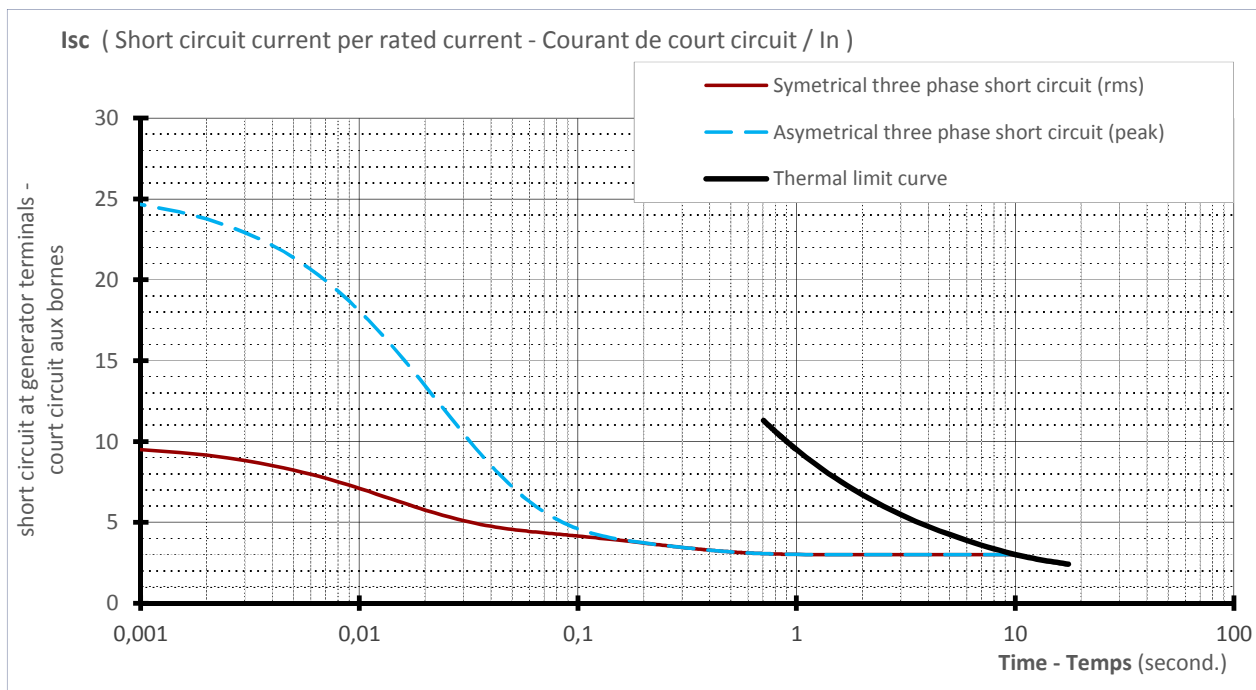
LS Reference: MB448-12-2017-1

Stator Current decrement curves

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



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

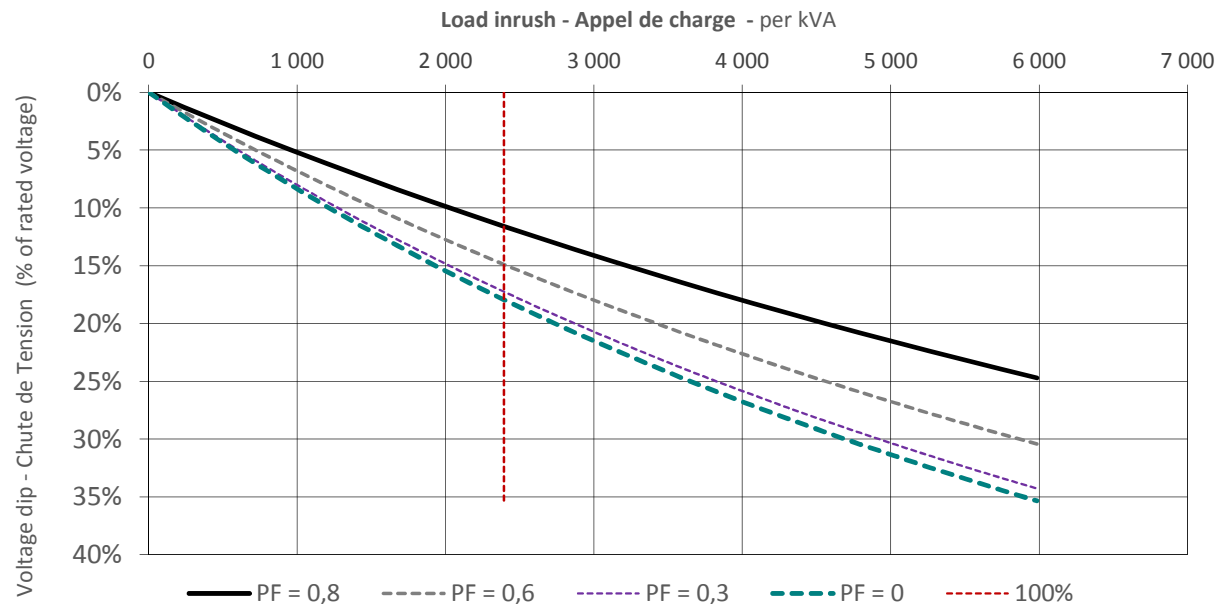


