Project Report

ENEL-371

Power System Design

Grain Processing Facility

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April 10, 2023

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1.1 Project Overview

For this project, we are required to assist in establishing a wheat manufacturing facility in Saskatchewan, Canada by an international company – From Field to Table. This facility will be used for grain processing which includes loading/unloading, storage, cleaning, drying, hulling, and milling in order to produce flour. The milling process is a delicate one and it cannot be interrupting for more than 10 seconds once it begins. Due to this, the project requires an emergency generator to the milling equipment. The client also requires that the lighting should also energized from the generator as well for life safety reliability. We will also be provided with a 25kV feed from SaskPower which will power the facility but the owner will purchase the Main Service Transformer. This project will require several stages involving planning, design, procurement, construction, and commissioning. For our planning stage, we will determine the scope of work, objectives, and deliverables. Procurement will involve selecting and purchasing the required equipment and materials. This will be determined based off the load list provided from the client. Overall, the project aims to establish a state-of-the-art wheat manufacturing facility that will meet the client's needs while ensuring safety and reliability and complying with the CEC as well as other safety and regulatory requirements.

1.2 Design Philosophy

1.2.1 First Design

My initial design philosophy involved reducing costs as much as possible to avoid the client having to spend as much money as possible. I initially made use of very few transformers and looked to group as many loads together regardless of whether they were of different areas of the grain processing facility. Because of this, I had lines running from the grain processing area to the main office and this proved to be quite costly. I also included 3 generators as well which proved to be a lot more costly than having less transformers.

1.2.2 Second Design

After supervisor review, I changed my original design philosophy to look to make the power system a lot more reliable and slightly more costly. The idea being while the cost might be higher than originally intended it would result in a more reliable and scalable long-term product with less points of failure. I decided that if in the future, a transformer was to potentially fail it would be better to have more transformers to share the load and reduce points of failure. Also, it is better to have to spend the extra money prior and make the system more reliable since if in the future a transformer fails and requires replacement it would require more money to make that possible. I have a few transformers that also are not loaded very heavily since I felt that if in the future the client wanted to have additional loads added to the transformer, they would have that option. This is something that I had to carefully consider since transformers operate at their best efficiency at 50% to 60% load. Some of the 600V to 208V transformers are loaded quite lightly and this choice was made to ensure future scalability. I also chose to have multiple 600V to 208V, Delta – Wye transformers since I felt that the neutral line voltage of 120V is quite beneficial for the client to have – especially for lumped loads. In the future, if they felt they needed other 208V loads in the future, then they also have that option to add those loads if needed.

1.3 System Reliability

1.3.1 Points of Failure

In terms of system reliability, after having my initial design philosophy reviewed and correcting major issues such as having multiple points of failure, I feel that my system is quite reliable. Prior to this iteration of design, my system had too many points of failure and if one transformer were to fail it would cause close to half of the system to also fail. This was corrected by adding additional transformers to share loads. This was done in two ways – firstly by using transformers to separate the Grain Processing Area (GPA) and Office and secondly to ensure less points of failure. The first reason essentially allows the GPA to be self reliant on not dependent on the Office at all since they have their own transformers to operate their own sub-systems. It is also important to note that if a breaker were to trip or potentially fail in one area, a technician does not need to go to a different facility in the grain manufacturing plant to fix it. If a breaker fails in the GPA, then they can stay within the GPA area to fix the breaker. The only exception to this being the MUA-OFF motor load, which is responsible for air conditioning/heating system for the Office. This was kept closer to the 600V GPA motor loads. Furthermore, I also corrected the multiple points of failure by making use of a few 600/208V, Delta – Wye transformers in order to separate loads. I kept many of the lumped loads in their own transformers, for example the general-purpose loads for the GPA are kept on their own to ensure if they fail, they do not result in the Office area general purpose loads also failing. Furthermore, I kept the general-purpose, lighting and the exhaust fan (EX-FAN) motor loads tied together on a separate transformer for the same reason. To ensure if they fail then they are not in any way connected to the GPA and will not result in any points of failure. The last main point of reliability is the emergency power generator, I chose to use a 600/347, Diesel generator with a standby power of up to 1500kW. This is a lot more power than we need, but in terms of scalability if we need to add more loads to the transfer switch this will be able to support that. My transfer switch is connected to a 600/347V distribution system which also connects to another 600/208V, Delta – Wye transformer which is responsible for powering the lights for the office.

