Alternating Current (AC)
Study/Report

Cyclone Generation Substation
Burns & McDonnell

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Introduction

Station service transformers are required to provide power to all substation auxiliary alternating current (AC) loads. Calculating the power rating of an AC service transformer requires load power consumption data, but the size is not determined strictly by adding all available loads consequently yielding overly conservative results. To properly size the transformer, some electric loads are multiplied by a diversity factor, which scales the load to a value dependent on usage probability. For example, the chances that all receptacles will be used at any one instant at rated power will likely not happen; therefore, the receptacle loads would be multiplied by a very small diversity factor. Another factor to consider is the climate. In winter, there will primarily be heating loads, and conversely, the summer would primarily be HVAC or transformer fan loads. The objective of this study is to calculate the required station service transformer size to supply the Cyclone substation under an assumed worst-case scenario.

System Design

Energized Substation AC Loads

The following table displays the apparent power rating of auxiliary equipment in the substation. In the last three columns, the total, winter, and summer VA show the predicted loads, and each column is individually summed. The total VA sum portrays a loading scenario for the substation where every load is used simultaneously at rated power; this scenario is assumed to be infeasible considering the diversity factors for both the winter and summer scenarios are neglected. The winter and summer VA totals account for ambient temperatures by reducing temperature dependent loads from the total to more accurately mimic power consumption seen in each season, and additionally, various diversity factors have been integrated independent of temperature accounting for the probabilistic nature of some loads including receptacles.

Table 2-1 Energized Substation AC Loads

Load Description	QTY	Volts Req'd	VA Rating	Diversity Factor (DF)		Total VA	Winter VA	Summer VA
				Winter	Summer			
Exterior Building Lights (3-70W lights) [1]	3	120	70	0.6	0.5	210	126	105
Interior Building Lights (33-64W lights) [2]	33	120	64	0.8	0.8	2112	1690	1690
120V Building Receptacles [3]	12	120	180	1	1	2160	2160	2160
Roof Vent Fans [4]	2	120	180	0	1	360	0	360
Switchyard Up Lights (15-400W lights) [5]	15	120	400	0.6	0.4	6000	3600	2400
Switchyard Floodlights (6-400W lights) [6]	6	120	400	0.6	0.4	2400	1440	960
HVAC [7]	2	240	10120	1	1	20240	20240	20240
Control Room Exhaust Fan [8]	2	240	373	1	1	746	746	746
SCADA Power Bar [9]	1	120	600	1	1	600	600	600
125VDC Battery Charger [10]	2	240	780	1	1	1560	1560	1560
Switchgear Room Heater [11]	2	240	5000	1	0.5	10000	10000	5000
138kV Circuit Breaker Heaters (H) [12]	9	240	250	1	0.5	2250	2250	1125

138kV Circuit Breaker Heaters (TH) [13]	18	240	375	1	0.5	6750	6750	3375
138kV Circuit Breaker Receptacles [3]	3	120	180	1	1	540	540	540
69kV Circuit Breaker Heaters (H) [14]	2	240	250	1	0.5	500	500	250
69kV Circuit Breaker Receptacles [3]	1	120	180	1	1	180	180	180
Transformer Heaters (HR) [15]	6	240	675	1	0.5	4050	4050	2025
Transformer Fan Motors [17]	8	240	125	0.25	1	1000	250	1000
Transformer Receptacles [3]	1	125	180	1	1	180	180	2500
MOAB Heaters [16]	1	120	150	1	0.5	150	150	75
[#] = Assumptions/Notes				TOTAL LOAD (kVA) =		61.988	57.012	44.571

Notes and assumptions used for Table 2-1 are as follows:

[1] Exterior building lights assumed on for around half of the day but on for longer during winter.

[2] Interior control building lighting consists of two 32W bulbs at each fixture.

[3] Receptacle load calculated based on 180VA NEC requirement.