ALTERNATOR MAIN CURVES LSA 52.3 L12 / 4P

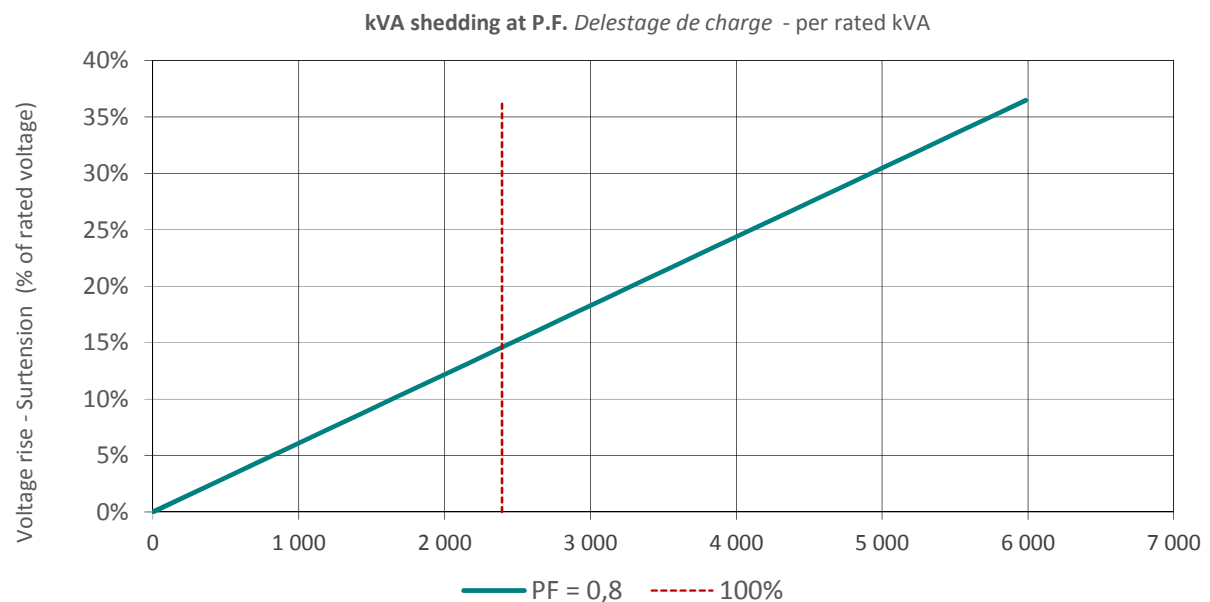
LS Reference: MB448-12-2017-1

Transient Voltage Variation

Transient voltage dip curve versus load impact



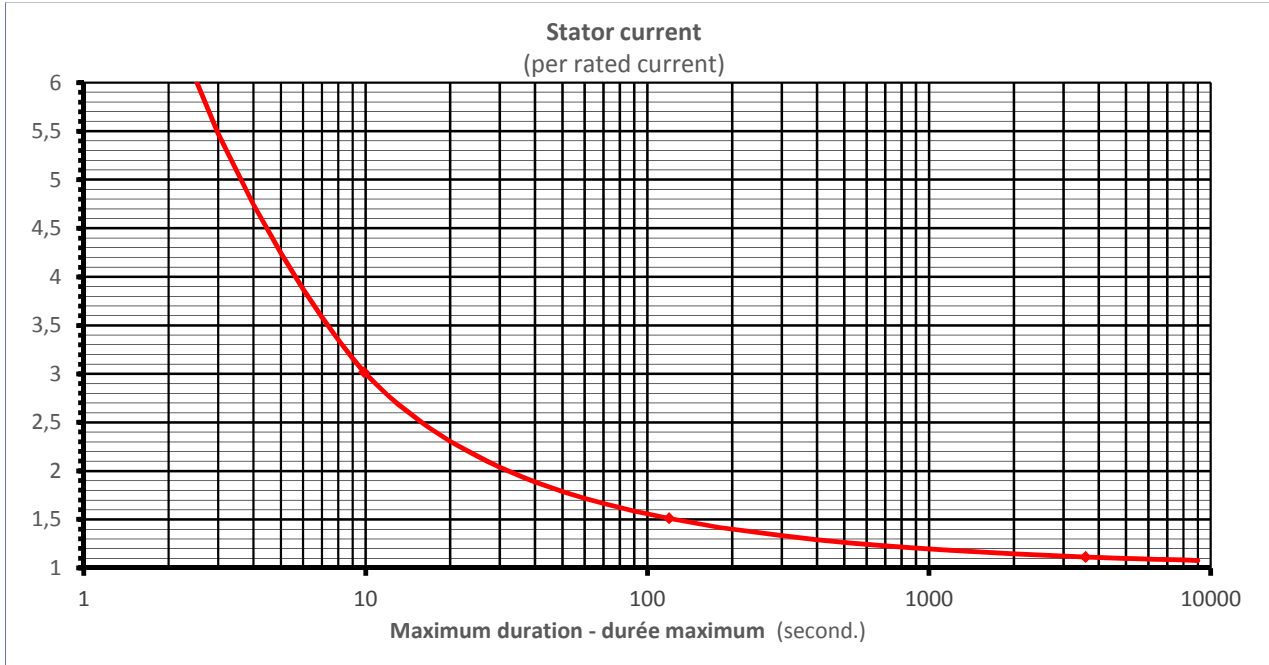
Transient voltage rise curve versus load rejection