1.3.2 Overcurrent Protection

The most important aspect of overcurrent protection is to ensure that we correctly size our devices to account for any potential overcurrent as well as proper selection of protection devices. According to the Canadian Electrical Code's guidelines, I made sure that our breakers are 250% of the full load current for all motor loads. For transformers, the breakers are based on the minimum current ampacity value and must be 125% of the full load current. It is always safe to go slightly over the MCA for the transformers to account for potential overcurrent. I made sure to follow standard breaker sizes for these as well. Conductor sizing also needs to be done correctly to ensure that it can handle the full load current value that each motor load carries. It is general practice to choose a larger full load ampacity when sizing the conductors. For example, if we have a FLA of 75A but it is not available on Table 2 of the CEC code then we can choose an FLA of 85 to select our conductor size. This is crucial since we can cause serious damage to our motor loads, transformers, distribution systems and overall power system if we do not do account for this overcurrent.

1.4 Risk/Hazard Assessment & Mitigation Strategy according to CEC regulations

Risk	Mitigation
Equipment not suitable for hazardous location	Ensure all equipment is marked for the specific hazardous location (Class and Division) in which it will be installed
Maximum surface temperature exceeds ignition temperature	Ensure the maximum surface temperature rating marked on equipment does not exceed the minimum ignition temperature or lower of the dust cloud or dust layer ignition temperature for the hazardous location in which the equipment will be installed
Inadequate sealing of equipment for use with specific gas	Ensure that all equipment used with butadiene, ethylene oxide, or propylene oxide is isolated in

	accordance with Rule J18-108 1) by sealing all conduit 16 trade size or larger
Use of equipment not marked for specific dust	Ensure all equipment marked for Class II locations has markings for the specific dust indicated by one or more of the following atmospheric group designations: Group E, consisting of combustible metal dust; Group F, consisting of carbon black, coal, or coke dust; or Group G, consisting of flour, starch, or grain dust
Identify and analyze potential sources of flammable volatile liquids, flammable gases, or vapors that may be handled, processed, or used in the area.	Implement measures to minimize the release of flammable liquids, gases, or vapors into the environment, including the use of closed containers and systems.
Conduct a ventilation assessment to ensure that the area has adequate ventilation to prevent the accumulation of significant quantities of vapour-air or gas-air mixtures in concentrations above 25% of their lower flammable limit (LFL).	Implement measures to prevent ignition sources in the area, such as spark-resistant tools and equipment.
Identify potential sources of combustible dust and conduct a hazard assessment to determine whether dangerous concentrations of suspended dust are likely in the area.	Implement effective ventilation systems to prevent the accumulation of flammable gases and vapors.
Implement effective dust control measures to prevent the formulation of explosive or ignitable concentrations of suspended dust.	Use non-sparking electrical equipment in the area, and ensure that all electrical wiring and equipment are properly grounded and bonded.
The type and quantity of flammable substances or dust in the location	Use enclosed containers or systems to confine flammable substances or dust as much as possible.
The potential sources of ignition, such as electrical equipment or static electricity	Ensure that buildings or areas are adequately ventilated to prevent the accumulation of significant quantities of flammable substances or dust.
The likelihood of the formation of explosive or ignitable mixtures due to normal or abnormal operating conditions	Implement effective dust control equipment and preventive measures to prevent the formation of explosive or ignitable concentrations of suspended dust.