[4] Single motor fan at 1.5 FLA. These are assumed to be closed during the winter.

[5] Up lights specified at maximum available wattage for worst condition adjustment.

[6] Flood lights specified at maximum available wattage for worst condition adjustment.

[7] Using worst case scenario power consumption values or 10kW for summer cooling.

[8] 1/2 HP fan motors

[9] Assumed 5A, 120VAC continuous load.

[10] Load based on Alpha Technologies ASCWM-125DC-52A.

[11] Based on Global Industrial Multi-Watt Unit Heater.

[12] 3 (H) heaters per 138kV circuit breaker. Based on Siemens drawing 72480995471 provided.

[13] 3 (TH) heaters per 138kV circuit breaker. Based on Siemens drawing 72480995471 provided.

[14] 2 (H) heaters per 69kV circuit breaker. Based on Siemens drawing 72480995473 provided.

[15] 72 kV-142 kV transformer. Number of heaters and load size based on provided drawing D-101 25.

[16] Based on HX-56509 Switchgear heater.

[17] 1/6 HP fan motors.

AC Loads During Construction

The energized substation AC loads will be served from permanent station power transformers connected to the 138kV bus in the substation. That source will not be available until energization of the 138kV bus, however some of the substation loads will require AC service prior to energizing the bus. The following table displays the apparent power rating of auxiliary equipment in the substation that are presumed to be utilized prior to energization of the substation. The loading analysis for this scenario utilizes similar diversity factors and seasonal loading as the energized substation loads. The assumption made for this load calculation is for all unnecessary fans and heaters to not be connected until the station is energized.

Table 2-2 AC Loads During Construction

Load Description	QTY	Volts Req'd	VA Rating	Diversity Factor (DF)		Total VA	Winter VA	Summer VA
				Winter	Summer			
Exterior Building Lights (3-70W lights) [1]	3	120	70	0.6	0.5	210	126	105
Interior Building Lights (33-64W lights) [2]	33	120	64	0.8	0.8	2112	1690	1690
120V Building Receptacles [3]	12	120	180	1	1	2160	2160	2160
Roof Vent Fans [4]	2	120	180	0	0	360	0	0
Switchyard Up Lights (15-400W lights) [5]	15	120	400	0.6	0.4	6000	3600	2400
Switchyard Floodlights (6-400W lights) [6]	6	120	400	0.6	0.4	2400	1440	960
HVAC [7]	2	240	10120	0	0	20240	0	0

Control Room Exhaust Fan [8]	2	240	373	0	0	746	0	0
SCADA Power Bar [9]	1	120	600	1	1	600	600	600
125VDC Battery Charger [10]	2	240	780	1	1	1560	1560	1560
Switchgear Room Heater [11]	2	240	5000	1	0.5	10000	10000	5000
138kV Circuit Breaker Heaters (H) [12]	9	240	250	1	0.5	2250	2250	1125
138kV Circuit Breaker Heaters (TH) [13]	18	240	375	1	0.5	6750	6750	3375
138kV Circuit Breaker Receptacles [3]	3	120	180	1	1	540	540	540
69kV Circuit Breaker Heaters (H) [14]	2	240	250	1	0.5	500	500	250
69kV Circuit Breaker Receptacles [3]	1	120	180	1	1	180	180	180
Transformer Heaters (HR) [15]	6	240	675	1	0.5	4050	4050	2025
Transformer Fan Motors [17]	8	240	125	0.25	1	1000	250	1000
Transformer Receptacles [3]	1	125	180	1	1	180	180	2500
MOAB Heaters [16]	1	120	150	1	0.5	150	150	75
[#] = Assumptions/Notes				TOTAL LOAD (kVA) =		61.988	26.026	18.225

Notes and assumptions used for Table 2-2 are as follows:

[1] Exterior building lights assumed on for around half of the day but on for longer during winter.

[2] Interior control building lighting consists of two 32W bulbs at each fixture.