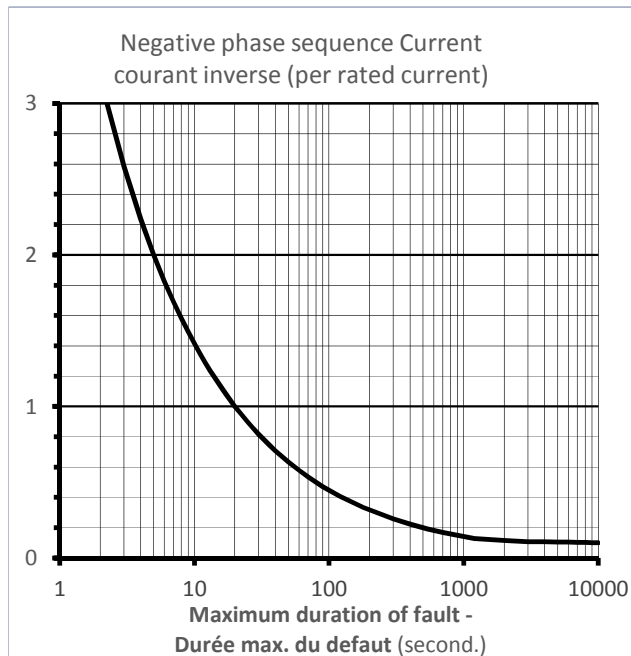
ALTERNATOR MAIN CURVES LSA 52.3 L12 / 4P

LS Reference: MB448-12-2017-1

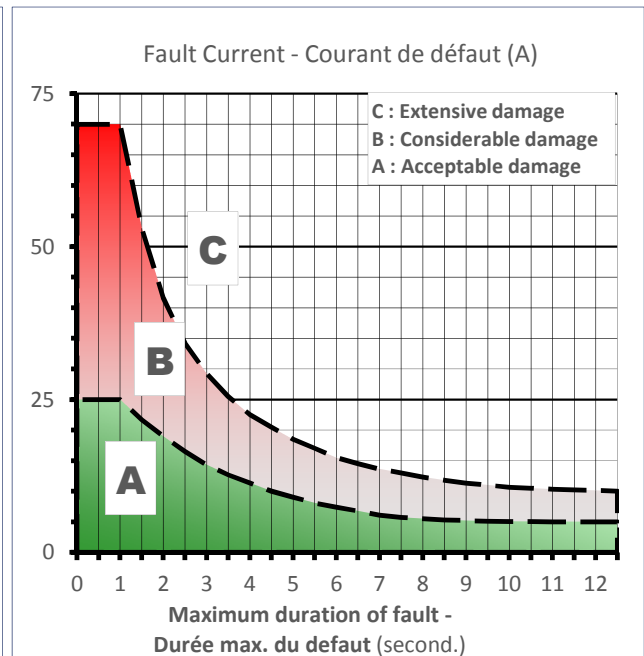
Thermal Damage Curve



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".

MTU Friedrichshafen GmbH

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Vorsitzender des Aufsichtsrates / Chairman of the Supervisory Board Axel Arendt

Geschäftsführung / Board of Management Andreas Schell (Vorsitzender / President and CEO), Marcus A. Wassenberg

Sitz der Gesellschaft / Domicile Friedrichshafen Handelsregister / Register Court Ulm, Nr. / No. HRB 630 227

Ust.-Ident.-Nr. / V.A.T. No. DE 811121844 Bankverbindung / Bank Details Deutsche Bank AG Stuttgart, (all currencies),

SWIFT/BIC DEUTDESSXXX, IBAN DE35 6007 0070 0162 9039 00 / Commerzbank AG Friedrichshafen, (EUR), SWIFT/BIC COBADEFF651, IBAN DE68 6514 0072 0170 0038 00

A Rolls-Royce Power Systems Company

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

A handwritten signature in black ink, appearing to be "C. Welz".

MTU Friedrichshafen GmbH
i.A. Robert Welz



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.”