1.5 Project Summary

During the design process of a grain processing facility's power system, I learned the importance of balancing cost and reliability. Initially, I prioritized cost reduction and grouped loads together, resulting in expensive lines and too few transformers, which led to many points of failure. After supervisor review, I changed my design philosophy to prioritize system reliability, resulting in additional transformers to share loads and fewer points of failure. I also ensured the overcurrent protection was correctly sized and selected, following the Canadian Electrical Code's guidelines. By balancing cost and reliability, the power system became more scalable, efficient, and less prone to failure.

Appendix A – Load List

"From Field to Table" Motor List												
Equipment ID	Quantitiy of motors	kW	HP	V	PH	FLA	MCA	BREAKER	EMERGENCY POWER REQ'D	LOCATION (BUILDING)	PROCESS	CONDUCTOR SPECIFICATIONS (use MCA)
CONV-UL	2	11.60	10	208	3Ph	32.2	40.25	80.50	N	GPA (Grain Processing Area)	Unloading conveyor motor	3 x #10 + bond
AU-UL	3	6.32	5	120	1Ph	30.4	38.00	76.00	N	GPA	Unloading auger	1 x #10 + bond
CONV-LO	2	11.10	10	208	3Ph	30.8	38.50	77.00	N	GPA	Loading conveyor motor	3 x #10 + bond
AU-LO	3	6.32	5	120	1Ph	30.4	38.00	76.00	N	GPA	Loading auger	1 x #12 + bond
WASHER	2	26.60	30	480	3Ph	32	40.00	80.00	N	GPA	Washing Process	3 x #8 + bond
DRYER	2	49.88	-	480	3Ph	60	75.00	150.00	N	GPA	Drying Process	3 x #4 + bond
HULL	2	129.90	125	600	3Ph	125	156.25	312.50	N	GPA	Hulling Process	3 x #00 + bond
MILL	2	80.02	75	600	3Ph	77	96.25	192.50	Y	GPA	Milling Process	3 x #3 + bond
MUA-GPA	1	102.88	100	600	3Ph	99	123.75	247.50	N	GPA	Air conditioning/Heating System	3 x #0 + bond
MUA-OFF	1	54.04	50	600	3Ph	52	65.00	130.00	N	Office Building	Air conditioning/Heating System	3 x #6 + bond
EX-FAN	3	1.33	3/4	120	1Ph	6.4	8.00	16.00	N	Office Building	Exhaust Fan	1 x #14 + bond
WATER-OFF	1	11.10	10	208	3Ph	30.8	38.50	77.00	N	Office Building	Water Pump	3 x #20 + bond

Table 1. Load list provided from client "From Field to Table"

"From Field to Table" Lumped Load List										
Equipment ID	**Quantitiy of Loads**	**kW**	**V**	**PH**	**FLA**	**BREAKER** *(see below)*	**EMERGENCY POWER REQ'D**	**LOCATION (BUILDING)**	**PROCESS**	**CONDUCTOR SPECIFICATIONS** *(conductors must match breaker size)*	**Combined kVA**
General Purpose	3	1.2	120	1	10	15	N	GPA (Grain Processing Area)	Interior and exterior plugs	1 x #14 + bond	3.6
General Purpose	3	1.4	120	1	11.6667	15	N	Office Building	Workstations, plugs etc.	1 x #14 + bond	4.2
Lighting	3	0.6	347	1	1.72911	15	Y	GPA (Grain Processing Area)	Lighting in building	1 x #14 + bond	1.8
Lighting	3	0.6	120	1	5	15	Y	Office Building	Lighting in office	1 x #14 + bond	1.8
Office Kitchen	3	1.6	120	1	13.3333	20	N	Office Building	Kitchen area in office building	1 x #14 + bond	4.8

Table 2. Lumped load list provided from client "From Field to Table"