[3] Receptacle load calculated based on 180VA NEC requirement.

[4] Single motor fan at 1.5 FLA. These are assumed to be closed during the winter. Deemed unnecessary during the construction phase.

[5] Up lights specified at maximum available wattage for worst condition adjustment.

[6] Flood lights specified at maximum available wattage for worst condition adjustment.

[7] Using worst case scenario power consumption values or 10kW for summer cooling. Deemed unnecessary during the construction phase.

[8] 1/2 HP fan motors. Deemed unnecessary during the construction phase.

[9] Assumed 5A, 120VAC continuous load.

[10] Load based on Alpha Technologies ASCWM-125DC-52A.

[11] Based on Global Industrial Multi-Watt Unit Heater.

[12] 3 (H) heaters per 138kV circuit breaker. Based on Siemens drawing 72480995471 provided.

[13] 3 (TH) heaters per 138kV circuit breaker. Based on Siemens drawing 72480995471 provided.

[14] 2 (H) heaters per 69kV circuit breaker. Based on Siemens drawing 72480995473 provided.

[15] 72 kV-142 kV transformer. Number of heaters and load size based on provided drawing D-101 25.

[16] Based on HX-56509 Switchgear heater.

[17] 1/6 HP fan motors.

Conclusion

In Table 2-1, the winter scenario presents the worst case for the energized substation AC load of 57kVA. The standard size distribution transformer that meets this loading is rated at 62kVA, which should adequately serve for station service. While the calculated worst case loading of the substation is 99.79% of the station power transformer nameplate rating this does not necessarily mean that any additional AC loading will detrimentally overload the station power transformer. IEEE C57.12.23-2009 states the kVA rating is developed by measuring the oil temperature near the top of the transformer tank, and the temperature should not pass 55° C for the specified nameplate rating to preserve the life of the transformer. In IEEE C57.910-2011, an approximation table illustrates the relationship of dropping ambient temperatures (°C) to increasing kVA (%) as a 1:1 ratio with an assumed average of 30° C as the base point. Even though IEEE states that the relationship is conservative, it is advised to add an additional 5° C margin. Also note that under the worst-case scenario loading of 99.79% will take place when the ambient temperature is approximately -7° C or lower considering that is when the 138kV breaker tank heaters are set to turn on which make up 32.4% of the total winter load. When the ambient temperature is -7° C, the rating of the transformer could potentially be increased by 32% [30°C (assumed ambient) – (-7) °C (worst case scenario temperature) – 5°C (IEEE recommended margin)] without compromising the transformer life expectancy. This would provide additional capacity for future loading without comprising the life of the transformers. It should also be noted that industry practice and Burns & McDonnell operational practices allow for temporary overloading of transformers above the nameplate rating.

The construction AC loading analysis was performed to provide Burns & McDonnell with information required to properly size the temporary construction AC service. As outlined In Table 2-2, the winter scenario presents the worst-case AC loading for the substation during construction. Per the analysis the worst-case construction load for substation equipment is 26kVA, this load would be adequately fed by a 400A, 120/240V single phase service. This loading is for substation equipment only and does not include any additional construction loads (trailers, equipment, tools etc.). Anticipated additional construction loads should be served from a separate source or added to the substation equipment loading to determine the total AC service size required for construction. The construction AC service sizing should consider Burns & McDonnell's transformer loading operational practices and consider that the peak loading is expected during periods of cool ambient temperatures.

References

[1] IEEE Std C57.12.23-2009, IEEE Standard for Submersible Single-Phase Transformers: 167 kVA and Smaller; High Voltage 25000V and Below; Low Voltage 600V and Below.

[2] IEEE Std C57.81-2011, IEEE Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators.

[3] Burns & McDonnell Engineering Standards, Section 1, AC Systems.

[4] National Electric Code (NFPA 70 NEC).

[5] Provided vendor drawings for 69kV breaker, 138kV breaker, and 72kV/142kV transformer.