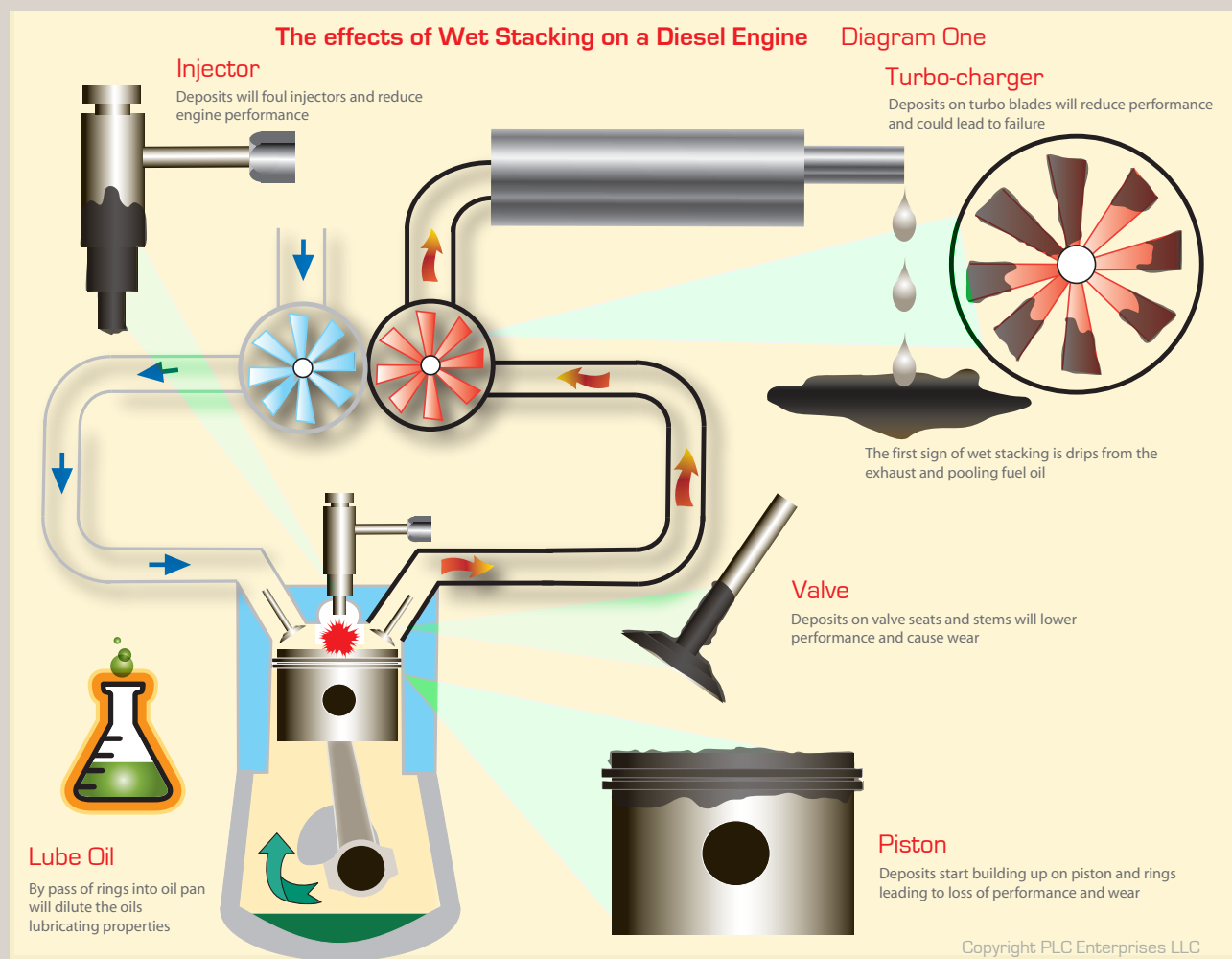
The National Fire Protection Agency (NFPA), in their NFPA 110 Code for Emergency and Standby Power Systems section 6 - 4.2 (1996 edition) refer to wet stacking as a field term indicating the presence of unburned fuel or carbon in the exhaust system. The later 1999 edition suggests a more quantitative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

The installation information provided in this information sheet is informational in nature only, and should not be considered the advice of a properly licensed and qualified electrician or used in place of a detailed review of the applicable National Electric Codes and local codes. Specific questions about how this information may affect any particular situation should be addressed to a licensed and qualified electrician.



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San Antonio
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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



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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YouTube: <http://www.youtube.com/CatPowerGeneration>

LEXE0832-00 October 2014

ANEXO D – DIAGRAMA UNILINEAL ELÉCTRICO

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QUICKSTART PROJECT 475 MW - CHILE
CENTRAL DE RESPALDO SAN JAVIER I
ESQUEMA UNIFILAR GENERADORES & CABINAS 23kV
GENERATING & 23 kV SINGLE LINE DIAGRAM
INDICE / INDEX

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HOJA/SHEET	DESCRIPCION/DESCRIPTION	REV	FECHA/DATE
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2	11BBA10-NAVE DE POTENCIA 11-CABINAS 23 kV / POWERHOUSE 11-23kV SWITCHGEAR	03	09.05.19