Appendix B – Transformer Chart

"From Field To Table" Transformer Chart												
Equipment ID	**KVA**	**V(p)**	**V(s)**	**XFMR CONFIG**	**FLA(p)**	**MCA(p)**	**BREAKER (p)**	**CONDUCTORS (p)**	**FLA(s)**	**MCA(s)**	**CONDUCTORS SPECS (s)**	**TOTAL CONNECTED LOAD**
Transformer Name	kVA Rating	Primary	Secondary	Delta or Wye (Primary & Secondary)	Primary	Primary	Primary	Primary	Secondary	Secondary	Secondary	kW (Primary = Secondary)
Transformer 1	**150**	600	208	Delta-Wye	144.33757	180.421959	200	3 x #000 + bond	416.358367	520.447959	3 x #1000 + bond	83.32
Transfomer 2	300	600	480	Delta-Delta	288.67513	360.843918	375	3 x #500 + bond	360.843918	451.054898	3 x #700 + bond	152.8
Transformer 3	9	600	208	Delta-Wye	8.660254	10.8253175	15	3 x #14 + bond	24.981502	31.2268775	3 x #10 + bond	3.6
Transformer 4	30	600	208	Delta-Wye	28.867513	36.0843918	45	3 x #8 + bond	83.2716734	104.089592	3 x #2 + bond	13
Transformer 5	3	600	208	Delta-Wye	2.8867513	3.60843918	15	3 x #14 + bond	8.32716734	10.4089592	3 x #14 + bond	1.8

Table 3. Transformer chart w/ conductor sizing

Appendix C – Transformer Calculations

Design Project Calculations

Date

Sample Calculation for T-1:

total connected load: 83.32 kW

KVA Rating chosen: 150 kVA

$\frac{83.32\ kW}{150\ kVA} \times 100\% = 55.5\%$ loaded

- Leaves Capacity of 44.5% for potential loads

FLA Primary for T-1:

$FLA\ (I_p) = (150\ kVA / 600V) / \sqrt{3}$
$= 144A$

$MCA = 144A \cdot 1.25 = 180.4A$

- 200A breaker size chosen

Date

Emergency Generator Calculations:

total connected load = 163.6 kW

kVA rating chosen = 275 kVA

$\frac{163.6\ kW}{275\ kVA} \times 100\% = 59.5\%$

- leaves capacity of 40.51% for potential loads

Appendix D – Generator Cutsheet

Power Generation

Diesel Generator Set Model DFMB 60 Hz

1500 kW, 1875 kVA Standby
1250 kW, 1563 kVA Prime

Description

The Cummins Power Generation DF-series commercial generator set is a fully integrated power generation system providing optimum performance, reliability, and versatility for stationary standby or prime power applications.

A primary feature of the DF GenSet is strong motor-starting capability and fast recovery from transient load changes. The torque-matched system includes a heavy-duty Cummins 4-cycle diesel engine, an AC alternator with high motor-starting kVA capacity, and an electronic voltage regulator with three-phase sensing for precise regulation under steady-state or transient loads. The DF GenSet accepts 100% of the nameplate standby rating in one step, in compliance with NFPA110 requirements.

The standard PowerCommand® digital electronic control is an integrated system that combines engine and alternator controls for high reliability and optimum GenSet performance.

Optional coolant heaters improve starting in extreme operating conditions. A wide range of options, accessories, and services are available, allowing configuration to your specific power generation needs.

Every production unit is factory tested at rated load and power factor. This testing includes demonstration of rated power and single-step rated load pickup. Cummins Power Generation manufacturing facilities are registered to ISO9001 quality standards emphasizing our commitment to high quality in the design, manufacture, and support of our products. The generator set is CSA certified, and the PowerCommand control is UL508 listed.

All Cummins Power Generation systems are backed by a comprehensive warranty program and supported by a worldwide network of 170 distributors and service branches to assist you with warranty, service, parts, and planned maintenance support.