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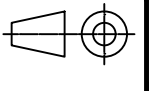
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02	ISSUED FOR CONSTRUCTION	LEA	M.P.A.	A.M.S.	24.04.19
01	UPDATED	LEA	M.P.A.	A.M.S.	24.01.19
00	FIRST ISSUED	M.G.D.	M.P.A.	A.M.S.	24.10.17
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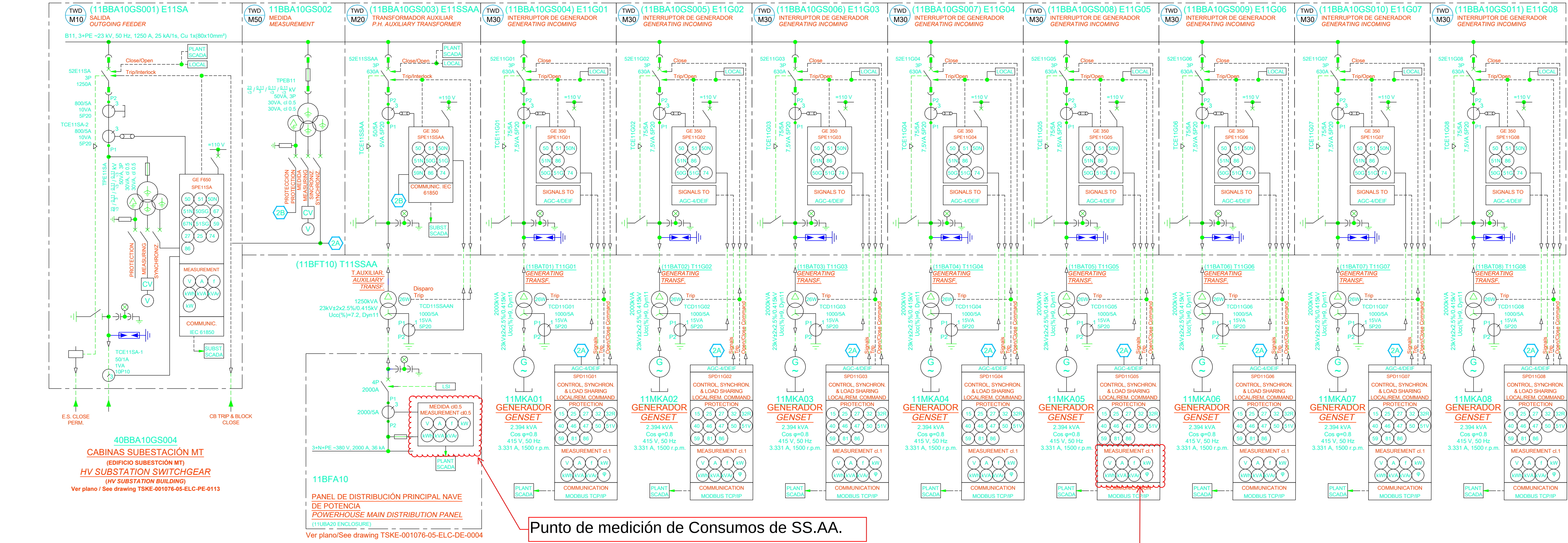
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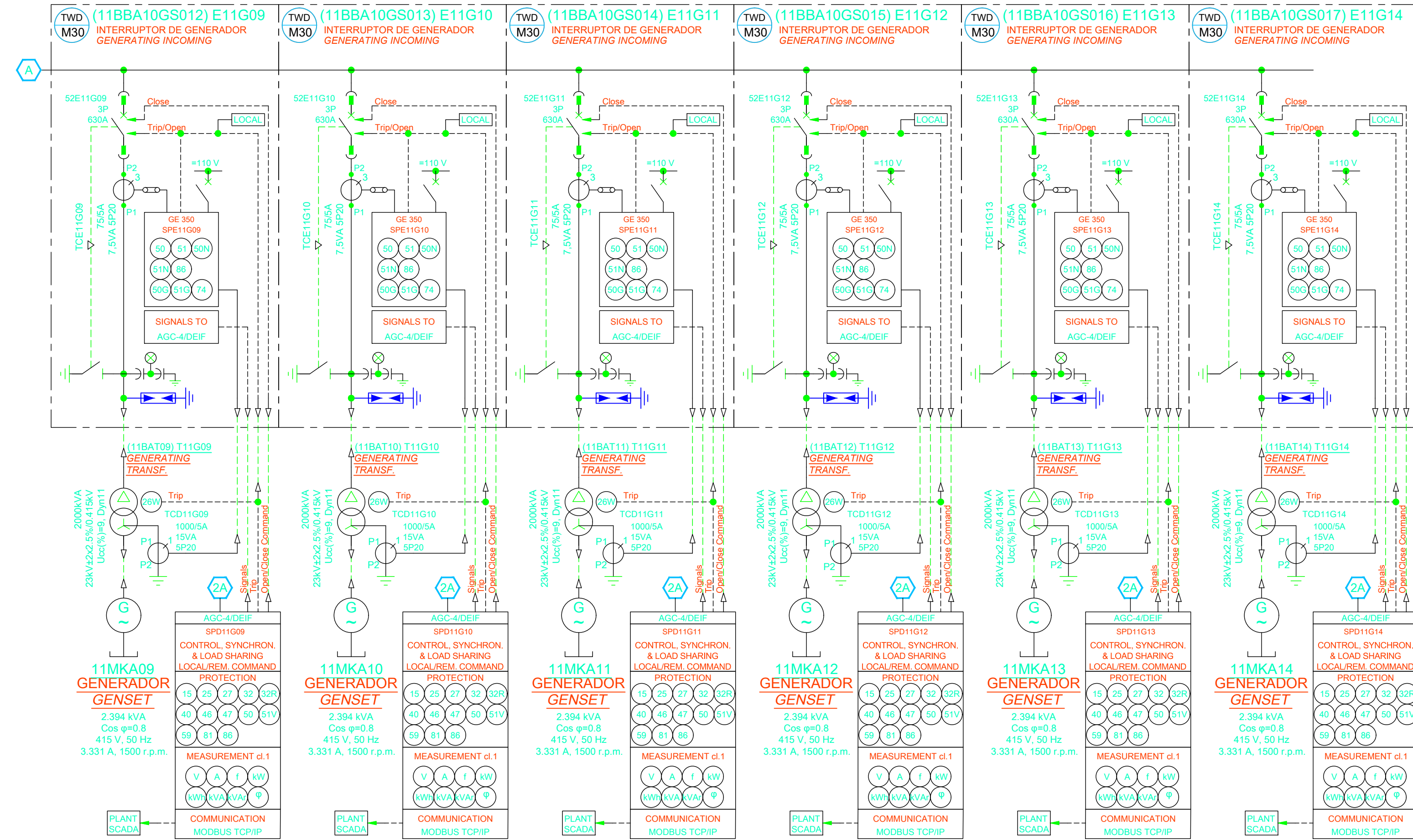
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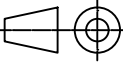
NAVE DE POTENCIA 11, CABINAS DE MT 23kV
POWERHOUSE 11, 23 kV SWITCHGEAR (11UBA10 ENCLOSURE)



Punto de medición de Consumos de SS.AA.

Potencia bruta puede ser medida como la suma de la potencia leída por cada medidor ubicado a la salida de los grupos electrogenos



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QUICKSTART PROJECT 475MW CHILE
CENTRAL DE RESPALDO SAN JAVIER I

ESQUEMA UNIFILAR 66kV & CABINAS 23kV
66kV & 23kV SINGLE LINE DIAGRAM
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2	ESQUEMA UNIFILAR EXTERIOR EHV 66/23kV / SINGLE LINE DIAGRAM OUTDOOR EHV 66/23kV	7	24.10.19
3	40BBA10-SUBESTACION AT-CABINA 23kV / 40BBA10 - HV SUBSTATION 23kV SWITCHGEAR	7	24.10.19

7	PRIME COMMENTS	C.M.L.	J.L.A.	R.A.R.	24.10.19
6	FOR CONSTRUCTION	C.M.L.	J.L.A.	R.A.R.	31.07.19
5	ISSUED FOR CONSTRUCTION	C.M.L.	J.L.A.	R.A.R.	06.04.19
4	ISSUED FOR CONSTRUCTION	C.M.L.	J.L.A.	R.A.R.	11.04.19
3	ACCORDING COMMENTS	M.B.G.	J.L.A.	R.A.R.	28.02.19
2	ACCORDING COMMENTS	M.B.G.	J.L.A.	R.A.R.	19.02.19
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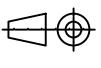
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QUICKSTART PROJECT 475MW - CHILE
CENTRAL DE RESPALDO SAN JAVIER I

DRAWING TITLE:
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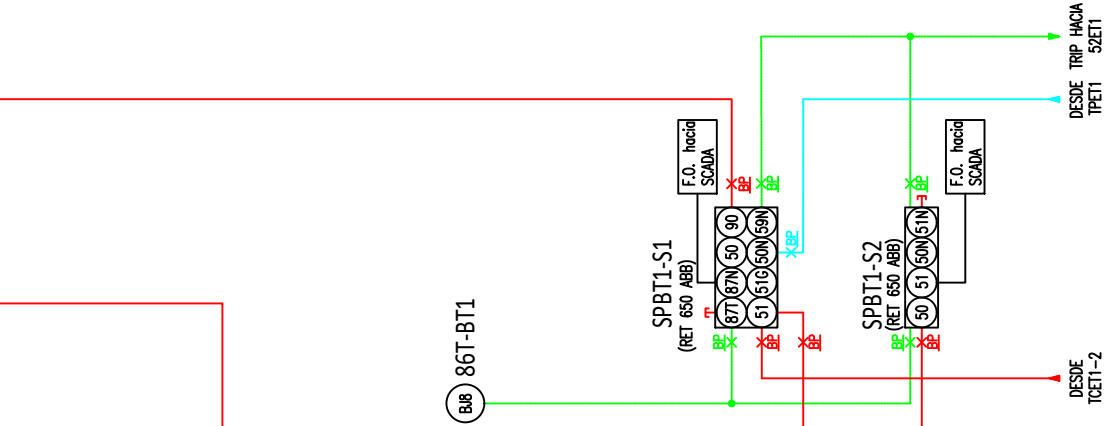
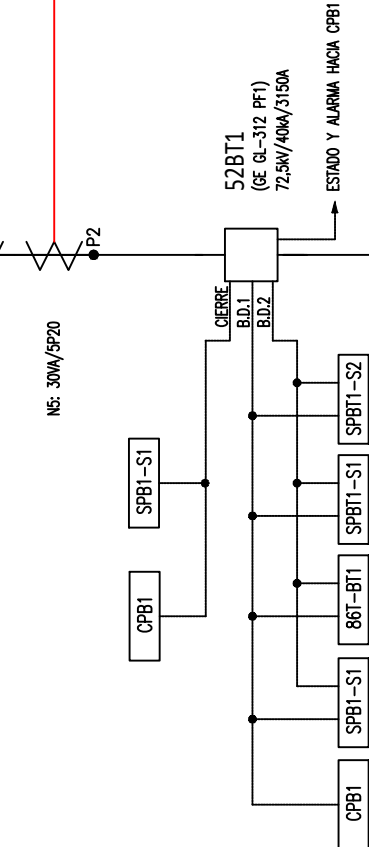
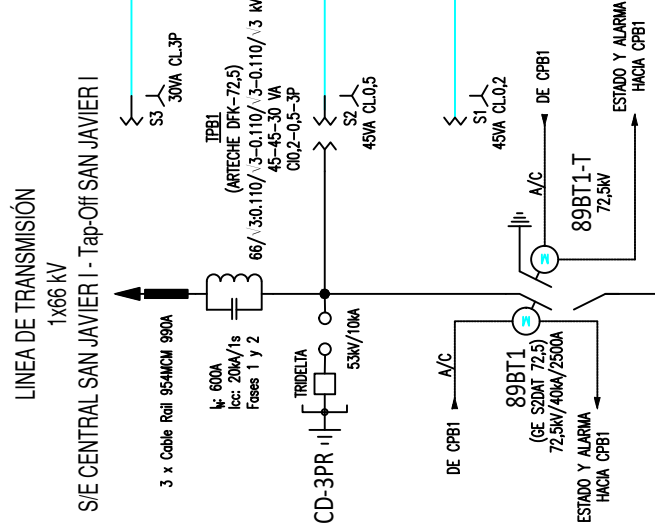
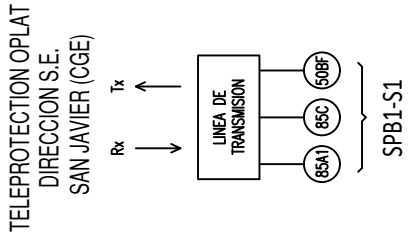
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(PRIME ENERGIA QUICKSTART)