Features

- **UL Listed Generator Set** - The complete generator set assembly is available Listed to UL2200.
- **Cummins Heavy-Duty Engine** - Rugged 4-cycle industrial diesel delivers reliable power, low emissions, and fast response to load changes.
- **Permanent Magnet Generator (PMG)** - Offers enhanced motor starting and fault clearing short circuit capability.
- **Alternator** - Several alternator sizes offer selectable motor starting capability with low reactance 2/3 pitch windings; low waveform distortion with non-linear loads, fault clearing short-circuit capability, and class H insulation.
- **Control System** - The PowerCommand electronic control is standard equipment and provides total genset system integration, including automatic remote starting/stopping, precise frequency and voltage regulation, alarm and status message display, AmpSentry™ protection, output metering, auto-shutdown at fault detection, and NFPA 110 compliance.
- **Cooling System** - Provides reliable running at rated power in ambient temperatures through 50°C.
- **Structural Steel Skid Base** - Robust skid base supports the engine, alternator, and radiator.
- **E-Coat Finish** - Dual electro-deposition paint system provides high resistance to scratches, corrosion, or fading.
- **Certifications** - Generator sets are designed, manufactured, tested, and certified to relevant UL, NFPA, ISO, IEC, and CSA standards.
- **Warranty and Service** - Backed by a comprehensive warranty and world wide distributor network.

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Generator Set

The general specifications provide representative configuration details. Consult the outline drawing for installation design.

Specifications – General

See outline drawing 500-2966 for installation design specifications.

Unit Width, in (mm)	89.6 (2277)
Unit Height, in (mm)	98.7 (2507)
Unit Length, in (mm)	222.5 (5652)
Unit Dry Weight, lb (kg)	24200 (10977)
Unit Wet Weight, lb (kg)	25470 (11553)
Rated Speed, rpm	1800
Voltage Regulation, No Load to Full Load	±0.5%
Random Voltage Variation	±0.5%
Frequency Regulation	Isochronous
Random Frequency Variation	±0.25%
Radio Frequency Interference	IEC 801.2, Level 4 Electrostatic Discharge IEC 801.3, Level 3 Radiated Susceptibility IEC 801.4, Level 4 Electrical Fast Transients IEC 801.5, Level 5 Voltage Surge Immunity MIL STD 461C, Part 9 Radiated Emissions (EMI)

Cooling	Standby	Prime
Fan Load, HP (kW)	75.0 (56.0)	75.0 (56.0)
Coolant Capacity with radiator, US Gal (L)	102.0 (386.1)	102.0 (386.1)
Coolant Flow Rate, Gal/min (L/min)	535.0 (2025.0)	535.0 (2025.0)
Heat Rejection To Coolant, Btu/min (MJ/min)	55500.0 (58.8)	46375.0 (49.2)
Heat Radiated To Room, Btu/min (MJ/min)	16930.0 (17.9)	14320.0 (15.2)
Maximum Coolant Friction Head, psi (kPa)	15.0 (103.4)	15.0 (103.4)
Maximum Coolant Static Head, ft (m)	60.0 (18.3)	60.0 (18.3)

Air		
Combustion Air, scfm (m^3/min)	4100.0 (116.0)	3300.0 (93.4)
Alternator Cooling Air, scfm (m^3/min)	6720.0 (190.2)	6720.0 (190.2)
Radiator Cooling Air, scfm (m^3/min)	68000.0 (1924.4)	68000.0 (1924.4)
Max. Static Restriction, in H_2O (Pa)	0.5 (124.5)	0.5 (124.5)

Rating Definitions

Standby Rating based on: Applicable for supplying emergency power for the duration of normal power interruption. No sustained overload capability is available for this rating. (Equivalent to Fuel Stop Power in accordance with ISO3046, AS2789, DIN6271 and BS5514). Nominally rated.
Prime (Unlimited Running Time) Rating based on: Applicable for supplying power in lieu of commercially purchased power. Prime power is the maximum power available at a variable load for an unlimited number of hours. A 10% overload capability is available for limited time. (Equivalent to Prime Power in accordance with ISO8528 and Overload Power in accordance with ISO3046, AS2789, DIN6271, and BS5514). This rating is not applicable to all generator set models.
Base Load (Continuous) Rating based on: Applicable for supplying power continuously to a constant load up to the full output rating for unlimited hours. No sustained overload capability is available for this rating. Consult authorized distributor for rating. (Equivalent to Continuous Power in accordance with ISO8528, ISO3046, AS2789, DIN6271, and BS5514). This rating is not applicable to all generator set models.