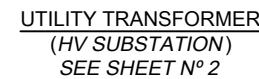
BUSBAR 23kV

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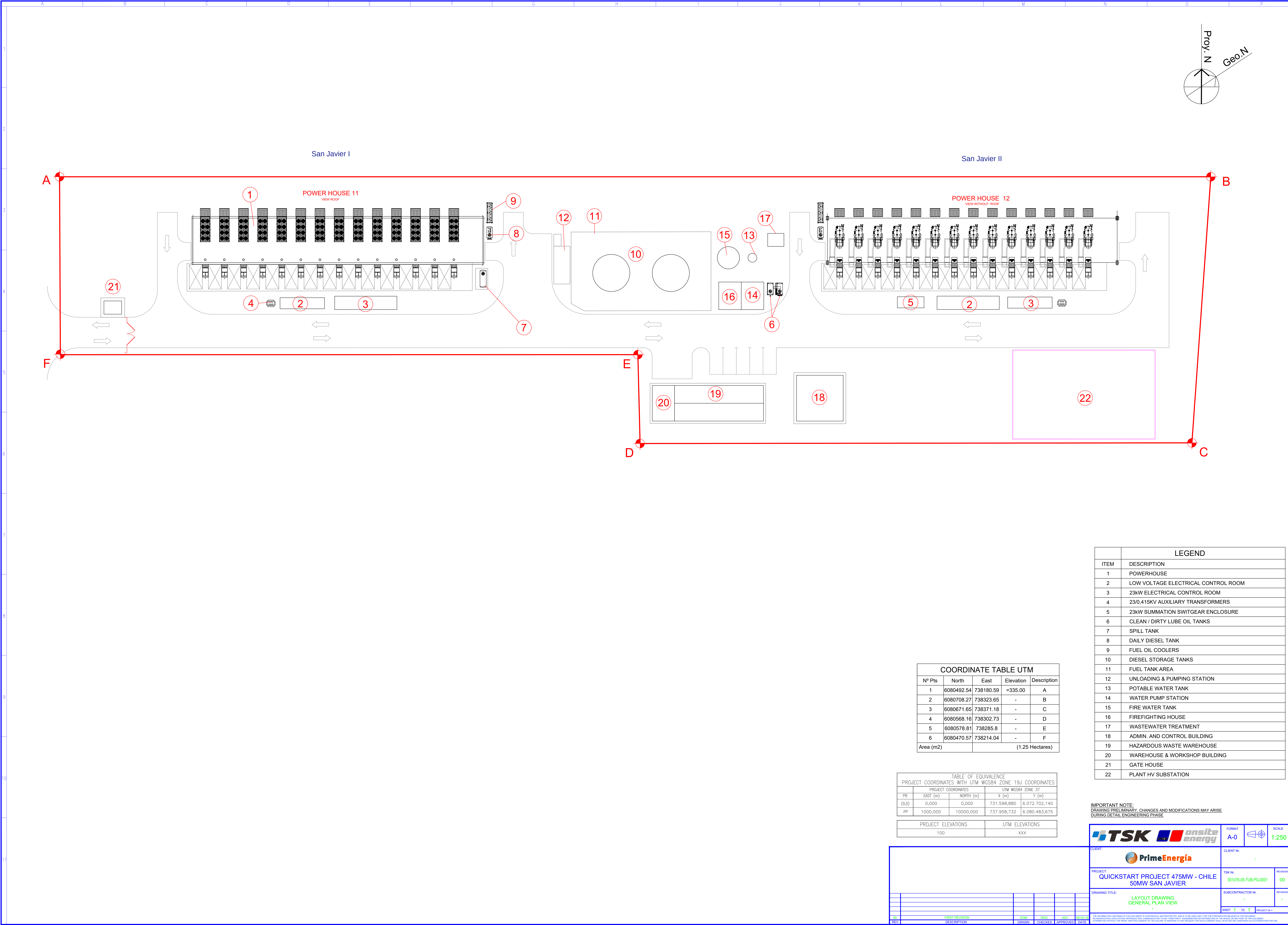
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	<table border="1"> <tr> <td>SHEET 02</td> <td>TO 03</td> <td>PROJECT N° =</td> </tr> </table>	SHEET 02	TO 03	PROJECT N° =	
SHEET 02	TO 03	PROJECT N° =			

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EDIFICIO SUBESTACIÓN DE MT, CABINAS DE MT 23 kV
HV SUBSTATION BUILDING, 23 kV SWITCHGEAR
CENTRAL DE RESPALDO SAN JAVIER I



ANEXO E – LAYOUT CENTRAL GENERADORA



COORDINATE TABLE UTM				
N° Pts	North	East	Elevation	Description
1	6080492.54	738180.59	≈335.00	A
2	6080708.27	738323.65	-	B
3	6080671.65	738371.18	-	C
4	6080568.16	738302.73	-	D
5	6080578.81	738285.8	-	E
6	6080470.57	738214.04	-	F
Area (m2)		(1.25 Hectares)		

TABLE OF EQUIVALENCE				
PROJECT COORDINATES WITH UTM WGS84 ZONE 19J COORDINATES				
PROJECT COORDINATES		UTM WGS84 ZONE 37		
PR	EAST (m)	NORTH (m)	X (m)	Y (m)
(0,0)	0,000	0,000	731.598,880	6.072.702,140
PP	1000,000	10000,000	737.956,732	6.080.483,675

PROJECT ELEVATIONS		UTM ELEVATIONS	
100		xxx	

LEGEND	
ITEM	DESCRIPTION
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

 		FORMAT		SCALE
		A-0		1:250
CLIENT		CLIENT N°		
 PrimeEnergía		-		
PROJECT:		TSK N°		REVISION
QUICKSTART PROJECT 475MW - CHILE		001076-05-TUB-PG-0001		00
50MW SAN JAVIER				
DRAWING TITLE:		SUBCONTRACTOR N°		REVISION
		-		-
LAYOUT DRAWING				
GENERAL PLAN VIEW				
		SHEET 1	TO 1	PROJECT N°
				-
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REV	DESCRIPTION	DRAWN	CHECKED	
00	FIRST REVIEW	EGM	RAZ	
				DATE

ANEXO F – 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	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: Manuf.: Leroy & Somer Type: LSA 52.3 L12 - 4 No.: 610132 / 23	Engine Manuf.: MTU Type: 16V/4000 G24F No.: 548100389	Page 1 von 1 Date: 06.02.2019 TB: Testbench B OP: AN 518285
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Time	Load	Frequency	Voltage	Current			Power Factor	Active Power	Fuel Consumption		Lube Oil		Coolant		Air System				Fuel	Speed/Requested Torque
				I (L1)	I (L2)	I (L3)	φ	P	Cons.	Spec.	Pressure	Temp.	Temp.	Pres.	Temp.	Temp.	Temp.	Pres.	Temp.	
min	%	Hz	V	A	A	A		kW	kg/h	g/kWh	Before Engine ECU bar	Before Engine °C	After Engine ECU °C	After Engine ECU bar	Air Before Engine °C	Water before Inter-Cool. ECU °C	Air before Zyl. ECU °C	Air Bef. Zyl. abs. ECU bar	Before Engine °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
Acceptance run																				
5 min	0-100	50,0	415	2587	2610	2623	1,00	1872	388,80	207,69	6,57	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		13,5	1500 / 13441

Step load test after start:	Speed shifting area from 480 Hz to 513 Hz	Overspeed - Shutdown at 1950 1/min.
Switch on: 50% Load after 10 sec	Run-up time from start order to 50 Hz in 6 s	Lube Oil Pressure Warning 3,5 bar, Shutdown 3,2 bar
75% Load after 13 sec	Coolwater Temp. Warning 102 °C; Shutdown 104 °C	Fuel Pressure before Filter Warning 4,3 bar, Shutdown 3,8 bar
100% Load after 26 sec	Coolwater Intercooler Temp. Warning 75 °C; Shutdown 78 °C	Fuel Temp. Warning 110 °C; Shutdown 115 °C
Switch off: 100 - 0% Load after 31 sec		

Engine-shutdown through security equipment if lube oil pressure ≤ 1 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)
Signature Test Bench MTU Onsite Energy Systems GmbH	Signature Quality Department MTU Onsite Energy Systems GmbH Gayer Patrick	Signature buyer/customer

MTU Onsite Energy Systems GmbH
Rothacher Straße 1
94099 Burstorf, Germany

Lastlauf / Load Test (500ms)