Site Derating Factors

Rated power available up to 4000 ft (1220 m) at ambient temperatures up to 104°F (40°C). Above 4000 ft (1220 m), derate at 4% per 1000 ft (305 m) and 1% per 10°F (2% per 11°C) above 104°F (40°C).

Engine

Cummins heavy duty diesel engines use advanced combustion technology for reliable and stable power, low emissions, and fast response to sudden load changes.

Electronic governing provides precise speed regulation, especially useful for applications requiring constant (isochronous) frequency regulation such as Uninterruptible Power Supply (UPS) systems, non-linear loads, or sensitive electronic loads. Optional coolant heaters are recommended for all emergency standby installations or for any application requiring fast load acceptance after start-up.

Specifications – Engine

Base Engine	Cummins Model KTTA50-G2, Series Turbocharged and Aftercooled, diesel-fueled
Displacement in^3 (L)	3067.0 (50.3)
Overspeed Limit, rpm	2100 ±50
Regenerative Power, kW	168.00
Cylinder Block Configuration	Cast iron, 60° V 16 cylinder
Cranking Current	1280 amps at ambient temperature of 32°F (0°C)
Battery Charging Alternator	45 amps
Starting Voltage	24-volt, negative ground
Lube Oil Filter Types	Five spin-on, full flow
Standard Cooling System	122°F (50°C) ambient radiator

Power Output	**Standby**	**Prime**
Gross Engine Power Output, bhp (kWm)	2220.0 (1656.1)	1855.0 (1383.8)
BMEP at Rated Load, psi (kPa)	313.0 (2158.1)	263.0 (1813.3)
Bore, in. (mm)	6.25 (158.8)	6.25 (158.8)
Stroke, in. (mm)	6.25 (158.8)	6.25 (158.8)
Piston Speed, ft/min (m/s)	1875.0 (9.5)	1875.0 (9.5)
Compression Ratio	13.9:1	13.9:1
Lube Oil Capacity, qt. (L)	160.0 (151.4)	151.0 (142.9)
Fuel Flow		
Maximum Fuel Flow w/c180, US Gal/hr (L/hr)	193.0 (730.5)	193.0 (730.5)
Maximum Fuel Flow w/c174, US Gal/hr (L/hr)	260.0 (984.1)	260.0 (984.1)
Maximum Inlet Restriction, in. Hg (mm Hg)	4.0 (101.6)	4.0 (101.6)
Maximum Return Restriction, in. Hg (mm Hg)	6.5 (165.1)	6.5 (165.1)
Air Cleaner		
Maximum Air Cleaner Restriction, in. H_2O (kPa)	25.0 (6.2)	25.0 (6.2)
Exhaust		
Exhaust Flow at Rated Load, cfm (m^3/min)	10505.0 (297.3)	8330.0 (235.7)
Exhaust Temperature,°F (°C)	870.0 (465.6)	850.0 (454.4)
Max Back Pressure, in. H_2O (kPa)	41.0 (10.2)	41.0 (10.2)

Fuel System	Direct injection, number 2 diesel fuel, fuel filter; automatic electric fuel shutoff

Fuel Consumption		**Standby**				**Prime**			
60 Hz Ratings, kW (kVA)		**1500 (1875)**				**1250 (1563)**			
	Load	1/4	1/2	3/4	Full	1/4	1/2	3/4	Full
	US Gal/hr	27.7	54.2	78.5	103.3	24.2	46.2	66.5	86.9
	L/hr	105	205	297	391	92	175	252	329